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# Building decorative materials

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# 1

# Introduction

This chapter introduces the classifications and technical standards of building decorative material; briefly states its status and functions in construction projects.

## 1.1 Status and Development of Building Decorative Materials



Modern architecture should not only meet the need of people's everyday life, but also create a comfortable living environment for people. Material decorating the building surface and beautifying the environment is called building decorative material or "facing material", which is the material base of building decoration projects. General decorative impression and function are achieved and highlighted by the texture, shape, design and pattern, and function of building decorative material and other auxiliary products.

The decorative effect of building decorative material, which is the combination of material, technology, model designing and aesthetics, is greatly restrained by the material itself, especially is affected by its decorative features such as gloss, texture, design and pattern. E.g., when the external wall of a high building is decorated with glass curtain wall and aluminum curtain wall, it reveals to people a modernistic architectural style with its bright gloss, brilliant colors and kaleidoscope-like shining appearance. Building decorative material is the important material base of building decoration. Only after we know about the functions and characteristics of building decorative material, make right selections according to building and environment conditions can we maximize the advantages of each material and make the best use of everything, finally realize the design idea. In general, building decorative material has outstanding features in construction practice.

With the rapid development of building industry and the growing demands of people in material and spirit, great progress has been made in modern decorative material in China. And it has also been greatly stimulated by the construction of a great number of luxurious hotels, restaurants, large marketplaces, gymnasiums and entertainment buildings. With the progress of science and technology and the development of building material industry, the field of new decorative material will step into a new stage in type, specification and grade, and will become more and more functionalized, integrated, serialized and standardized. As people are being better off, they will grow higher and higher demands for qualified buildings with more and better functions. All these will be realized mostly depending on material with suitable functions. Therefore, multifunctional building decorative material with features such as lightweight, high strength, high durability, fire proofing, shock resistance, heat preservation, sound insulation and water proofing will be highly required in the future.



## 1.2 Types of Building Decorative Materials

There are varieties of building decorative material which is classified according to different factors. For instance, according to application site, it is classified to external and internal wall, floor, suspended ceiling and roof decorative materials etc. (See Table 1.1); according to chemical composition, classified to metal, non-metal and composite materials etc. (See Table 1.2).

**Table 1.1 Classification of Building Decorative Material Based on Application Site**

| Type | Application site | Commonly-used decorative material |
|---|---|---|
| External wall decorative material | Decorative material applied to all external parts of a building, including external walls, terraces and awnings etc. | Natural granite, ceramic decorative products, glass products, external wall coating, metal products, decorative concrete, decorative mortar |
| Internal wall decorative material | Decorative material applied to internal structures, including internal wall surface, dados, plinths, partition walls, flower shelves etc. | Wallpaper, wall cloth, internal wall coating, fabric ornaments, plastic facing decorative board, marble, artificial stone, internal wall glazed tile, artificial board/sheet, glass products, thermal insulation and sound absorption decorative board |
| Floor decorative material | Decorative material applied to such structures as ground surface, floor surface and stairs etc. | Carpet, floor coating, natural stone, artificial stone, ceramic floor tile, wood floor, plastic floor |

Continued

| Type | Application site | Commonly-used decorative material |
|---|---|---|
| Ceiling decorative material | Decorative material applied indoors and for ceiling decoration | Gypsum board, decorative mineral wool sound absorption board, decorative perlite sound absorption board, glass wool, decorative sound absorption board, decorative calcium-plastic foam absorption board, decorative polystyrene foam plastic sound absorption board, fiber board, coating |

**Table 1.2 Classification of Building Decoration Material Based on Chemical Composition**

| | | | |
|---|---|---|---|
| Metal material | Ferrous metal | Steel, stainless steel, colored stainless steel, aluminum and aluminum alloy, copper and copper alloy, gold, silver | |
| | Nonferrous metal | | |
| Nonmetal material | Inorganic material | Natural finishing stone | Natural marble, natural granite |
| | | Ceramic decorative products | Glazed tile, colored glazed tile, ceramic mosaic tile |
| | | Glass decorative products | Heat absorption glass, hollow glass, laser glass, embossed glass, color glass, hollow glass brick, glass mosaic, coated glass, mirror glass |
| | | Gypsum decorative products | Decorative gypsum board, gypsum plaster, mounted decorative gypsum board, decorative gypsum sound absorption board, gypsum art products |
| | | White cement, colored cement | |
| | | Decorative Concrete | Colored concrete pavement brick, cement concrete tile |
| | | Decorative mortar | |
| | | Mineral cotton, perlite decorative products | |
| | Organic material | Decorative wood products | Plywood, fiberboard, laminated wood board, rotary-cut veneer, wood flooring |
| | | Bamboo and rattan decorative products | |
| | | Decorative fabric | Materials such as carpet, wall covering and curtain etc. |
| | | Plastic decorative products | Plastic wallpaper, plastic floor, plastic decorative board |
| | | Decorative coating | Floor coating, external wall coating, internal wall coating |
| Composite material | Organic and inorganic material | Decorative calcium-plastic foam sound absorption board, artificial marble, artificial granite | |
| | Metal and nonmetal material | Color-coated copper plate | |

## 1.3 Brief Introduction of Technological Standards of Building Decorative Materials

To ensure the quality, modernized production and scientific management of decorative material, unified standards must be established to regulate the technical requirements of products, mainly including product specifications, classifications, technical requirements, test methods, regulations of inspection, labels, transportation and storage precautions etc. e.g., each cement, ceramic or steel product has its own product standards.

The standard of building decorative material is the technical basis for grading the quality of products and the inspection and acceptance basis to both sides of supply and demand.

**1. Commonly-used Standards in China**



(1) National Standard

National standard includes compulsory standard (code name GB) and recommended standard (code name GB/T). Compulsory standard is technical guidance document which must be implemented nationally. Products' technical specification must meet requirements specified in compulsory standard. Recommended standard can be replaced with other relevant standard.

(2) Industry (or department) Standard

Each industry (or competent department) establishes technical standard to regulate the product quality in the industry. It is also national guidance document though it is issued by the production department in charge. Examples are: Building Material Standards (code name JC) and Building Industry Standards (code name JG) etc.

(3) Local Standard

Local standard is local technical guidance document issued by local competent department (code name DBJ) and applied locally.

(4) Enterprise Standard

It is technical document enacted and issued by an enterprise to guide its own production (code name QB), and only applied to the enterprise. Enterprise standard should be formulated for each product which has no national standard or ministerial level standard to follow. Moreover, the technical requirements in enterprise standard should meet or surpass the similar (or relevant) national standard.

**2. World Standard and Regional Standard**

World-wide "ISO" international standard.

Leading group standard and company standard in the world, such as ASTM Standards "American Society for Testing and Material", BS "British Standards" and so on.

Regional standard. Standard adopted in industrially advanced countries, such as Deutsche Industrie Normen "DIN", Japanese Industrial Standards "JIS" and so on.

## 1.4 Functions and Selection of Building Decorative Materials



**1. Functions of Building Decorative Material**

The purposes of interior and exterior decoration of a building are to beautify its appearance and acquire certain architectural art style, create a multifunctional elegant interior environment and effectively enhance its durability. These purposes are mostly realized by using building decorative material on building surface.

Architecture is plastic arts. Its appearance effect is achieved by the color of the material and the shape, proportion and the virtual and real contrast of the whole building, and is also affected by the texture, line style and color of exterior wall decorative material. Functions of decorative material are mainly exhibited in the following four aspects.

(1) Texture

Texture is the comprehensive feeling given by the material's surface structure, patterns and designs, colors, glosses and transparency etc. Different material gives people different feelings due to its degree of softness or hardness, lightness or weightiness, roughness or slenderness, coldness or warmness etc. Different surfaces of the same material reveal different textures, e.g. common glass and embossed glass, mirror granite and axe-chopped stone give people different feelings with their own textures. Same surface processing approach usually creates same or resembled texture, though sometimes there is a slight difference. For instance, artificial marble or imitative wood wares are not as compatible or real as those made of natural marble or wood, though sometimes they look almost the same as genuine ones.

(2) Color, Gloss and Transparency

Color is the result of the material's selective absorption of spectrum. Different colors give people different feelings. For example, red and pink make people feel warm and enthusiastic, green and blue give people the feeling of serenity, coolness and quietness. Gloss, represented by glossiness, is the nature that material surface directionally reflects light. Smoother surface has higher glossiness. In direct reflection, material surface shows specular features, so the reflection is also called mirror reflection. Different glossiness creates different brightness to material surface. It also enlarges the field of vision or creates a different virtual and real contrast. Transparency is another property related to light. An object which transmits light and can be penetrated is called transparent body, whereas an object which transmits light but can not be penetrated is called translucent body, and an object which neither transmits light nor is penetrated is called opaque body. Materials with different transparency can be used to keep out light or adjust the brightness of light to create different optical effects according to actual needs and also make an object image clear or blurred.



(3) Shape and Size

To decorative materials such as bricks, plates and coiled materials, there are specified requirements and specifications in shapes and sizes, natural patterns, textures and artificial patterns or designs. Various line styles and designs are made up of decorative materials in different shapes and sizes, patterns, colors and glosses etc. to create different decorative effects to meet the needs of different building structures and line styles.

(4) Stain Resistance, Good Clean-ability and Scrub-resistance

Stain resistance refers to the ability of the material surface to resist the action of dirt and to retain its prime color and gloss. Clean-ability refers to the nature that the material surface is easy to be cleaned by wind, rain or manual cleaning. Strong stain resistance and good clean-ability assure that the decorative effect of the material keep fresh for a longer time, so they should be taken into consideration when we are selecting decorative material for floors, platforms, external walls, washrooms and kitchens etc. Material's scrub-resistance is actually its wear-resistance, classified to dry-scrub resistance (named as dry-scrub resistance) and wet-scrub resistance (named as washing-resistance). The higher scrub-resistance, the longer service life the material has.

**2. Selection of Building Decorative Material**

There are varieties of building decorative material with different functions and features, as well as different application purposes. Therefore, there are couples of things to be considered in selection

(1) The Type and Grade of the Building to be Decorated

Public and residential buildings need to use different decorative materials. Residence is where people live. Apart from working time, people usually hang out most of their time in their houses. Therefore, the interior decoration of houses is to provide a comfortable living environment. Buildings such as offices, classrooms, libraries, luxurious hotels and large marketplaces should adopt different materials according to their grades and decorative durability. Granite mirror plate has great wear-resistance and excellent decorative effect, so it's suitable for public places in luxurious hotels such as lobbies, corridors and stairways. To common residential living rooms, it's suitable to adopt ceramic flooring tiles.

In building decoration, it is costly to apply only high-end materials, and it is difficult to create certain architectural art style to adopt too many types and styles of materials.

(2) Decorative Effect

Material's line style, size and texture create a very clear decorative effect to people both psychologically and visually. As to texture, we should make full use of the innate natural patterns and designs and the prime colors of materials or various artificially imitated patterns and designs like those of natural materials to achieve decorative effects such as simplicity, quiet elegance, nobility and dignity; with regard to size, it should meet certain proportion. For instance, marble and colored terrazzo tile create better effect applied in a hall than in a residential house. Both material's innate texture and line style are factors of the overall effect of the building decoration. For instance, applying aluminum alloy decorative plates to external walls will create an effect with concavo-convex line styles.

(3) Application Environments and Functions of the Decorated Part

For example, bathrooms and kitchens are often heavily filled with vapor and smoke. The wall surface there should be covered with smooth internal wall glazed tiles to simplify the work of washing and cleaning. Plastic wallpaper is widely used as internal wall decorative material, but rarely applied to internal wall-surface in residential houses because it is easy to get dirty. It's very suitable to adopt fabric wallpaper to cover bedroom walls. Ceramic flooring tiles are usually adopted in living rooms in southern areas due to its cleanness, excellent appearance and coolness; in northern cold area, it's appropriate to use wood flooring with certain thermal insulation and preservation. Anti-slip feature of materials should be considered for the decoration of moist ground. For instance, it's wise to apply anti-slip ceramic mosaic tiles to washroom and bathroom ground. The ground of stores and waiting rooms, often crowded with people, should be decorated with colored terrazzo, ceramic flooring tiles or marble.

(4) Expense of Decorative Material

Economic index of decorative material is used to estimate the cost and the expense of a decorative project. It is considered in three factors:

1) Reference price. Price known from the manufacturers' product catalogs and relevant brochures.

2) Market price.

3) Construction surcharge.

Decorative material's price has a direct relationship with the cost of architectural decoration. To ensure that the decorative project is economical, its one-off investment and future maintenance fee should be taken into consideration when we are selecting material.



## 1.5 Learning Goals and Methods of the Course

The academic goal of the course *Building Decorative Materials* is to coordinate with the teaching and learning of major subjects and to establish a great knowledge foundation for architectural decorative design and construction. In order to master and correctly select decorative materials, firstly, it's very important to learn about the components, functions and applications of various materials, among which the most important is the functions and characteristics of materials and other contents should be learned based on this center; secondly, we should keep in close touch with construction practice, as *Building Decorative Materials* is a course that can be learned efficiently and effectively only in practice. So in learning, we should combine theory and practice together and manage to carry out more on-site practice; thirdly, the method of comparison is helpful. By comparing various components and structures of materials, we can learn and master their characteristics and applications, especially their common properties and particularities.

Questions for thinking and practical tasks at the end of each chapter make a summary of the theoretical knowledge and practical applications, so they must be mastered and well done.

## Questions for Reviewing and Thinking

1.1 What is building decorative material? How is it classified?

1.2 What are the functions of building decorative material?

1.3 Which factors should be considered in the selection of building decorative material?

# 2

# Basic Properties of Building Decorative Materials

This chapter discusses how the compositions, structures and conformations of a material affect its nature, focuses on the physical and mechanical properties and introduces the decorative properties and durability of decorative material.

Building decorative material is one of the important branches of building material, so it has the basic properties of the later. It not only creates great decorative effect but also has certain performances such as water-proofing, corrosion-proofing, heat preservation, fire-proofing, sound absorption and sound insulation etc. The basic properties of building decorative material include physical and mechanical properties, which are the basis for scientific selection and appropriate application of the material.



## 2.1 Physical Properties of Building Decorative Materials

Physical property here means any aspect of decorative material that can be measured or perceived without changing its identity.

### 2.1.1 Properties Related to Mass

**1. Density**

Density is defined as the mass per unit volume of the material in absolute dense condition. Calculating density( $\rho$ ):

$$\rho = \frac{m}{V}$$

In the equation: $\rho$ is the density, (g/cm$^3$ or kg/m$^3$);

$m$ is the mass, (g or kg);

$V$ is the volume in absolute dense condition (excluding pores) (cm$^3$ or m$^3$).

Material's density $\rho$ depends on its components and internal structure.

**2. Apparent Density**

Apparent density (once called as volume weight) is defined as the mass per unit volume of the material in natural state. Calculating apparent density ( $\rho_0$ ):

$$\rho_0 = \frac{m}{V_0}$$

In the equation: $\rho_0$ is the apparent density (g/cm$^3$or kg/m$^3$);

$m$ is the mass (g or kg);

$V_0$ is the volume in natural state (including internal pores) (cm$^3$or m$^3$).

Material's density $\rho_0$ depends on its components and interior structure.

Material's mass in any water containing state can be taken to measure its apparent density, but it should be stated. Material's apparent density is related to both its density and the volume of its internal pores. The bigger porosity it has, the smaller its apparent density becomes.



**3. Bulk Density**

Bulk density is defined as the mass per unit volume of powders or granules in bulk state. Bulk density ( $\rho_0'$ ) is caculated:

$$\rho_0' = \frac{m}{V_0'}$$

In the equation: $\rho_0'$ is the bulk density (g/cm$^3$ or kg/m$^3$);

$m$ is the mass, (g or kg);

$V_0'$ is the bulk volume (including pores between granules) (cm$^3$ or m$^3$).

**4. Compactness and Porosity**

Compactness is defined as the amount of solid substance filled in the material, i.e., the ratio of solid volume to the overall volume of the material. Calculating compactness:

$$D = \frac{V}{V_0} \times 100\% = \frac{\rho}{\rho_0} \times 100\%$$

In the equation: $D$ is the compactness (%);

$V$ is the volume of solid substance in the material (cm$^3$or m$^3$);

$V_0$ is the volume of the material (including the volume of internal pores) ($cm^3$or $m^3$);

$\rho_0$ is the apparent density of the material ($g/cm^3$or $kg/m^3$);

$\rho$ is the density of the material ($g/cm^3$or $kg/m^3$).

As to particulate material such as sand and stone, porosity is taken to stand for the compactness among the grains. Porosity is defined as the fraction of the volume of voids over the total volume of the material. Calculating porosity:

$$P = \frac{V_0' - V_0}{V_0} \times 100\% = \left(1 - \frac{\rho_0'}{\rho_0}\right) \times 100\%$$

Generally, the bigger the internal porosity is, the smaller the volume density and the lower the strength become, thus the material becomes weaker in wear-resistance, freezing resistance, impermeability, corrosion resistance, water tolerance and durability, whereas its heat preservation, sound absorption, water absorption and moisture absorption will become stronger. These stated features are related to both material's porosity and the features of pores (such as open pores, closed pores and spherical pores etc.). Density and apparent density of several types of commonly-used building decorative material are shown in Table 2.1.



**Table 2.1 Density, Apparent Density and Porosity of Some Commonly-used Building Decorative Materials**

| Material | Density ($g/cm^3$) | Apparent density($kg/m^3$) | Porosity |
|---|---|---|---|
| Granite | 2.6-2.9 | 2500-2850 | 0.2-4 |
| Gravel | 2.6-2.7 | 2000-2600 | — |
| Sand | 2.6-2.8 | | |
| Common concrete | 2.6 | 2100-2600 | 5-20 |
| Common vitrified brick | 2.5-2.8 | 1500-1800 | 20-40 |
| Cement | 3.0-3.2 | | |
| Pine wood | 1.55 | 400-800 | 55-75 |
| Steel | 7.85 | 7850 | 0 |
| Gypsum board | 2.60-2.75 | 800-1800 | 30-70 |

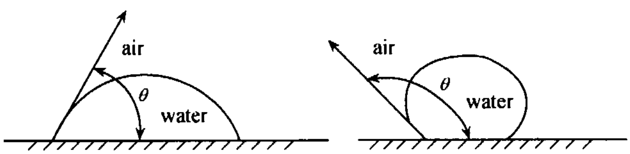
## 2.1.2 Properties Related to Water

### 1. Hydrophilicity and Hydrophobicity

Some material gets wet in water but some doesn't. The former has the nature of hydrophilicity, the later has the nature of hydrophobicity.

The wet state of the material is represented with "wetting angle" $\theta$, which is the angle formed by the tangent line along the surface of the water drop and the material surface at the intersection point where the material, water and air intersect when the material touches water. Smaller $\theta$ angle indicates that the material is more likely to get wet. If the angle <90°[See Figure 2.1 (a)], the material has strong hydrophilicity, e.g. wood and brick. The reason why material is hydrophilic is that the attracting force between material molecules and water molecules is bigger than the cohesive bonding force between water molecules, thus the material gets wet in water. If $\theta$>90°, refer to Figure 2.1 (b), the material has strong hydrophobicity, e.g. asphalt, paraffin and plastic etc. The reason is that the attracting force between material molecules and water molecules is smaller than the cohesive bonding force between water molecules, thus the material doesn't get wet in water. Hydrophobic material performs better in water-proofing and moisture-proofing, so it's commonly used as water-proof material.






(a) hydrophilic materials (b) hydrophobic material

Figure 2.1 Schematic Illustration of Material's Wet State

**2. Wate Absorption**

Water absorption refers to the ability of material to absorb water when immersed in it and is represented with water absorbing capacity.

Water absorbing capacity is defined as the ratio of the weight of water absorbed by a material in saturated state over the weight of the dry material. It is classified to mass water absorption ($W_W$) and volume water absorption ($W_V$):

$$W_W = \frac{m_2 - m_1}{m_1} \times 100\%$$

$$W_V = \frac{V_W}{V_0} = \frac{m_2 - m_1}{V_0} \times \frac{1}{\rho_W} 100\%$$

In the equation: $W_W$ is mass water absorbing capacity (%);

$W_V$ is volume water absorbing capacity (%);

$m_2$ is the mass of material saturated with water (g);

$m_1$ is the mass of material in absolute dry state (g);
$\rho_W$ is the density of water, take $1 g/cm^3$ at normal temperature.

Mass water absorbing capacity is adopted for most materials. Material with smaller apparent density has stronger hydroscopic property. For instance, the mass water absorbing capacity of wood is more than 100%, the mass water absorbing capacity of common concrete ranges between 2%-3%, common clinker brick's ranges between 8%-20%, granite's ranges between 0.2%-0.7%. Water absorbing capacity is related to the properties of the material, especially to its porosity and features of the pores etc.

### 3. Moisture Absorption

Moisture absorption is defined as the property that the material absorbs water in the air. Moisture absorption is represented with water ratio.

Water ratio is the ratio of the weight of water contained in the material over the weight of the material in absolute dry state.

Moisture absorption of a material is related to the temperature and humidity of the air. Higher air humidity and lower temperature will increase material's moisture absorption, and vice versa.



### 4. Water Resistance

Water resistance is defined as the ability of material to resist the ingress of water and retain its prime functions in long-term water saturated state.

To structural material, water resistance refers to the change in its intensity; to decorative material, it mainly means the change in color, gloss and shape etc. and the existence of bubbles or slip cracks etc. Water resistance is represented in different ways for different materials. For instance, the water resistance of architectural coatings usually refers to if it bubbles or chips off, whereas for constructional material it is represented with the softening coefficient (the ratio of the compressive strength of a material in water saturated state to its compressive strength in absolute dry state).

Materials with softening coefficient $K_p = 0 - 1.0$. $K_p \geqslant 0.85$ are classified as waterproof materials. Structures which often suffer from moisture or water should adopt materials with $K_p \geqslant 0.75$. Fundamental structures should adopt materials with $K_p \geqslant 0.85$. When its water content increases, a material becomes weaker in its internal cohesive bonding force and its strength is weakened to various degrees, even dense stone can not be free from such influence. The strength of granite decreases by 3% after being in water for a long time. The influence is even greater to common vitrified bricks and wood materials.

**5. Impermeability**

Impermeability is defined as the property of a material that it cannot be pervaded by water or other liquids. It is represented with permeability coefficient $K$ which reflects the flow rate of water in the material. Bigger $K$ indicates that water in the material is flowing faster, and the material's impermeability is weaker. Impermeability is also represented with impermeability level $P_n$, i.e. the maximum exudation pressure resisted by the material, such as $P_6$, $P_8$, $P_{10}$ and $P_{12}$ etc. Material's impermeability is not only related to its hydrophilicity or hydrophobicity, but also to its porosity and pore features. Smaller porosity leads to stronger impermeability.



### 2.1.3 Properties Related to Heat

**1. Thermal Conductivity**

Thermal conductivity is defined as the ability of a material to conduct heat from its one side to the other. It is represented with thermal conductivity coefficient $\lambda$ . Smaller $\lambda$ indicates that the material has stronger heat insulation and preservation. Generally, the thermal conductivity coefficient of metal, inorganic and crystalline material is bigger than that of organic and non-crystal material. Material with bigger porosity has smaller thermal conductivity coefficient. Coefficient of thermal conductivity depends on the components, porosity, pore size and features as well as water ratio of the material.

**2. Thermal Capacity**

Thermal capacity is defined as the quantity of heat necessary to produce a unit change of temperature in a unit mass of a material. Walls and roofs made of material with high thermal capacity can keep stable indoor temperature for a long time. Building material's thermal capacity can be represented with specific heat, i.e., the quantity of heat required to raise 1kg of substance by 1K of temperature.

## 3. Burning Resistance and Fire Resistance

(1) Burning Resistance

Material's nature of resistance to burning is called burning resistance, which is an important factor affecting building's fireproofing and fire resistance degree. Combustion grades of commonly-used building decorative materials are specified in "*Architectural Interior Decoration Design Code for Fire Protection*" (GB50222-95). Refer to Table 2.2. When a material is burning, the harm to human body created by noxious smoke and gas is far beyond the fire itself. Therefore, in the interior decoration and renovation of a building, materials that release heavy smoke and noxious gas while burning should be avoided. GB50222-95 has already made strict regulations on the burning rating of building decorative materials applied to different interior sections of a building.

**Table 2.2 Combustion Grades of Commonly-used Interior Building Decorative Materials**

| Materials | Grade | Examples |
|---|---|---|
| Materials used in all sections | A | granite, marble, terrazzo, cement products, concrete products, gypsum board, lime products, Mongolia earth products, glass, ceramic tile, ceramic mosaic, steel, aluminum, aluminum alloy etc. |
| Ceiling and roofing materials | B1 | thistle board, fibrous plaster, cemented chip board, mineral wool decorative sound insulation board, glass wool decorative sound insulation board, perlite decorative sound insulation board, nonflammable plywood, medium density fibreboard, rock wool decorative board, flame resisting wood, aluminum anchor composite material, aluminum casing FRP composite material etc. |
| Wall Surface materials | B1 | thistle board, fibrous plaster, cemented chip board, mineral wool stave, block of glass wool, perlite board, flame resisting plywood, flame resisting medium density fibreboard, flame retarded plastic decorative board, flame resisting dihedron shaving board, multicolor finish, flame resisting wallpaper, flame resisting textile wall paper, flame resisting imitative granite decorative board, chlorine-oxide mirror cement assembling wall panel, flame resisting FRP slab, PVC plastic weatherboarding, lightweight high strength composite wall panel, flame retardant mould pressing wood composite board, color flame retardant building board/wood based panels, flame resisting FRP etc. |
| | B2 | various natural wood, wooden building board, bamboo, decorative paper plates, decorative wood laminated veneer, wood grain print building board, plastic overlay decorative board, polyester decorative board, compound plastic decorative board, plastic fiberboard, plywood, plastic wallpaper, non-spinning textile wallpaper, textile wall paper, compound wallpaper natural material wallpaper, artificial leather etc. |

Continued

| Materials | Grade | Examples |
|---|---|---|
| Flooring materials | B1 | hard PVC plastic floor, cemented chip board, cemented excelsior board, chloroprene rubber floor etc. |
| | B2 | semi-hard PVC plastic floor, PVC coiled material floor, wood floor, polyvinyl chloride fiber carpet etc. |
| Decorative fabric | B1 | various flame resisting fabric with fire-retardant finish |
| | B2 | pure wool decorative cloth, pure linen decorative cloth, other fire-retardant finish fabric etc. |
| Other decorative materials | B1 | polyvinyl chloride plastic, poly-carbonated plastic, silicone plastic decorative material, various fire-retardant finish fabric etc. Additional reference see ceiling and roofing material, wall facing material |
| | B2 | fire-retardant finish products such as polyethylene, polypropylene, polyurethane, polystyrene, fiberglass reinforced plastics, chemical fiber fabric, wood product etc. |

Notes: 1) Thistle board fitted on steel joist can be used as Grade A decorative material;

2) When plywood is covered with Grade A finishing fireproof paint, it can be used as Grade B1 decorative material;

3) Paper, textile wallpaper with unit mass smaller than 300g/m$^2$ pasted on Grade A backing material, they can be used as Grade B1 decorative material;

4) Inorganic paint on Grade A backing material can be used as Grade A decorative paint. Organic paint on Grade A backing material with its covering rate smaller than 1.5kg/m$^2$ can be used as Grade B1 decorative material; when painting on Grade B1and B2 backing material, organic paint should be tested together with its backing material to determine its burning rating;

5) Other decorative materials are curtain, drapery, counterpane and furniture textile wrapper etc.



In addition, it has been regulated by the government that the decoration and renovation of the following buildings or interior sections should adopt non-burning or nonflammable materials.

1) Guest rooms and rooms for public activities in luxurious hotels;

2) Tele-studios, recording studios and audio-visual classrooms;

3) Large and medium electronic computer rooms.

(2) Fire Resistance

Fire resistance is defined as the ability of a material to stand intact and to keep its functions from decreasing when it is on fire or at high temperature. It is represented with tolerance time (h), called limit of fire resistance, i.e. the time from the critical moment the material meets with fire to the critical moment the material loses its supporting power or its fire insulating ability, or its integrity is damaged measured with specified method. The difference between burning resistance and fire resistance is that burning resistant material may not be fireproof, whereas fire resistant material is burning resistant. For example, metal and glass are incombustible, but they get deformed and melted at high temperature or in fire, so they are not fire resistant material; steel is incombustible, but its limit of fire resistance is only 0.25h.

## 2.2 Mechanical Properties of Building Decorative Materials

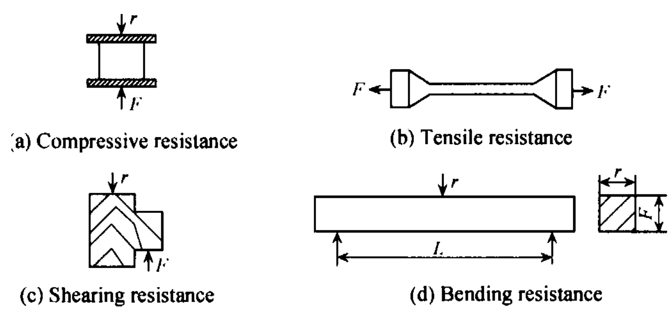
### 2.2.1 Material's Strength

**1. Definition**

Strength is defined as the ability of a material to resist destruction under the action of external force (load). When a material receives an external force, stress is generated inside itself and it increases accordingly together with the external force. When the cohesive bonding force of the material can not resist the action of the external force, it is destroyed. The stress value at the critical moment is defined as the strength of the material which is also named as ultimate strength.

According to different forms of external force, building decorative material's strength is classified as compressive strength, tensile strength, bending strength, shearing strength (Figure 2.2), rupture strength, peeling strength, shock strength and wearing resistance etc.





(a) Compressive resistance (b) Tensile resistance

(c) Shearing resistance (d) Bending resistance

Figure 2.2 Schematic illustration of Material's external force

**2. Strength Grade**

Strength grade refers to the levels of different materials, for instance, concrete and mortar etc. are classified according to their strength grade. Fragile material (such as common vitrified clay brick, stone, cement and concrete etc.)

is graded mainly based on its compressive strength; plastic and ductile material (such as steel etc.), mainly based on its tensile strength.

**3. Specific Strength**

Specific strength is the ratio of the strength of a material over its density. It is an important index used to evaluate the strength performance of a material. Materials with higher specific strength are lighter and stronger. It's very important to adopt materials with high specific strength or to improve their specific strength so as to increase the height of buildings, decrease the dead load of structures and to cut the cost of projects etc.

## 2.2.2 Elasticity, Plasticity, Brittleness and Ductility

**1. Elasticity**

Elasticity is defined as the ability of a material to deform under the action of external forces and fully recover to its prime form after the withdrawing of external force. This fully recoverable deformation is called elastic deformation, which is proportional to its load.



**2. Plasticity**

Plasticity is the nature that a material deforms under the action of external forces, but after the external force disappears, part of the deformation can not recover. This irreversible deformation is called plastic deformation. Within elasticity limit, steel is close to perfect elastic material, whereas other building materials are mostly non-perfect elastic. When non-perfect elastic material receives force, elastic deformation and plastic deformation may take place simultaneously.

**3. Brittleness**

Brittleness is defined as the nature that when material receives force to a certain extent, it is destroyed suddenly but there is no apparent plastic deformation in the destruction. The characteristic of brittleness is that even though the material is close to the critical point of destruction, the deformation is still very tiny. Concrete, glass, tile, stone and ceramic etc. are brittle materials. They have weak shock resistance and low tensile strength, but high compressive strength.

**4. Ductility**

Ductility is defined as the ability of a material to absorb a great amount of energy and deform to a great extent but being free from destruction under the action of impact or vibrating load. The characteristic of ductility is that the plastic deformation is relatively bigger and the tensile strength and compressive strength are relatively higher. Building steel, wood and rubber etc. are ductile materials. Materials applied to bridge surfaces, road surfaces and crane beams are required to have higher shock resistance and ductility.

### 2.2.3 Material's Hardness and Wearing Resistance

**1. Hardness**

Hardness is the ability of a material surface to resist pressing-in action or hard scratching. To different materials, hardness is tested with different measuring methods. The hardness of materials such as steel, wood and concrete etc. is measured with pressing-in method, whereas natural mineral's hardness is tested with scratching method. The stronger hardness, the better wearing resistance the material has, but the harder it is processed.



**2. Wearing Resistance**

Wearing resistance is the ability of a material surface to resist wearing. It is represented with wear rate *N*. Material's wearing resistance is related to its hardness, strength and internal structure. The stronger the hardness is, the better wearing resistance the material has. Material's wear rate is sometimes represented with the volume difference (loss) before and after wearing; sometimes it is represented with wearing times. Materials with stronger hardness and better wearing resistance should be adopted at places such as ground surfaces, road surfaces, stairs and other places bearing greater wearing.

**3. Durability**

Durability is defined as the ability of a material to resist the action from various internal and external destructive factors or corrosive medium in a long period and to retain its prime properties. In application, materials not only bear various actions of external force, but also receive destructive actions from physical, chemical, biological and mechanical factors.

Physical actions include light, heat, electricity, temperature difference, humidity difference, wetting and drying cycles, freezing and thawing cycles and dissolution etc. These factors may make material shrink and expand, and such repeated or long-term actions will gradually damage the material.

Chemical actions include various acids, alkalis, salts and their water solutions, various subversive gases, which can fundamentally change the material's components and deteriorate the material, e.g., chemical corrosion of paste matrix and rustiness of steel.

Biological actions include the aggressive action of bacteria and insects etc. which can cause corrosion and destruction to materials, e.g., the corrosion of wood and plant fiber materials etc.

Mechanical actions include impact, fatigue load, various gases, liquids and solids etc. which make materials torn and worn etc.

Durability is a comprehensive property of a material, including wearing resistance, rub-resistance, water resistance, heat resistance, light fastness, impermeability, aging resistance, corrosion resistance and stain resistance etc. There are different requirements for the durability and duration to materials with different components and properties and materials applied to different places. For example, decorative materials with certain water resistance are required for buildings in moist environments; materials applied to the external walls of buildings in northern areas should have a great performance of freezing resistance; floor decorative materials should have certain hardness and wearing resistance and so on. Durable life is relative, e.g., the durable life of granite is required to be up to decades or hundreds of years, whereas the best external wall coating can serve only 10-15 years.



## 2.3 Properties Related to Acoustics

### 2.3.1 Sound Absorption

Sound absorption is the ability that a material can absorb sound in the air. When sound wave transmits to material's surface, part of it is reflected, part passes through the material, the rest of it transfers into the material. Material's sound absorption is measured with sound absorption coefficient, which is the percentage of the absorbed energy to the overall energy formerly transmitted to the material by the sound wave. It is related to the frequency and incidence direction of the sound, therefore sound absorption coefficient refers to the mean absorption value to the sound of certain frequency from all directions.

Sound absorption efficiency is related to the following factors: ① material's mass density. To the same porous material, its mass density increases, the absorption efficiency to low frequency sound becomes better and the absorption efficiency to high frequency sound decreases. ② material's thickness. Increasing the thickness can enhance the absorption to low frequency sound, but it makes little difference to high frequency sound. ③ material's pore features. More pores in smaller size increase the sound absorption effect. In contrast, material with bigger pores has weak sound absorption effect.

### 2.3.2 Sound Insulation

Sound wave spreads via the air and the solid in a building structure, therefore sound insulation is classified as insulation of air-borne sound and insulation of solid-borne sound.



#### 1. Insulation of Air-borne Sound

The ratio of the power of transmission sound to the power of incidence sound is defined as sound transmission coefficient $\tau$. The bigger ratio it is, the weaker sound insulation the material has. Material's or components' sound insulation ability is represented with acoustical reduction factor $R$. In contrast to sound transmission coefficient, when acoustical reduction factor $R$ is bigger, the material's or components' sound insulation is stronger. To homogeneous material, its acoustical reduction factor should meet "mass law", i.e., the material with bigger mass per unit area or bigger volume density has stronger sound insulation. Light material has smaller mass, so its sound insulation is weaker than that of compact material.

#### 2. Insulation of Solid-borne Sound

Solid-borne sound is generated by the action that a vibration source strikes on solid material and causes solid material to vibrate and create sound wave which radiates sound energy to every direction. Solid-borne sound loses little sound energy in spreading. Elastic material such as wood board, carpet, wall paper and sheet rubber etc. has stronger sound insulation.

## 2.4 Decorative Functions of Building Decorative Materials

Decorative material is defined as the facing material applied to the interior and external walls, pillar surfaces, floors, ceilings and roofs etc. of buildings. It mainly performs the functions of decoration, protection and other special purposes (such as thermal insulation, moisture proofing, fire proofing, sound absorption and heat insulation etc.). Decoration effect is mainly decided by the colors, textures and line styles of the applied materials.

### 1. Color

Color is an important factor affecting the appearance of buildings and even the surroundings. Generally, a facade using white as major color gives people lively and fresh feeling; a façade in dark color creates a solemn and dignified appearance. Warm colors as red, orange and yellow etc. make people feel enthusiastic, excited and warmhearted; cool colors as green, blue and violet etc. give people the feeling of serenity, quiet elegance and coolness. Because of different life and climate conditions as well as traditional customs, people have different feelings to colors.



### 2. Texture

Texture is a comprehensive feeling given by the thickness, hardness, roughness, texture structures, flower patterns and designs, differences in color etc. of the surface of materials. e.g., the rough surface of concrete and bricks shows a solid and boorish style; smooth and plain surface of glass and aluminum alloy reveals the legerity and lively style. Texture is related to the textural features, surface processing degrees and construction methods of materials as well as the shapes, structures and facade styles of buildings.

### 3. Line Style

Line style is defined as the decoration effect created by the decorative dividing joints and unevenness lines on the facade. For example, plaster, granite, dash rock and natural stone etc. should be divided into smaller pieces, which not only creates different facade appearances, but also prevents cracking. The divided size should be harmonized with the material. Commonly the joint width ranges between 10-30mm, and segments in different sizes can be combined to create various decorative effects.

## Summary

Learning and mastering various basic properties of building decorative materials is greatly significant for understanding, researching and applying the materials.

Main points: density, apparent density, volume density, bulk density, porosity of materials; water related properties, thermal conductivity, durability of materials and the factors affecting these properties.

Comprehension: components and structures of materials; the factors affecting thermal conductivity.

Understanding: fire resistance, burning resistance and wearing resistance of materials.

## Questions for Reviewing and Thinking



2.1 When the volume density of a material increases, how will its density, strength, water absorption, freezing resistance and thermal conductivity change respectively?

2.2 What is material's hydrophilicity and hydrophobicity?

2.3 What is material's water resistance? What kinds of material are water resistant?

# 3

# Building Decorative Stone

Stone is classified as natural and artificial stones. Stone with certain physical and chemical properties and used as building material is called building stone. Building stone with decorative properties and applied in building decoration after being processed is called decorative stone. Natural decorative stone not only has better performances such as high strength, hardness, wear resistance and durability etc., but also has unique decorative performance after surface processing and finishing. There is rich source of natural decorative stone and it has been the most widely-used building decorative material since long ago, and is still deemed as the most advanced building decorative material today.

Artificial decorative stone is a new synthetic decorative material. It has exhibited its advantages in every aspect such as material processing and production, application, decoration, performances and cost etc., so it is a decorative material to be greatly developed in the future.



## 3.1 Basic Knowledge of Rock and Stone

### 3.1.1 Classification of Rock

According to different geological conditions, rock is generally classified into three main types: magmatic rock, sedimentary rock and metamorphic rock.

**1. Magmatic Rock**

Magmatic rock is also called igneous rock, which is the condensation of magma when it intrudes into crust or erupts to earth surface from deep underground. When magma intrudes into crust, the intruded magma is condensed and crystallized and forms rock, called intruded rock, of which earth crust is mainly composed. Magmatic rock, according to its cooling-down conditions, is classified to plutonic rock (depth more than 3km) and supergene rock (depth less than 3km). Rock formed after magma breaking through the upper-exposed rock stratum, erupting out to earth surface, cooling down and condensing, is called extrusive rock (or volcanic rock). Volcanic rock is less used for decoration, but mainly used as aggregates to produce mortar and light aggregate concrete (such as pumice stone).

**2. Sedimentary Rock**

Sedimentary rock is formed after the parent rock is weathered, geologically transported and deposited etc. It is in layered structure, and each layer has different composition, structure, color and layer thickness. Compared with igneous rock, its features are weaker structural dense-status, smaller density, higher porosity and water absorption, lower strength and weaker durability.

Sedimentary rock is widely distributed in the earth, lying not deeply under the earth surface and easy for mining. According to its forming conditions, sedimentary rock is classified to mechanical sedimentary rock, chemical sedimentary rock and biological sedimentary rock. According to its binding material, it is classified to siliceous, argillaceous and calcareous. Typical siliceous rocks are quartz rock, sandstone, conglomerate and diatomite etc.; argillaceous rocks are mudstone, shale and oil shale etc.; calcareous rocks are limestone, dolomite, marl and lime-breccia etc.



**3. Metamorphic Rock**

Metamorphic rock is made when magmatic or sedimentary or even other metamorphic rock is subjected to high temperature and extreme pressure inside the crust. According to the changes that take place in the course of metamorphism alteration, it is further divided into ortho-metamorphic and para-metamorphic rocks.

Ortho-metamorphic rock is metamorphosed from magmatic rock. After metamorphosis, its structure and performances are weaker than those of the primary rock. For instance, gneiss which is metamorphosed from granite rock is more likely to delaminate and flake off, and its durability becomes weaker.

Para-metamorphic rock is metamorphosed from sedimentary rock. After metamorphosis, its structure and performances are better than those of the primary rock. For instance, marble, metamorphosed from lime-rock, has denser structure and stronger durability.

Commonly-used metamorphic rocks are marble, quartz rock and gneiss.

### 3.1.2 Properties of Stone

#### 1. Physical-Mechanical Properties of Stone

(1) Apparent Density

According to apparent density, natural stone is classified to heavy stone and light stone. Stone with apparent density more than 180kg/$m^3$ is defined as heavy stone, which is mainly used for structural bases, surfaces, floors, roads, external walls of houses and retaining walls etc. Granite and marble are denser natural stones, whose apparent density is close to their own standard density, around 2500-3100 kg/$m^3$; Stone with apparent density less than 1800kg/$m^3$ is defined as light stone, which is mainly used to build wall bodies such as the external walls of greenhouses etc.

(2) Compressive Strength

Evaluation of compressive strength of natural stone: adopt a cube with side length 70mm as test sample; the value of its compressive strength calculated with standard test method is taken as the evaluation criteria of the strength level. According to "*Code for Design of Masonry Structures*" (GB 50003-2001), the strength of natural stone is divided into seven levels as MU 100, MU80, MU60, MU50, MU40, MU30 and MU20.

(3) Water Absorption and Water Resistance

Stone's water absorption is related to its chemical composition, porosity and pore features etc. After absorbing water, its mineral bonding power decreases, therefore its structural strength becomes weaker.

Softening coefficient $K$ stands for stone's water resistance. Stone with $K>0.90$ is high water resistant; stone with $K$=0.70-0.90 is medium water resistant; when $K$= 0.60-0.70, the stone is weak in water resistance. Generally, stone with $K<0.80$ is not applicable for important structures.

(4) Frost Resistance

Stone's frost resistance is represented with the times of freezing-thawing cycles. When saturated with water and after specified times of freezing-thawing cycles, stone's frost resistance is deemed qualified if no penetrating crack appears and its mass loss is less than 5% and strength reduction less than 25%.

(5) Wear Resistance

Wear resistance is defined as the ability of stone to resist comprehensive external forces such as abrasion, edge cutting and impact etc during service.

Wear resistance is represented with the abrasion value per unit area. Stone with strong wear resistance should be adopted at places such as roads, floors and steps etc.

**2. Decorative Nature of Stone**

The main purpose of adopting decorative stone is to decorate and beautify the appearance of buildings. The decorative nature of stone is related to its structures, textures, colors and surface features.

The structure of stone is defined as the particular crystalline state of different components of stone during its formation. Texture is the arrangement form of crystal orientation, which not only decides the external appearance of stone, but simultaneously affects its properties such as anisotropy and isotropy etc. Color and surface form of stone should be selected based on the requirements for the texture and color of the decoration. Moreover, it is notable to select facing stone in suitable size. In consideration of aesthetics, intuitive and visual effect, single slab in larger size looks better, which, of course, must firstly ensure the symmetric and beautiful arrangement of the geometric figure on decoration surface. For a larger area slab, its thickness should also increase, then the self-load and price will increase.



**3. Durability of Stone**

Facing stone for out-door decoration requires strong stability, weather-resistance and ageing-resistance to provide continual protection to buildings in a long period. With outstanding physical properties, granite has become the best option for out-door decoration; marble with well crystallized and dense structure can also be adopted for out-door decoration, however, marble with un-even structure such as fossil clasolite and breccia is easy to be eroded by water or sulfurous gas, so is not applicable for out-door application, neither is stone that is too sensitive to frost.

**4. Radioactivity of Stone**

The radioactivity of stone should be highly considered. It is derived from natural radionuclide in crustal rock. Natural radionuclide widely existing in natural rock mainly includes uranium and thorium decay products and Kalium-40 etc. During the decay process, the radionuclide generates natural radioactive gas Rn. People who live in environment with dense radon for a long time will breathe in and accumulate radon in lungs, which emits great amounts of radiation and does harm to people's health.

The content of radionuclide varies greatly in different rocks. Most of natural stone contains a little of radioactive material, which usually does no harm to human health. But the radioactive material index of some granite products is bigger than standard index, and these products will pollute the environment in long-term service, so must be controlled. "*Limits of Radionuclide in Building Materials*" (GB6566-2001) has classified, based on specific radioactivity, building decorative stone into types A, B and C. the application scope for A-type stone is not restrained; B-type stone is not applicable for interior facing decoration of I-type civil buildings, but is applicable for the exterior facing decoration of I-type civil buildings and the interior and exterior facing decoration of other buildings; C-type stone is only applicable for the exterior facing decoration of buildings.



## 3.2 Natural Building Decorative Stone

### 3.2.1 Natural Marble

Marble is metamorphic rock created after the metamorphosis of such rocks as limestone, calcite, dolomite and serpentine under high pressure and high temperature. The main component of marble is calcium carbonate ($CaCO_3$ about 50%), plus a little acidic oxide $SiO_2$, so marble belongs to alkaline crystalline rock. In stone industry, marble includes all kinds of carbonate rock or magnesium carbonate rock and relevant metamorphic rock which have similar properties with marble.

**1. Performances, Features and Types of Natural Mable**

(1) Performances of Natural Marble

1) Even structure, fine and smooth texture and high compressive strength.

2) Dense structure but medium hardness; ease of process such as sawing and carving etc.

3) Weak weather-resistance and weak acid resistance. Because $CaCO_3$ in marble is easy to catch corrosion from acidic materials ($CO_2$, $SO_2$ etc.) in the environments, its surface will lose gloss after corrosion, and become rough and porous. So except special types (such as Han white jade marble and wormwood green marble etc.), marble is not applicable for out-door use.

4) Excellent decorativeness and good processability. Marble has colorful texture and is beautiful and elegant after being processed. It is one of the most ideal facing materials. The decorative effect of marble in light colors is solemn and elegant, marble in dark colors is magnificent and noble.

5) Strong wear resistance, low water absorption and good durability.

Physical mechanical property indexes of natural marble are shown in Table 3.1.

**Table 3.1 Physical Mechanical Property Indexes of Natural Marble**

| Item | | Index |
|---|---|---|
| Apparent density ($kg/m^3$) | | 2500-2700 |
| Strength (MPa) | Compressive strength | 47-140 |
| | Folding strength | 3.5-14 |
| | Shearing strength | 8.5-18 |
| Average toughness (cm) | | 10 |
| Average weight wearing rate (%) | | 12 |
| Water absorption (%) | | <1 |
| Expansion coefficient $\times 10^{-6}$(℃) | | 9.02-11.2 |
| Durable years (year) | | More than 20 |

(2) Decorative Features and Types of Natural Marble

There are many kinds of marble with fine and exquisite texture and soft, smooth and luster surface catering to the favorites of people. Three types are mainly exploited and applied at present: cloud- grey marble, white marble and colored-flower marble.

1) Cloud-grey marble. Cloud-grey marble is named because its color is as grey as cloud, or it looks like natural cloud floating on its grey background. It has great processability and is mainly adopted to produce building veneers. It is the most commonly exploited and applied kind.

2) White marble. Pure marble is white. It is beautiful and brilliant, and white just like jade, it is also named Han white jade—the precious type in marble family and the unique decorative material for important structures.

3) Colored-flower marble. Colored-flower marble is in lamellar form and is made of the part between the layers of cloud-grey marble. It is the top class in marble family. After grinding and polishing, it looks like a natural picture with colorful, beautiful and various appearances, which is rare in the world. The flower-pattern features and types of commonly-used domestic marble are shown in Table 3.2.

**Table 3.2 Flower-pattern Features and Types of Commonly-used Domestic Mable**

| Name | Features | Origin |
|---|---|---|
| Han white jade | As white as jade, with slight spots and grains | Fangshan, Beijing; Huangshi, Hubei |
| Crystal white | White crystal, with slight spots and grains | Hubei |
| Snow cloud | White and grey varying between each other | Yunfu, Guangdong |
| Snowflake | White and light grey varying between each other, with even crystals and more yellow spots | Yexian, Shandong |
| Shadow crystal white | Ivory white, with some dimpled grains in colors from reddish to deep ochre among the ivory white | Gaozi, Jiangsu |
| Windy snow | Ash grey with some dark grey halo strips | Dali, Yunnan |
| Darken crystal white | White jade with micro-crystalline, black grains or spots. | Quyang, Hebei |
| Cloud grey | White or light grey, with fog-like or cloudlike black ashy grains | Fangshan, Beijing |
| Crystal grey | Grey with slight reddish brown, even fine crystal grains, some grey stripes or super color spots among the grey | Quyang, Hebei |
| Camel grey | Dusty grey grounding, with some deep yellow-ocher grains | Suzhou, Jiangsu |
| Sea wave | Light gray grounding, with some steel-grey stripes of dark color or light color alternating | Hubei |
| Worm wood green | Cyan grounding, with some leaf-like and flake-like stripes in deep grey and white | Fangshan, Beijing |
| Residual snow | Ash grey, with black stripes | Tieshan, Hebei |
| Snail green | Dark grey grounding, covered with cyan and white spiral-thread flower patterns | Fangshan, Beijing |
| Brocade grey | Light black-ash grounding, with red and ash-grey grains | Daye, Hubei |
| Milky way | Light grey grounding, with densely distributed pink grains mixed with yellow grains | Xialu, Hubei |
| Tangerine pith | Light grey grounding, with densely distributed pink and violet-red leaf veins | Changxing, Zhejiang |
| Dark wall | Black, with a few light black spots or a few yellow stripes | Huolu, Hebei |
| Dark night | Black with a few white grains or white spots | Suzhou, Jiangsu |
| Dark jade | Ink black | Guzhou, Guangxi |
| Iran resin yellow | Light yellow, with more rice-yellow grains | Huangshi, Hubei |
| Grease | Grease grounding, with some deep yellow veinlets and transparent stray-crystals | Yixing, Jiangsu |
| Colored cloud | Light emerald-green grounding, with deep and light green floccus, purple spots and stripes | Huolu, Hebei |
| Jasper | Tender green or deep green intermingling with white floccus | Lianshanguan, Liaoning |
| Speckled green | Ash grey grounding, deep grass-green spots and maculosus stripes | Laiyang, Shandong |
| Sunglow | Mineral yellow with khaki as ground color, with deep-yellow lapping stripes and black halos | Shunyi, Beijing |

There is great amount of marble reserves in China, about more than $40\times10^8m^3$of more than 400 styles and types. Among them the better types are pure white marble including "Han white jade" in Fangshan, Beijing; "Guichi white" in Anhui; "Quyang white" in Hebei and "snowflake white" in Yexian etc.; pure black marble including "Gulin black" in Guangxi; "Shuangfeng Black" in Hunan and "Moyu Black" in Anyang etc.; red marble types are "Dongbei red" in Tieling, Liaoning and "Laishui Red" in Hebei etc.

Presently there are large amount of marble from abroad in the market, which are named mainly after their colors and patterns, e.g., Cream Marfil and Norway red etc.

### 2. Classification, Grading, Naming and Marking of Natural Marble Slab

(1) Classification of Natural Marble Slab

According to shape, natural marble slabs are classified to normal slabs (N) and irregular slabs (or sketch plates) (S). Normal slabs are rectangle or square; irregular slabs are slabs in other shapes.

(2) Grading of Natural Marble Slabs

Based on dimensional deviation, flatness allowed tolerance, angle allowed tolerance limit, appearance quality and specular glossiness etc., natural marble slabs are divided into superior quality (A), first quality (B) and good quality (C).

(3) Naming and Marking of Natural Marble

Natural marble's naming sequence is as follows: appellation of origin of quarry block, name of pattern, and color feature, code name of marble (M).

Marking sequence is as follows: name, type, dimensions, grade and standard code. For example, normal slab made of white marble blocks that come from Fangshan, Beijing, its dimension is 600mm×400mm×20mm, slab quality is grade B, then it's named and marked as:

Naming: Fangshan Han white jade marble

Marking: Fanshan Han white jade (M) N 600×400×20 B JC79

### 3. Quality Technical Requirements for Natural Marble Slab

The quality technical requirements for natural marble slab include: dimensional allowed tolerance, flatness allowed tolerance limit, angle allowed tolerance limit, appearance defect requirements. According to the specifications in "*Natural Marble Building Slabs*" (JC/T79-2001), the quality technical requirements for marble slab of different grades should refer to Table 3.3 and Table 3.4. Moreover, the standard has specified that each batch (50-100m$^2$ as one batch) of slabs should be of the same color and pattern and should not be apparently different from the standard sample. For non-finalized auxiliary products, the dark and light color tones on each part of the slab surface should transit gradually, and flower-pattern features should be in coordinated state without abrupt changes.

The glossiness of slab is controlled according to its chemical composition, and the control value should not be lower than the value specified in Table 3.5.

**Table 3.3 Technical Requirements of Natural Marble Slabs** (mm)

| Item | Dimension | | Allowed tolerance | | |
|---|---|---|---|---|---|
| | | | Grade A | Grade B | Grade C |
| Dimensional allowed deviation | Length, width | | 0<br>-1.0 | 0<br>-1.0 | 0<br>-1.5 |
| | thickness | ≤12 | ±0.5 | ±0.8 | ±1.0 |
| | | >12 | ±1.0 | ±1.5 | ±2.0 |
| Flatness allowed tolerance limit | Slab length | <400 | 0.20 | 0.30 | 0.50 |
| | | ≥400 | 0.50 | 0.60 | 0.80 |
| | | ≥800 | 0.70 | 0.80 | 1.00 |
| | | ≥1000 | 0.80 | 1.00 | 1.20 |
| Angle allowed tolerance limit | Slab length | ≤400 | 0.20 | 0.30 | 0.50 |
| | | >400 | 0.50 | 0.60 | 0.80 |

**Table 3.4 Requirements on the Front Appearance Defect of Natural Marble Slabs**

| Name | Specific content | Grade A | Grade B | Grade C |
|---|---|---|---|---|
| Crack | The allowed quantity (pcs) of crack to a slab more than 10mm long | | | |
| Broken corner | The allowed quantity (pcs) of broken corner for each slab; the broken corner should be less than 3mm long and wide along the slab edge (those less than 2mm long and wide excluded) | 0 | 1 | 2 |
| Broken edge | The allowed quantity (pcs) of broken edge for each slab; the broken edge should be less than 8mm long and less than 1.5mm wide (those less than 4mm long and less than 1mm wide excluded) | | | |
| Color spot | The allowed quantity (pcs) of color spot on each slab; the area of the spot should be less than 6cm$^2$ (those less than 2cm$^2$ excluded) | | | |
| Sand hole | Diameter of the hole should be less than 2mm | None | Not apparent | Not affect using |

**Table 3.5 Requirements on the Specular Glossiness of Natural Marble Slabs**

| Content of major chemical composition (%) | | | | Specular glossiness (gloss unit) | | |
|---|---|---|---|---|---|---|
| Calcium oxide | magnesia | Silicon dioxide | Loss on ignition | Grade A | Grade B | Grade C |
| 40-56 | 0-5 | 0-5 | 30-45 | 90 | 80 | 70 |
| 25-35 | 15-25 | 0-15 | 35-45 | | | |
| 25-35 | 15-25 | 10-25 | 25-35 | 80 | 70 | 60 |
| 34-37 | 15-18 | 0-1 | 42-45 | | | |
| 1-5 | 44-50 | 32-38 | 10-20 | 60 | 50 | 40 |

### 4. Storage and Selection of Natural Marble

As the surface of natural marble slab is bright, fine and smooth, easy to get stained and scratched, slabs should be stored indoors or covered when stored outdoors. They should be respectively piled properly according to types, sizes, grades or application places in structure. For erect piling, the polished surfaces of slabs should be put against each other, the inclined angle of slabs should be less than 15°, and a cushion or resemble filling is needed between two slabs, piling height should less than 1.5m; for flat piling, the ground surface must be flat, piling height should not be more than 1.2m. Package piling height should not be over 2m.

Natural marble is among super decorative materials. Natural marble polished slabs are mainly applied to large structures or structures requiring advanced decoration, for instance, the internal walls, columns, platforms and floors in public buildings such as marketplaces, exhibition halls, restaurants, theatres, libraries and office buildings etc. Natural marble slabs are adopted to produce craftworks such as wall paintings, seat screens, hanging screens and wall hangings and used for assembling flowerpots or inlaid in advanced hardwood carved furniture etc. Except for special types, marble is not applicable for out-door use.



## 3.2.2 Natural Granite

All kinds of magmatic rock with properties similar to those of granite and metamorphosed rock with silicate mineral as its main composition are called granite in stone industry.

According to geological condition, granite is the plutonic rock of igneous rocks. The main rock-forming minerals in granite are feldspar (crystal aluminosilicate), quartz (crystal $SiO_2$) and a little amount of mica (lamellar hydrous aluminosilicate). According to chemical composition, granite mainly contains $SiO_2$ (around 70%) and $Al_2O_3$ and a little amount of CaO and MgO, so it is acidic crystalline rock. Its color depends on the color of feldspar and the little amount of mica and other dark color minerals in it. Generally it looks grey, yellow, rosy, pink, black or grey and black. The types in dark colors are more precious and famous.

**1. Performances, Features and Types of Natural Granite**

(1) Performances and Features of Natural Granite

1) Dense structure, hard texture, high compressive strength and strong wearing resistance.

2) Good chemical stability, strong weather resistance and corrosion resistance.

3) Unique decorative effects and excellent texture. After polishing, the gloss and texture of the slab become very decent and elegant, showing different beautiful spot-like patterns with different glosses. There are tiny and even crystalline grains on the patterns which are covered with starry bright spots of mica and sparkling with quartz crystals.

4) Low heat-resistance. The strength of quartz will quickly reduce when it is heated to expand at high temperature.

Major performance indexes of natural granite are given in Table 3.6.

**Table 3.6 Major Performance Indexes of Natural Granite**

| Item | | Index |
|---|---|---|
| Apparent density ($kg/m^3$) | | 2500-2700 |
| Strength (MPa) | Compressive strength | 120-150 |
| | Folding strength | 8.5-15 |
| | Shearing strength | 13-19 |
| Average toughness (cm) | | 8 |
| Average weight wear-rate (%) | | 12 |
| Water absorption (%) | | $<1$ |
| Expansion coefficient /$\times 10^{-6}$(℃) | | 5.6-7.34 |
| Durable years (year) | | 75-200 |

(2) Types of Natural Granite

There is a great storage of granite in our country. The discovered reserve e is up to 100 billion $m^3$ in more than 150 styles or types distributing in many areas such as Shandong, Guangdong, Fujian, Sichuan, Guangxi, Beijing, Henan, Hunan, Xinjiang, Zhejiang, Jiangsu and Heilongjiang etc. Major granite types in our country are white tiger in Beijing, Jinan Cyan in Jinan, black granite in Qingdao, Shimian Red in Sichuan, Jiangjun Red in Hubei, Princess Red in Lingqiu, Shanxi. The following precious and famous types are as well-known as those of worldwide famous brands (such as Clara White, India Red and Brazil Blue): "Tianshan Blue" from Xinjiang; "China Red" from Ya'an, Sichuan; "Taibai Cyan" from Hunyuan Qingciyao, Shanxi; "Fuping Black" in Fuping, Hebei; "Fengzhen Black" in Mongolia and "Yixian Black" in Hebei etc. The types, features and origins of some types of domestic granite are listed in Table 3.7.

**Table 3.7 Types, Features and Origins of Some types of Granite in Our Country**

| Manufacturer | Name | Decorative performance |
|---|---|---|
| Fengshan, Quanzhou, Fujian | Sapphire | Light bluish grey |
| Beijing Marble Factory | Jinan Cyan<br>White Tiger<br>Jiangjun Red | Black with little white spots<br>Pink with black spots<br>Black-ash, brownish-red and light gray with little mottles |
| Yexian Marble mineral in Shandong (Laizhou brand) | Laizhou White<br>Laizhou Cyan<br>Laizhou Black<br>Laizhou Red<br>Laizhou Brownish Black | White ground with black spots<br>Black ground with bluish-white spots<br>Black ground with ash-grey spots<br>Pink ground with dark grey spots<br>Black ground with brown spots |
| Hubei Huangshi Marble factory | Jinan Cyan<br>Seasame Cyan<br>Red Granite | Black<br>White ground with black spots<br>Red ground with black mottles |
| Jinan Granite factory | Jinan Cyan<br>Red Granite Slab<br>White Granite Slab | Super black<br>Red-violet<br>White |



In the world, granite material is classified into three grades: quality granite polished slab mainly includes Brazilian Black, African Black, Indian Red and so on with pure dark tone and even grains; the intermediate granite material is mainly in pink, light violet and light green, etc. with the features of rough medium-grains, even colors and less varieties; low-grade granite slabs are in grey and pink etc.

### 2. Classifications, Grading, Naming and Marking of NaturalGranite Slab

(1) Classifications of Natural Granite Slab

As being specified in ministry standard "*Natural Granite Building Slab*" (JC/T205-2001), slabs are classified to normal slabs (N) and irregular slabs (or sketch plates)(S) according to their shapes. There are two sorts of normal slabs: square and rectangle; other slabs are irregular ones.

According to different applications, slabs are classified to the following four types.

1) Axed slab. Processed by chipping; rough surface with regular strip-like axe traces.

2) Planed Slab. Processed with machine; flat surface with parallel planed traces.

3) Rough grinding slab. By rough grinding, the surface is smooth and lack of luster.

4) Bright finished slab. Processed by grinding and polishing, with bright surface, exposed crystals; some types have vivid colors and beautiful patterns just like marble slabs.

According to surface finishing degrees, slabs are classified to the following three types:

1) Rubbed slab (RB). With flat and smooth surface.

2) Polished slab (PL) . With flat surface and specular gloss.

3) Rough slab (RU). With flat and rough surface and more regular processed stripes, including planed slab, axed slab, hammered slab and singed slab.



(2) Grading of Natural Granite

According to dimensional allowed tolerance, flatness allowed tolerance limit, angle allowed tolerance limit and appearance quality, natural granite slabs are graded into superior quality (A), first quality (B) and good quality (C).

(3) Naming and Marking of Natural Granite Slab

Natural marble's naming sequence is as follows: appellation of origin of quarry block, name of patterns and color tones, and granite (G).

Marking sequence is name, type, dimension, grade and standard code.

For example, Grade A polished slab made of Shandong Jinan black granite block in dimensions 600mm×400 mm×20 mm, named and marked as follows:

Naming: Jinan Cyan granite

Marking: Jinan Cyan (G) N PL 600×4000×20 A JC205

### 3. Technical Requirements of Natural Granite

To ensure decorative effect, the appearance quality and flower patterns of each natural granite slab in the same construction project should be in essence the same and there should be no apparent dimensional deviation among slabs of the same size. However, due to the differences in material quality and the processing level etc., there might be certain differences in its appearance quality, which may lead to imperfection in decorative effect and constructional operation etc. Therefore, the government has stipulated quality standards for natural marble slabs. According to "*Natural Granite Building Slabs*" (GB/T18601-2001) and "*Natural Granite Building Slabs*" (JC/T205-2001), the technical requirements for natural granite building slabs are shown in Table 3.8 and Table 3.9.

**Table 3.8 Technical Requirements for Natural Granite Building Slabs (mm)**

| Item | Dimension | | Honed and polished slab | | | Rough slab | | |
|---|---|---|---|---|---|---|---|---|
| | | | Grade A | Grade B | Grade C | Grade A | Grade B | Grade C |
| Dimensional allowed deviation | Length, width | | 0-1.0 | 0-1.0 | 0-1.5 | 0-1.0 | 0-1.0 | 0-1.5 |
| | Thickness | ≤12 | ±0.5 | ±1.0 | +1.0-1.5 | — | | |
| | | >12 | ±1.0 | ±1.5 | +2.0-2.0 | +1.0-2.0 | +2.0-2.0 | +2.0-3.0 |
| Flatness allowed tolerance limit | Slab length | <400 | 0.20 | 0.35 | 0.50 | 0.60 | 0.80 | 1.00 |
| | | ≥400 | 0.50 | 0.65 | 0.80 | 1.20 | 1.50 | 1.80 |
| | | ≥800 | 0.70 | 0.85 | 1.00 | 1.50 | 1.80 | 2.00 |
| Angle allowed tolerance limit | Slab length | ≤400 | 0.30 | 0.50 | 0.80 | 0.30 | 0.50 | 0.80 |
| | | >400 | 0.40 | 0.60 | 1.00 | 0.40 | 0.60 | 1.00 |

**Table 3.9 Requirements on the Front Appearance Defect of Natural Granite Slabs**

| Name | Specific content | Grade A | Grade B | Grade C |
|---|---|---|---|---|
| Broken edge | Broken edge with length not more than 10mm and width not more than 1.2mm (those less than 5mm long and less than 1.0mm wide excluded); the allowed quantity (pcs) of broken edge for each meter of the edge | | | |
| Broken corner | Broken corner with length not more than 3mm, width not more than 3mm along the slab edge (those less than 2mm long and wide excluded); the allowed quantity of broken corner for each block of slab | None | 1 | 2 |
| Crack | Crack with length not more than 1/10 of the overall length from the two crack ends to the slab edges (those less than 2mm long excluded); the allowed quantity (pcs) of crack for each block of slab | | | |
| Color spot | Spot not more than 15mm×30mm (those less than 10mm×10mm excluded); the allow quantity (pcs) of color-spot for each block of slab | | | |
| Color stripe | Stripe length not more than 1/10 of the overall length from the two stripe ends to the slab edges, (length less than 40mm excluded); the allowed quantity (pcs) of color stripe for each block of slab | | 2 | 3 |
| Hollow | There are hollows on the front surface of rough slab | | Not clear | Not affect using |

**4. Storage and Selection of Natural Granite**

The storage method of natural granite is in essence the same as that of natural marble.

Natural granite, an advanced building decorative material, is mainly applied to large public buildings or interior and exterior decoration projects which require luxurious decoration. Generally, the surface of polished granite slab and rubbed granite slab is bright and smooth and has excellent texture, so such slab is usually adopted for the decoration of internal walls and floors and the external walls of some structures. And it can also be used to decorate interior or exterior column surfaces, dados, stairs, steps and sculptures etc. as well as bar counters, service counters, cash counters, showcases and furniture etc. The surface of rough granite slab is rough and boorish, so it is mainly adopted for the decoration of exterior wall bases and wall surfaces, which create the style of primitive simplicity and nature.

The radioactivity of natural stone is a great issue widely concerned by people. It is proved that most of natural stone contains a little radioactive stuff, which generally does no harm to human health. However, there are some granite products whose radioactive substance index exceeds the specified standard, and these products will pollute the environments during long term service, so they must be controlled in application. For home decoration, Grade A products are eligible, B and C are not applicable. In addition, when buying stone articles, it is very important to ask for qualification certificate of radioactivity test. And taking it seriously will help to prevent the beautiful stone from doing harm to people.



## 3.2.3 Blue Slate and Slate Veneers

**1. Properties and Selection of Blue Slate**

Blue slate is a kind of aqueous sedimentary rock. Its main mineral composition is $CaCO_3$. With soft texture and weak weather resistance, its weathering status and durability are different due to the different burial depths of the rock. If the slate lies in the crust surface (upper crust) due to the shallow burial depth and heavy weathering effect, the rock is in lamellar form and easy to crack or split into lamellar slate which can be directly used in construction. So people living around the producing areas have the roofs and floors of their houses made of blue slate since long time ago. Such slab works easily and not costly to produce, usually in rectangle or square with side length ranging between 300-600mm. Slabs with natural traces and different colors as dark red, grey, green, blue and purple etc. on the surface are combined to create colorful and natural stylish decorative walls. This kind of slate largely exists in the northeast and southwest areas of our country. Deeply-buried slate is thicker and has stronger compressive strength (may reach 210MPa) and more ideal durability and can be processed to needed slabs. According to finishing method, it is classified as rough (natural cleft surface) slate and polished (polished surface) slate.

Made by splitting along the natural texture of the rock with cold chisel, rough slate, whose surface is not grinded and with clear textural traces, is in rich colors as dark red, celadon (grayish green), blue, purple and yellow. Different kinds of the slate can be combined to create colorful, diversified and natural stylish slate facing veneer, which feels natural and wild just like natural material when applied to internal walls. For flooring, it is not only nonslip, but also creates hard and "soft" combination effect.



Polished slate is a rare and precious facing material used for column and wall decoration. Irregular slabs can be composed to form a regular natural design in special decorative style.

In recent years, blue slate has been adopted in the construction of many new public structures in our country. For instance, Beijing Zoo Reptile Hall and Shenzhen Museum Exhibition Building are glazed with slate veneers, and have achieved marvelous architectural decorative effect.

## 2. Features and Selection of Slate Veneers

Slate is metamorphic rock extracted and transformed from clay shale and its mineral compositions are the tiny granules of feldspar, quartz, mica and clay. Slate is in lamellar structure, which is easy to cleft into slabs. Its cleavage surface is perpendicular to the direction of the pressure it receives but has nothing to do with the former sedimentary layer. Slate has solid and dense structure and strong hardness; it is water resistant, durable and difficult to soften in water; its service life can be several decades or more than one hundred years. In black, blue-black, grey, bluish grey, purple, red and motley spots etc, it is an excellent finishing material. The disadvantages are heavier self-weight, weaker ductility, easy to crack and break when shocked and shaken, and it is hard to grind and polish.

In Europe and America, slate veneer, as one of the most popular facing materials, is mostly applied to sloping roofs instead of other roofing material and to non-polished external walls in recent years. Usually it is made into face-tile form to be affixed directly on wall surface with cement mortar or special cementing compound, with thickness between 5-8 mm, length between 300-600mm， width between 150-250mm. It has been introduced to our country and usually applied to external wall facing decoration and some parts of internal wall decoration. By taking the advantage of its special color tones and textures, the exotic European and American styles can be achieved.

## 3.3 Artificial Facing Stone

### 3.3.1 Introduction of Artificial Stone

Artificial stone (also called synthetic stone) is made up of cement or unsaturated polyester as bonding agent, the inorganic powder of natural marble or calcite, dolomite, siliceous sand and glass dust etc., and proper amount of fire retardant, stabilizer and dyestuff etc. It is processed by molding and solidifying through blending, concreting, vibrating, compressing and pressing.

Artificial stone appeared in America in 1958, with a history of 40 years. We started to employ artificial stone samples, technical data and production equipments in the end of 1970s; then stepped into development in the 1980s; currently some products have reach international level of the same sort of products in quality and have been successfully applied in the decoration projects of advanced buildings.



**1. Types of Artificial Stone**

According to the raw materials for production, artificial stone is classified to the following four types.

(1) Cement Artificial Stone

Cement artificial stone is made in this way: take all kinds of cement such as regular cement, silicate cement or slag cement etc. as bonding agent, sand as fine aggregate, and crushed marble, granite or industrial residue etc. as coarse aggregate, then process them through mixing, churning, molding, pressure steam-curing, grinding and polishing.

Such kind of artificial stone has weaker physical performances and its decorative performances such as surface patterns and glosses are inferior to those of natural stone, but it is affordable. Terrazzo-concrete and all kinds of tiles are of cement-type artificial stone.

Besides silicate series cement, aluminate cement is also adopted as bonding agent for some cement artificial stone. In hydrating, aluminate cement generates colloidal aluminum hydroxide, which keeps filling in the capillary holes of artificial stone to form dense structure and create smooth surface layer. Therefore, after molding, its surface, not polished, is smooth and glossy with better decorative effect.

(2) Resin Artificial Stone

Resin artificial stone is made in this way: take organic adhesives such as unsaturated polyester etc. as bonding agent and mix it with natural crushed stone, rock powder and pigment or dyestuff, then process them through concreting, molding, solidifying by solidified agent, demolding, drying and polishing etc. This method is popular both at home and abroad.



(3) Compound Artificial Stone

The bonding agent of compound artificial stone includes inorganic and organic bonding material. Firstly, bond filling materials such as rock powder etc. into mold with inorganic bonding agent; secondly, sink it into organic monomer with polymerizing function to polymerize it to compound artificial stone at certain conditions. Slab products can be produced in two layers, that is, for the under-layer, rock powder is bonded and molded with cheap but stable inorganic bonding material; the surface layer is made of polyester and marble powder. Both are combined to produce colorful and glossy decorative veneer.

Inorganic bonding material includes many sorts of cement, such as ordinary silicate cement, white cement, fly ash cement, slag cement, high-speed cement and aluminum cement etc. Organic monomer can be styrene, methyl-methacrylate, acrylonitrile, butadiene and dichloroethylene etc., which can be solely or combinedly used.

(4) Sintered Artificial Stone

The production technique of sintered artificial stone is similar to that of ceramic. Mix rock powder of plagioclase, quartz, pyroxene and calcite etc., hematite powder and some kaolin together to make blank with grouting method, then mold it with semi-dry-pressing method, after that put it in the kiln at temperature around 1000℃ for sintering and producing the stone. Such kind of artificial stone is stable durable, but due to the high temperature sintering, its energy consumption and production cost is higher, therefore it is rarely adopted in practice.

Among the above four types, resin artificial stone has the best physical and chemical performances. It has easily-designed patterns and good reproduction quality but is more costly; cement type artificial stone is the most affordable but it has weaker corrosion-resistance, and is likely to have micro cracks, therefore, it is made into slabs but not for making sanitary wares etc.; compound artificial stone has the advantages of the former two types: with excellent physical and chemical performances and low cost; sintered artificial marble is made of clay and rock powder as raw material but needs high temperature sintering, so it consumes large energy and costs more, and with high breakage rate, it is rarely adopted in practice.



There is a huge storage of natural stone in our country, but presently its yield rate is only around 30% due to the shocking waste. The huge amount of crushed stone left in the production, which should have been converted to treasure and taken as the raw material of artificial stone, is now treated as waste. So the development of artificial stone meets the basic strategy of comprehensively making use of national resources of our country and is important for the scientifical utilization of stone resources. It has been stiputated in "Mineral Resources Protection Act" that the exploitation of mineral resources be restrictively controlled and the waste of mineral resources be prevented effectively. Artificial stone is adopted as floor veneer material in the interior decoration of buildings. Examples are Hong Kong Convention and Exhibition Center, Shanghai Pudong First Department Store, Shenzhen World Trade Center Building and Beijing COFCO Plaza. The development in these years proves that artificial stone is to have a remarkable developing landscape.

**2. Features of Artificial Stone**

Artificial stone is made of natural stone as its raw material, so it has some inherited advantages but at the same time loses some disadvantages of natural stone. Artificial stone has the following specific features:

1) Many types; with the textures and grains of natural stone but no difference in color or grain; in selection, it is not necessary to take color difference into consideration.

2) With strong stain resistance, it is easy to clean because there is no pore on its surface and oil and water stain can't penetrate in easily.

3) Thinner and lighter than natural stone; easy for transportation. If adopted for flooring, it reduces the body bearing of the building.

4) The back surface of artificial stone is processed into corrugations, so it is easy to plaster with the base. It requires simple technique in construction and makes the walls and the floors stronger after decoration.

5) Artificial stone costs 1/10 as much as natural stone, and has no radioactivity. Presently it is the most ideal green and safe material which meets the consumption principles of people in the 21$^{st}$ century.

6) Artificial stone takes natural rock powder as major raw material, which is an example of the utilization of waste materials.

Artificial stone has the above advantages. However, it is inferior to natural stone in color, grain and texture, which leads to a slight unappealing visual effect.



**3. Applications of Artificial Stone**

According to different application areas, artificial stone is mainly applied to the following aspects.

1) Table tops: tops of unitary cupboards in kitchens, dining table tops and even furniture can be made of such material. Natural stone has natural patterns and colors, but doesn't allow for bending, and its curved surface is hard to process. Artificial stone has surpassed the shortages and can be made into various models through plastic molding or hot pressing. As to tops, seamless integral effect is more appealing.

2) Walls and floors: artificial stone is lighter and thinner,with strong corrosion-resistance and stain resistance. It can imitate natural stone in patterns and glosses with less color difference and excellent overall decorative effect. So it is applicable to walls, columns and floors etc. as facing material.

### 3.3.2 Commonly-used Artificial Stone

Artificial stone is a widely used material in decorative projects. Commonly-used are building terrazzo slab, artificial marble slab, artificial granite slab and mini-crystal glass plate etc.

**1. Building Terrazzo Slab**

(1) Features of Building Terrazzo Slab

Building terrazzo slab is a building decorative slab made of cement as bonding agent and marble gravels in different sizes as aggregate, and then produced through processes such as mixing, molding, curing and grinding etc.

Building terrazzo slab has higher strength. It is solid, dense and durable. Its patterns, colors and designs can be optionally combined. With more styles and types, it can be arranged to create different patterns and designs according to specific requirements in application, which not only shows good decorative effect, but also is cheaper and convenient for construction.

Besides silicate cement, aluminate cement is also taken to make building terrazzo slab which has dense and smooth surface structure, higher glossiness and strong moisture-proof performance.

(2) Applications of Building Terrazzo Slab

The production of building terrazzo slab has already been industrialized, mechanized and serialized. Its colors and patterns can be optionally combined to meet different needs. There are more affordable types to choose from compared with natural slab, so it is more widely used in building and decoration projects. Building terrazzo slab can be precasted into products or slabs in various shapes, and also can be casted on site. It is applied to buildings at places such as floors, walls, columns, windows, steps, baseboards and footboards etc.



(3) Classifications and Naming of Building Terrazzo Slab

Generally there are three methods to classify terrazzo slab.

1) According to surface finishing degree, it is classified into two types: ground terrazzo (M) and polished terrazzo (P);

2) According to the application areas in a structure, terrazzo articles can be classified into four types as terrazzo for walls and columns (Q); terrazzo for floors and building surfaces (D); terrazzo for base boards, standing boards and triangular plates etc. (T); terrazzo for partition panels, window boards and deck plates (G).

3) According to its appearance quality and physical mechanics performances, terrazzo is classified as superior quality (A), first quality (B) and good quality (C).

For building and decoration, the normal sizes of terrazzo slab are 300mm×300mm, 305mm×305mm, 400mm×400mm and 500mm×500mm. Other sizes can be negotiated by the manufacturer, the designer and the user.

The marking sequence is brand name, type, grade, size and standard code.

For instance, brand Diamond, size 400mm×400mm×25mm, grade B flooring polished terrazzo, is marked as Diamond Brand Terrazzo DPB400×400×25JC507.

(4) Quality Technical Requirements of Terrazzo

The quality technical requirements of terrazzo include dimensional allowed tolerance, appearance quality and physical performances. Physical performances include glossiness, strength and water absorption capacity etc. To the glossiness of polished terrazzo, grade A should be not lower than 45.0 gloss unit, grade B not lower than 35.0 and grade C not lower than 25.0. Its water absorption capacity should be no more than 8.0%. The average value of folding strength should not be less than 5.0MPa, and to a single piece, its minimum value should not be less than 4.0MPa.



**2. Polyester Artificial Stone**

Polyester artificial stone is a resin artificial stone made by adopting unsaturated polyester resin as bonding agent.

(1) Types of Polyester Artificial Stone

When producing polyester artificial stone, different pigments, different types of natural stone material in different granular sizes and different qualities are processed with indifferent production techniques or methods, therefore, the products are different in pattern, design, color and texture. According to the different surface designs, polyester artificial stone is classified as artificial marble, artificial granite, artificial agate and artificial jade etc.

1) Artificial marble. Resemble patterns and textures of marble.

2) Artificial granite. Resemble patterns, colors and textures of granite, e.g., pink ground with black spots and white ground with black spots.

3) Artificial agate. Resemble patterns and textures of agate. Its filling stuff is highly fine and pure and the product is translucent. The filling stuff includes aluminium hydroxide (termolecular crystalline water) and suitable marble powder.

4) Artificial jade. Resemble glosses of jade, translucent. Its filling stuff is highly fine and pure. Artificial jade can be delicately produced and classified to such types as amethyst, colorful green jade, rose quartz and Shantian jade etc.

(2) Features of Polyester Artificial Stone

1) Excellent decorative effect. Different pigments, different types of natural stone in different granular sizes and qualities are processed with indifferent production techniques and methods in production. Therefore the products are different in pattern, design, color and texture. It can nearly achieve the decorative effect of natural stone's.

2) High strength and strong wear resistance. Its compressive strength reaches up to 80-100MPa, folding strength up to 25-40MPa, Brinell hardness up to 32-40HB which is a little lower than that of natural marble, so it has stronger wear resistance.

3) Strong corrosion resistance and stain resistance. Taking unsaturated polyester resin as bonding agent, polyester artificial stone is strongly resistant to acids, alkalis and stains.

4) Simple production technique and excellent processability. Simple techniques are needed in the production of polyester artificial stone, main molding techniques including pouring, pressing and large block molding etc.. Moreover, it can be made into products in different shapes, sizes, colors and glosses according to design requirements. Compared with natural marble, it is more workable and easier for sawing, drilling and punching etc.

5) Weak thermal resistance and weather resistance. Unsaturated polyester resin is relatively weaker in thermal resistance, the service temperature is generally not higher than 200℃. Light, heat and electricity in the air may deteriorate the resin and make the slab surface gradually lose its gloss or even cause quality problems to the slab such as darkening or warpage, and then the decorative effect will be decreased. Polyester artificial stone is generally used indoors.

(3) Applications of Polyester Artificial Stone

Polyester artificial stone is a developing interior and exterior decorative material. Artificial marble and artificial granite can be adopted in interior decoration at places such as walls, columns, wall paintings and architectural reliefs etc. and used to produce sanitary wares such as bathtubs, washbasins with dressing table, stand washbasins and toilet bowls; artificial agate and artificial jade can be adopted to make artificial stone craftworks such as craft wall paintings, decorative relief sculptures and solid sculptures.

The process of polyester artificial stone in Italy is very developed and famous in the world. The imitated artificial marble has the similar stripes as natural marble, unique and special, but expensive. Presently, there are manufacturers producing polyester artificial stone in regions such as Beijing, Tianjin, Qingdao, Jiangsu and Guangdong in our country. Commonly-used types and dimensions of polyester artificial stone are listed in Table 3.10.

**Table 3.10 Commonly-used Types and Dimensions of Polyester Artificial Stone**

| Type | Item name | Dimension (mm) | | | Remark |
|---|---|---|---|---|---|
| | | Length | Width | Thickness | |
| Artificial marble slab | Reddish stone | 450 | 450 | 8-10 | More types and sizes, color and pattern features all imitated from natural marble |
| | Sky-blue snowflake | 800 | 800 | 15-20 | |
| | Flocculent dark green | 600 | 600 | 10-12 | |
| | Rosy dark-green | 700 | 700 | 12-15 | |
| Artificial granite slab | Cream white | 1730 | 890 | 12 | Many styles of design and color |
| | linen | 1730 | 890 | 12 | |
| | Colored cloud | 1730 | 890 | 12 | |
| | Royal red | 1730 | 890 | 12 | |
| | Brocade black | 1730 | 890 | 12 | |
| artificial jade slab | White-cloud violet | 400 | 400 | 10 | White |
| | Sky-bluish red | 400 | 400 | 10 | Bluish red |
| | Rosy quartz | 400 | 400 | 10 | Pink |
| | Black & white jade slab | 400 | 400 | 10 | Black and white patterns |
| | Hillside jade slab | 400 | 400 | 10 | Green |
| | Green-black-gold star | 400 | 400 | 10 | Green with golden spots |

### 3. Plastic-stone Skid Proof Floor Tiles

Plastic-stone skid-proof floor tile is a new artificial flooring material. It is a composite flooring material mainly made of polyvinyl chloride (PVC) processed with artificial synthesis method. The surface is a wear-resistant layer made of polyvinyl chloride resin, then the printing layer and natural stone powder, the bottom layer is water-proof. The thinnest product is 3mm thick. Plastic-stone skid-proof floor tile has strong anti-slip performance, certain ductility and heat preservation but doesn't feels as tough as natural marble; it can be produced into different colors, glosses and designs to achieve good decorative effects; with less self-weight than natural stone, it helps to decrease the bearing load of the floor, and is convenient for paving. It is especially applicable for the flooring decoration of kindergartens, residential houses for senior people and hospitals, also for the facing decoration of internal walls and columns etc.

## 4. Micro-crystalline Glass Plate

Micro-crystalline glass plate is also called microcrystalline stone, it is neither inorganic plate-glass traditionally used for light-picking nor heat-reflecting glass presently serving as glass curtain wall, but a new advanced luxurious building decorative material.

Micro-crystalline glass decorative plate is poly-crystal created by controlled-crystallization high-tech, which has dense structure, high strength, strong wear resistance and strong corrosion resistance. Its appearance has clear texture, fresh color and gloss, but no color difference or color-fading. Being a new advanced decorative material for luxurious structures, it is becoming a preference to many construction companies. Presently it has already replaced natural granite in the decoration of walls, floors, columns, stairs, dados and steps etc.

Micro-crystalline glass decorative plate has the same compositions as natural granite, both are silicate material. Apart from higher strength and corrosion-resistance than natural stone, it also has advantages such as smaller water-absorption capacity (0-0.1%), no radioactive pollution, adjustable colors and controllable dimensions etc. Moreover, it can be produced to arched plate. Table 3.11 is the comparison of micro-crystalline glass plate with marble and granite facing slab in the major performances.



**Table 3.11 Comparison of Micro-crystalline Glass Plate with Marble and Granite Facing Slab in Major Performances**

| Performances | Micro-crystalline glass plate | Marble slab | Granite slab |
|---|---|---|---|
| Density ($g/m^3$) | 2.70 | 2.70 | 2.70 |
| Compressive strength (MPa) | 300-549 | 60-150 | 100-300 |
| Folding strength (MPa) | 40-60 | 8-15 | 10-20 |
| Mohs hardness | 6.5 | 3-5 | 5.5 |
| Water absorption (%) | 0-0.1 | 0.3 | 0.35 |
| Diffused reflectance (%) | 89 | 59 | 66 |
| Acid-resistance (1%$H_2SO_4$) (%) | 0.08 | 10.3 | 1.0 |
| Alkali-resistance (1%NaOH) (%) | 0.05 | 0.30 | 0.10 |
| Heat expansion coefficient ($\times 10^{-7}$/℃) | 62 | 80-260 | 50-150 |
| Sea-water resistance ($mg/cm^2$) | 0.08 | 0.19 | 0.17 |
| Freezing-resistance (%) | 0.028 | 0.23 | 0.25 |

Micro-crystalline glass plate has unique and excellent decorative performance, so it has been popular since it came into being. In the last few years, it is applied in Japan for the decoration of internal and external walls and floors in the construction and renovation of bus stations, e.g. the station near Nagoya, Tokyo metro-station and Osaka metro-station etc. Moreover, micro-crystalline glass plate is largely applied in decoration projects of numerous public, commercial and industrial buildings.

Micro-crystalline glass serves as a unique decorative material in construction field, it also has a promising application prospect in machinery, chemistry and aircraft industries, and is one of the major directions for the development of intelligent architectural materials.

The construction and installation methods of micro-crystalline glass plate are traditional methods for stone construction, pasting and dry-hanging methods.



# Test on Decorative Materials

## Test on Stone Radioactivity

**1. According to the requirements in national standards and the radioactivity level of decorative materials, this test is divided into the following three types**

(1) A-type decorative materials

Materials with their radioactivity specific activity of natural radioactive species Ra-226, Th-232 and K-40 meeting all requirements of $I_{Ra} \leqslant 1.0$ and $I_{\gamma} \leqslant 1.3$ are classified as A-type decorative materials, which have no scope limitation for sale and usage.

(2) B-type decorative materials

Materials not meeting the requirements for A-type decorative materials but meeting all requirements of $I_{Ra} \leqslant 1.3$ and $I_{\gamma} \leqslant 1.9$ are classified as B-type decorative materials, which are not applicable for the interior decoration of I-type residential buildings, but applicable for the exterior facing decoration of I-type residential buildings and the interior and exterior facing decoration of any other buildings.

(3) C-type decorative materials

Materials not meeting the requirements for A-type and B-type decorative materials but meeting the requirements of $I_\gamma \leqslant 2.8$ are classified as C-type, which are only applicable for the exterior facing decoration of buildings and other out-door usage.

(4) Granite with $I_\gamma > 2.8$ is only applicable for places where people rarely go such as monuments, sea levees and bridge abutments etc.

**2. Test Method**

(1) Instruments

Low background multi-channel $\gamma$ spectrometer

(2) Sampling

1) Sample-taking. Take two portions of sample randomly with each portion no less than 3kg. One is sealed and stored, the other serves as test sample.

2) Sample-making. Crush the test sample and grind it to powder with granular diameter not more than 0.16m. Put it into the sample box in the same geometric form as the standard sample, then weight (accurate to 1g) and seal it, make it ready for test.

3) Measuring. When the natural radioactive decay chain in the sample almost reaches balance, in the same measurement conditions with the standard sample, measure the specific activity of Ra-226, Th-232 and K-40 with low background multi-channel $\gamma$ spectrometer.

4) The inaccuracy of measurement. When the overall amount of radioactivity specific activity of Ra-226, Th-232 and K-40 in the sample is more than $37\text{Bq}\cdot\text{kg}^{-1}$, this standardized test method requires to measure inaccuracy (expansion factor $K$=1), no more than 20%.

**3. Test Rules**

1) The radioactivity specific activity of Ra-226, Th-232 and K-40 listed in this standard are type-test items.

2) Under normal circumstances, carry out at least one type-test each year.

3) Carry out type-test at any time under any of the following cases:

① when a new product gets approved;

② when production technique or raw material is relatively greatly changed;

③ when it is produced in different locations.

4) Test Result Evaluation.

The test results of a decorative material are classified and evaluated based on related standards.

# Practice

Get to know the types, performances, prices and application statuses of decorative stone. Mainly learn and master the types, prices, applications and selection methods of different types of decorative stone.

**1. Objectives of the Practice**

Students are required to carry out investigation and practice in building decorative material markets and on constructional decoration sites. Collect all sorts of stone and get to know their names, appearances, operation requirements, application scopes and application statuses.



**2. Practice Modes**

(1) Investigation in building decorative material markets

Student grouping: 3-5 students as one team; go to markets to collect, survey and identify building decorative materials.

Investigation method: learn how to recognize different sorts of stone, find out prices, collect samples and master application requirements of the materials mainly by surveying, inquiring and collecting.

(2) Research on the applications of the materials on construction and decoration sites

Student grouping: 3-5 students as one team; led by teachers or persons in charge of the sites;

Investigation method: guided by teachers or persons in charge of the sites, introduce and explain the application status and notices of materials in construction practice adapted to the construction site and its actual conditions.

**3. Contents and Requirements of the Practice**

1) Complete the research diary carefully;

2) Write a research report;

3) Write a practice summary.

## Summary

This chapter introduces the classifications and basic properties of stone and the types, performances and application scopes of commonly-used facing stone in building and decoration projects. After learning about the performances of natural stone, students are required to understand and be familiar with their technique requirements and characteristics, master its types and performances, furthermore to be able to scientifically select stone, and make the best use of its functions and performances. It is important to master the types, performances and application scopes of commonly-used facing stone.

## Questions for Reviewing and Thinking

3.1 What types of rock are there based on their geological forming conditions? What are their characteristics?

3.2 What are the major compositions of marble and granite? Why is marble not applicable for exterior construction?

3.3 What are the differences between marble and granite in their natures?

3.4 What is artificial stone? How many types of artificial stone are there?

3.5 What are the major applications of artificial stone?

3.6 What are the types and characteristics of commonly-used artificial stone?

# 4

# Gypsum Decorative Materials

## 4.1 Basic Knowledge of Gypsum

Gypsum and its products have various functions such as heat preservation, thermal insulation, sound absorption and fireproofing etc. White in color, refined in quality, stable in volume and non-deformed after hardened, and good mould-ability when mixed with water, building gypsums have been used as indoor decorative material for a long time. Especially, they are made into all kinds of curlicues, pillars' ornaments and moldings etc. which are decorated on the surface of walls, pillars and ceilings, and create typical European-style decorative effect with its simplicity and strong cubic feelings. Traditional gypsum is clean-white and fine, but because of its lower accuracy in manufacturing process, it has now been replaced by all kinds of perfectly made and accurately processed colored anaglyphic art products, that is, painting the surface of traditional gypsum products with gold powder or other colors. Gypsums' products used in modern decoration are mainly all kinds of gypsum boards, such as thistle boards and various gypsums' decorative boards etc.



### 4.1.1 Building Gypsum

**1. Production of Building Gypsum**

Major raw material of gypsum is natural dihydrate gypsum ($CaSO_4 \bullet 2H_2O$) and natural anhydrite ($CaSO_4$) (also named hard gypsum). Both are named as raw gypsum. Common building gypsum is hemi-hydrate ($CaSO_4 \bullet \frac{1}{2} H_2O$), decomposed from dihydrate and anhydrite when heated to 1500-1700℃. So it is also called plaster of Paris or hemi-hydrate gypsum.

**2. Hardening and Hydration of Building Gypsum**

Gypsum is a kind of gelled material. When it is heated to an appropriate temperature, part or all of its water can be evaporated and it turns to be plaster of Paris. Then plaster of Paris changes into dihydrate—condensed and hardened gypsum—when mixed with water. These processes are called hardening and hydration, which are the technological basis of gypsum industry. The manufacture of gypsum gelled material generally refers to heating and dehydrating dihydrate gypsum and turning it to hemi-hydrate, then milling it into gypsum powder, which is the process of dehydration and hardening of gypsum. Whereas the condensing process of gypsum gelled material is the hydrating process of gypsum—the formation of dihydrate gypsum (solid) after hemi-hydrate gypsum (powder) absorbs water.

**3. Properties and Technical Requirements of Building Gypsum**



Gypsum and its products have many features such as lightweight, good temperature preservation and heat resistance, fire-proofing, sound absorption, plump in form, clear streak, smooth and fine surface, refined decoration and easy application in construction etc. Its properties mainly include following as peicots.

(1) Fast condensing and hardening, lower intensity

After building gypsum is mixed with water, the slurry begins to lose plasticity within 6-10 min, and completely hardened to produce intensity in 20-30 min. In theory, as hemi-hydrate is hydrated to dihydrate, it only needs as much water as 18.6% of the weight of itself. But in order to keep its necessary plasticity, it needs water as much as 60% to 80% of its own weight. After hardening, the excessive moisture evaporates, leaving many pores in the hardened gypsum, which reduces its intensity. To avoid such a result, certain amount of glue solution such as latex is added to slow down the speed of hardening and improve its intensity as gypsum is churned.

(2) Micro-expansion of its volume

The volume of the slurry will slightly expand at the beginning of its condensation and hardening. The expansion ratio is 0.5% to 1.0%. This leads to such features of molded gypsum products as smooth surface, accurate size, distinct and plump edges and corners, and refined decorative effects.

(3) High porosity, excellent thermal preservation and sound absorption

After building gypsum product is hardened, large amount of pores are formed inside. The porosity reaches as high as 50%, which results in small coefficient of heating conductivity but excellent thermal preservation, heat resistance and sound absorption.

(4) Certain degree of temperature-adjusting and humidify-adjusting

Because of its bigger thermal capacity, building gypsum product has the function of adjusting temperature to a certain degree. With a mass of pores inside it strongly absorbs the steam in the air and can adjust the humidity level of the air indoors.

(5) Poor water resistance and frost resistance

Gypsum product is porous and hydroscopic, and dihydrate gypsum is slightly dissolved in water, which leads to its poor water resistance and frost resistance.

(6) Good fire proofing, but poor fire resistance

Building gypsum product has small heating coefficient and slow heat transmission, and the water vapor produced when dihydrate gypsum is heated and evaporated can prevent fire from spreading. However, after hidydrate gypsum is dehydrated, its intensity is reduced, so building gypsum has poor fire resistance.

The specific gravity of commonly-used building gypsum is 2.5-2.7, the density of bulking volume is 800-1100 kg/m$^3$, the density of tight volume is 1250-1450 kg/m$^3$. Technical requirements of commonly-used building gypsum are shown in Table 4.1.



**Table 4.1 Technical Requirements of Commonly-used Building Gypsum**

| Index | | First grade | Second grade | Third grade |
|---|---|---|---|---|
| Compressive Strength ($\times 10^{-1}$MPa) | 1.5 h (no less than) | 40 | 30 | 20 |
| | Dry to permanent quality (no less than) | 100 | 75 | 70 |
| Tensile strength ($\times 10^{-1}$MPa) | 1.5 h ( no less than) | 9 | 7 | 6 |
| | Dry to permanent quality(no less than) | 17 | 13 | 11 |
| Setting time (min) | Initial set (no earlier than) | 4 | 4 | 4 |
| | Final set (no earlier than) | 30 | 30 | 30 |
| Fineness (900 pores /cm$^2$ screen residue)( no more than ) | | 15 | 25 | 35 |

**4. Applications of Building Gypsum**

Building gypsum is used as heating resistant, moisture preserving, sound absorbing and fire proofing material. As a building decorative material, it is widely used in ceiling and partition projects. Building gypsum can be used to manufacture concrete, high strength gypsum sticky powder, whitewashing gypsum, and all kinds of gypsum plates (such as thistle boards and decorative gypsum boards etc.), gypsum curlicues and pillar ornaments etc. Building gypsum and its products are largely used in projects such as finishing mortar, wall-surface putty, model making, anaglyphic products, plasterboard partitions and ceilings etc.

## 4.1.2 Other Gypsums

At different heating degrees and conditions, dihydrate-gypsum changes into different forms with greatly different properties, such as hemi-hydrate, anhydrate and high temperature calcined gypsum etc.

**1. Building Gypsum (hemi-hydrate gypsum)**

When dihydrate gypsum is dehydrated in saturated steam or in pressured water solution, $\alpha - CaSO_4 \bullet \frac{1}{2} H_2O$ is formed. If the dehydrating process of dihydrate gypsum is in a dry environment lacking water steam, then $\beta - CaSO_4 \bullet \frac{1}{2} H_2O$ is produced, called common building gypsum, and $\alpha - CaSO_4 \bullet \frac{1}{2} H_2$, high strength building gypsum. $\beta$ type hemi-hydrate gypsum is irregular scaly secondary particles, which are made up of very small single crystals. $\alpha$ type hemi-hydrate gypsum is made up of compact, complete, almost transparent and bulky primary particles. As $\beta$ type disperses to a greater degree than $\alpha$ type, it needs more water when mixed to plasticity slurry of the same consistency, so its intensity is weaker after hardening.

The following hydration reaction is likely to happen when hemi-hydrate gypsum meets water.

$$CaSO_4 \bullet \frac{1}{2} H_2O + 1\frac{1}{2} H_2O \longrightarrow CaSO_4 \bullet 2H_2O + Q$$

If the hydration reaction takes place in a stable slurry with definite fluidity, the mixture is gradually becoming thicker and thicker until it loses fluidity and condenses and hardens. When the slurry loses fluidity and begins to lose part of its plasticity, it is initial condensing. Final condensing refers that the slurry finally loses the plasticity and forms a structure with definite intensity.

Building gypsum is available for indoor advanced whitewashing, puttying in painting projects, producing gypsum ornaments, thistle boards and gypsum decorative boards etc.

**2. Anhydrite Gypsum (Anhydrite)**

$\alpha$ type and $\beta$ type anhydrite gypsums (dissoluble anhydrite)are produced when $\alpha$ type hemi-hydrate gypsum is heated to a temperature of 230℃ and $\beta$ type is heated to 360℃. The physical and mechanical properties of both are closely alike. The density is 2.5g/cm$^3$ and both can quickly absorb water in the air and then be hydrated. Their condensation speed is faster and needs more water to mix to standard consistency than hemi-hydrate gypsum. The intensity is weaker.

When anhydrite is heated to 400-750℃, indissoluble or infusibility anhydrite is produced. At this time, gypsum solid becomes tight and stable; the density reaches to 2.99 g/cm$^3$; it is difficult to be dissolved in water and the condensation speed is very slow. When added into certain excitants (all kinds of sulphate, alunite and lime etc. are commonly used), the gypsum solid may grow some ability of hydration and hardening. After the anhydrite mixture containing excitants is milled into powder, it is named as anhydrite cementing material.

Anhydrite cementing material is used to produce plastering mortar, concrete segments and building units etc.



**3. Calcined Gypsum**

Calcined gypsum is produced when dihydrate gypsum is fired at the temperature of 800-1100℃. At this time, a little calcium sulphate is decomposed to generate new phase CaO, which gives calcined gypsum certain hydrating ability. The condensation speed of calcined gypsum is slow. The amount of water demanded in standard consistency is about 25%-30% of its own weight. It has qualified wearing resistance after hardening and can be used for indoor terraces, so it is also called floor gypsum.

In addition, there are also medical-used and artificial gypsums. They are widely used in medical treatment (such as setting bones), arts and crafts (gypsum moulds and models etc.) and so on.

## 4.2 Gypsum Decorative Products

Building gypsum is suitable to serve as thermal resistant, moisture preserving, sound absorbing and fire proofing material. It's not only used as a material of finishing mortar, wall surface putty and gypsum curlicues, but also widely applied to produce various gypsum boards such as decorative gypsum board, inlaid decorative gypsum board, common thistle gypsum board and sound absorption perforation gypsum board etc.

### 4.2.1 Decorative Gypsum Board

It is a decorative board with no protective covering, which is made from building gypsum as basic material and a little strengthening fiber, cementing compound and modifier, and then is manufactured after mixing, shaping and baking etc. Decorative gypsum board has such features as light weight, high strength, moisture resistance, no deforming, fire proofing, fire resistance and adjusting indoor humidity. With excellent properties such as easy application in construction, good process-ability, it can be sawed, nailed, planed and stuck etc. Decorative gypsum board is applied to the decoration of internal walls and ceilings of industrial and civil buildings.



**1. Classifications and Specifications of Decorative Gypsum Board**

Decorative gypsum board is square. According to the type of edge section, it is classified into perpendicular and 45°chamfering; according to the functions, it's divided into common board, moisture resistant board, water resistant board and fire resistant board; according to the surface decoration effects, there are flat, perforated grill and embossed panels.

Dimensions of commonly used gypsum board are 500mm×500mm×9mm and 600mm×600mm×11mm. Here the thickness of the board refers to the vertical distance between the front and the back, excluding its edge chamfers, holes and embossment patterns.

**2. Product Marking of Decorative Gypsum Board**

There are varieties of decorative gypsum board, such as various flats, tracery embossed panels and perforated panels etc. Table 4.2 shows categories and codes of several kinds of gypsum decorative board.

**Table 4.2 Categories and codes of gypsum decorative boards**

| Category | Ordinary board | | | Moisture resistant board | | |
|---|---|---|---|---|---|---|
| | Flat | Perforated boards | Embossed panel | Flat | Perforated boards | Embossed panel |
| Code | P | K | D | FP | FK | FD |

### 3. Properties and Technical Requirements of Decorative Gypsum Boards

Decorative gypsum board has many properties such as light weight, high strength, fire proofing, sound insulation and high ductility etc. It can be processed in such ways as sawing, planing, nailing, drilling and sticking. It's convenient in application and installation. The physical mechanical properties of decorative gypsum board needs to meet the requirements in "*Decorative Gypsum Board*" (JC/T 799-96).

The right side of decorative gypsum board should not have such defects to weaken its decorative effects as pores, blots, crackles, unfilled corners, disproportion of colors and incomplete patterns etc. Its water ratio, water absorbing capacity, damp deflection should be subject to the requirements in Table 4.3.



**Table 4.3 Technical Requirements for Decorative Gypsum Boards**

| Item | Premium grade | | First grade | | Quality product | |
|---|---|---|---|---|---|---|
| | Average value | Maximum value | Average value | Maximum value | Average value | Maximum value |
| Water Ratio (≤) (%) | 2.0 | 2.5 | 2.5 | 3.0 | 3.0 | 3.5 |
| Water absorbing capacity (≤) (%) | 5.0 | 6.0 | 8.0 | 9.0 | 10.0 | 11.0 |
| Damp deflection (≤) (mm) | 5.0 | 7.0 | 10.0 | 12.0 | 15.0 | 17.0 |

### 4. Applications of Decorative Gypsum Board

The surface of decorative gypsum board, with rich colors and patterns, is smooth and pure white, the texture is refined. Embossed panel and perforated grill have stronger stereoscopic impression, which transmits the feeling of freshness and softness. And they have such properties as light weight, heat preservation, sound absorption, fire proofing, fire resistance and adjusting indoor humidity etc.

Decorative gypsum board is mainly used for the decoration of interior walls, suspended ceilings, non-bearing internal partitions and so on in industrial and civil buildings, i.e., the decoration projects of interior suspended ceilings and wall surfaces in buildings such as office buildings, theaters, restaurants, hotels, concert halls, shopping centers, meeting rooms, waiting rooms and kindergartens. Moisture resistant gypsum board should be used in environments with greater humidity.

### 4.2.2 Inlaid Decorative Gypsum Board

It is a kind of gypsum board with inlaid tongue-and-groove. Its physical mechanical properties are required to meet the requirements in "*Decorative Gypsum Board*" (JC/T 800-96). It has properties similar to those of decorative gypsum board, but creates better decorative effects due to its various colors, embossed patterns, different pore styles and arrangement modes. Meanwhile, when inlaid decorative gypsum board is installed, it only needs to be inlaid to keels without any additional fixing. The whole course is only assembling, and the boards in any position can all be randomly dismantled or replaced, which is greatly favorable for the execution of the project.



**1. Properties and Technical Requirements of Inlaid Decorative Gypsum Board**

(1) Properties of inlaid decorative gypsum board

Its physical mechanical properties need to meet the requirements in Table 4.4.

**Table 4.4 Physical mechanical properties of inlaid decorative gypsum boards**

| Unit area quality (≤) (kg/$m^2$) | | Water ration (≤) (%) | | | Breaking load(≤) (N) | | | | Mean absorbing factors (reverberation method) (≥) |
|---|---|---|---|---|---|---|---|---|---|
| | | Premium grade | First Grade | Quality product | Premium grade | | First Grade | Quality product | |
| Average value | 16.0 | 2.0 | 3.0 | 4.0 | Average value | 196 | 176 | 157 | |
| Maximum value | 18.0 | 3.0 | 4.0 | 5.0 | Minimum value | 176 | 157 | 127 | 0.3 |

Note: Sound absorption coefficient is a requirement only for sound absorption board.

(2) Technical requirements of inlaid decorative gypsum board

1) Appearance quality. The right side of inlaid decorative gypsum board should not have such defects as pores, blots, crackles, unfilled corners, disproportion of colors and incomplete patterns to affect the decorative effects.

2) Allowable deviation in size, unevenness and right angle deviation degree. The allowable deviation for the side length ($L$), the laying height ($H$)and the thickness ($S$) of the board, together with the unevenness and right angle deviation degree ( $\delta$) should be subject to the regulations in Table 4.5.

**Table 4.5 Allowable deviation in size, unevenness and right angle deviation degree of inlaid decorative gypsum boards** (mm)

| Item | | Premium Grade | First Grade | Quality product |
|---|---|---|---|---|
| Side Length $L$ | | ±1 | | +1<br>−2 |
| Laying Height $H$ | | ±0.5 | ±1.0 | ±1.5 |
| Thickness of side $S$ | $L$=500 | ≥25 | | |
| | $L$=600 | ≥28 | | |
| Unevenness | | 1.0 | 2.0 | 3.0 |
| Angle deviation degree | | ±1.0 | ±1.2 | ±1.5 |

3) Mass per unit area. The average mass per unit area should not exceed 16.0 $kg/cm^2$, and single maximum weight should not exceed 18.0 $kg/cm^2$.

4) Water ratio. The board must be dried, and its water ratio should not exceed the regulations in Table 4.6.

**Table 4.6 Regulations of water ratio for inlaid decorative gypsum boards** (%)

| Grade | Premium grade | First grade | Quality product |
|---|---|---|---|
| Average value | 2.0 | 3.0 | 4.0 |
| Maximum value | 3.0 | 4.0 | 5.0 |



5) Breaking load. The board must have sufficient mechanical strength, and its breaking load should not be less than the regulations in Table 4.7.

**Table 4.7 Breaking load for inlaid decorative gypsum boards** (N)

| Grade | Premium grade | First grade | Quality product |
|---|---|---|---|
| Average value | 196(20.0) | 176(18.0) | 157(16.0) |
| Minimum value | 176(18.0) | 157(16.0) | 127(13.0) |

6) Additional requirements of sound absorption board. Inlaid sound absorbing board must have certain degree of sound absorption. The average sound absorption coefficient by reverberation method at the six frequencies 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. The average absorption coefficient measured with reverberation chamber method $as \geqslant 0.3$. Every kind of sound absorbing gypsum board must be attached with sound absorption spectrum curve, installed either by sticking or by adopting different

structures. The number of perforated pores, the style of pores and the categories of sound absorption material are decided by manufacturers themselves.

**2. Applications of Inlaid Decorative Gypsum Board**

Inlaid decorative gypsum board has such features as light weight, high strength, sound absorption, moisture resistance, fire proofing, fire resistance, no deformation and adjusting indoor humidity etc. It's convenient in application and installation and can be sawed, nailed, planed and stuck up etc. Especially, it creates better decorative effects and has better sound absorption.

Inlaid decorative gypsum board is applicable for the decoration of indoor suspended ceilings and some parts of wall surface in public and monumental buildings such as theaters, restaurants, hotels, auditoriums, concert halls, meeting rooms, waiting rooms and exhibition halls etc.

### 4.2.3 Thistle Board



Thistle board, a kind of light weight thin board made from hemi-hydrate gypsum and protective covering as major raw materials and proper amount of fiber, cementing compound, coagulation accelerator and retarder, is produced through such steps as slurry preparation, shaping, cutting and baking. It mainly includes common thistle board, fire proofing thistle board and water proofing thistle board etc.

The physical mechanical properties of commonly-used thistle board refer to the requirements in national regulation "*Common Thistle Board*" (GB 9775-99). It has many advantages such as light weight, bending resistance and high impact resistance, fire proofing, heat preservation and heat insulation, excellent earthquake resistance as well as better sound insulation and adjusting indoor humidity etc. However it has poor water resistance and the maximum fire resistance time is only 5-15 min. Common thistle board also has excellent process-ability and can be sawed, nailed, planed and so on. The board is one of the light weight boards widely used at present as it is easy to install and thus saves time in construction.

**1. Shapes and Dimensions of Thistle Board**

Thistle board is rectangular. The long side is wrapped by protective covering, and the short side is the cut plane vertical to the long side. The long side of the board is in five shapes such as rectangle (code J), 450 chamfer angle (code D), wedge (code C), semi-circle (code B) and circle (code Y). Thistle board can be divided into common, fire resistant and water resistant thistle board according to its functions.

Common thistle board (code P) is made by taking building gypsum as major raw material, adding proper amount of fibers and admixtures to make core veneer, and then sticking thick protective paper covering on the surface. Protective paper covering is mainly to improve the board's bending resistance and impact resistance.

Water resistant thistle board (code S) is a kind of light weight building board, which takes building gypsum as major raw material, and is produced by adding proper amount of water resistant admixture to compose water resistant core veneer, which is then strongly cohered with a water resistant protective paper covering. Its physical mechanical properties should be subject to the regulations in "*Water Resistant Thistle Board*" (JC/T801-96). Water resistant gypsum board has better water resistance and its other properties are similar to those of common thistle board. It's mainly used in the decoration projects in humid places such as kitchens and toilets etc.



Fire resistant thistle board (code H) is a kind of fire resistant light weight building board made by taking building gypsum as major raw material, adding right amount of inorganic fire resistant fiber materials to compose the core veneer, which is then being strongly cohered together with a protective paper covering. Its fire stability (the property of un-crackling as it is fired at high temperature) is expressed by its stable time on fire. Its physical mechanical properties should meet the regulations in "*Fire Resistant Thistle Board*" (JC/T 802-96).

Specifications of common thistle board: the length is 2440mm and 3000mm; the width is 900mm and 1200mm; the thickness is 9mm, 10mm, 12mm, 15mm and so on.

### 2. Properties and Technical Requirements of Thistle Board

Thistle board has such advantages as light weight, bending resistance and impact resistance etc. In addition, it has good properties such as fire proofing, heat preservation, heat insulation, earthquake proofing and good sound insulation and excellent process-ability (such as sawing, nailing and planing). It is easy to install and thus saves time. It also helps to adjust indoor temperature and humidity.

The main raw materials used for manufacturing thistle board are hemi-hydrate gypsum and specialized protective paper covering (the thickness of the paper$\leqslant$0.6mm). According to the regulations in "*Thistle Board*" (GB/T9775-1999), its technical requirements are as follows:

1) Appearance quality. The surface of gypsum panel should be flat and smooth without such defects to affect the application as breakage, corrugation, groove, blot, over burnt, deficiency of material, leaking material at the edges or fall-off of the paper covering etc.

2) Size Deviation. Size deviation of thistle board should not exceed the regulations in Table 4.8, and the length difference between the two diagonals should not exceed 5mm.

**Table 4.8 Size deviation of thistle boards** (mm)

| Item | Length | Width | Thickness | |
|---|---|---|---|---|
| | | | 9.5 | ≥12.0 |
| Size Deviation | 0 | 0 | ±0.5 | ±0.6 |



3) Breaking load. Vertical and transverse breaking load of the board should not less than the regulations in Table 4.9.

**Table 4.9 Breaking load** (N)

| Thickness of the board (mm) | Breaking load | |
|---|---|---|
| | Vertical | Horizontal |
| 9.0 | 360 | 140 |
| 12.0 | 500 | 180 |
| 15.0 | 650 | 220 |
| 18.0 | 800 | 270 |
| 21.0 | 950 | 320 |
| 25.0 | 1100 | 370 |

4) Mass per unit area. Mass per unit area of the board should not exceed the regulations in Table 4.10.

**Table 4.10 Mass per unit area of thistle boards**

| Thickness of the board (mm) | Mass per unit area ($kg/m^2$) | Thickness of the board (mm) | Mass per unit area ($kg/m^2$) |
|---|---|---|---|
| 9.0 | 9.0 | 18.0 | 18.0 |
| 12.0 | 12.0 | 21.0 | 21.0 |
| 15.0 | 15.0 | 25.0 | 25.0 |

5) Coherence of the protective paper covering paper with the gypsum core. Protective paper covering should be strongly cohered with the gypsum core, which should not be exposed when tested with the regularized method.

6) Water ratio. Water ratio of water resistant thistle board should not exceed 10%.

7) Fire stability. Stable time of fire resistant thistle board should not be less than 20 min. The time of other boards is usually 5-10 min.

**3. Applications of Thistle Board**

Common thistle board is suitable for the decoration of indoor suspended ceilings, wall surfaces, partitions, internal partitions of such buildings as office buildings, theaters, restaurants, hotels, waiting rooms and residences. The surface of the decorated places needs to be reprocessed (such as puttying, painting with emulsion varnish or sticking wall paper and so on). However, it is only applicable in dry environments, not in moisture environments such as kitchens, toilets and places where air humidity exceeds 70%.



Water resistant thistle board is stronger in water resistance, and the other properties are similar to those of common thistle board. It is mainly used in humid places and places where air humidity exceeds 70%, i.e., kitchens, toilets and water closets etc. Its surface also needs to be reprocessed.

The properties of fire resistant thistle board are similar to those of common thistle board except that it is better in fire proofing. As fire resistant thistle board is fixed on steel keel, it can be used as Grade A fire resistant decorative material.

### 4.2.4 Sound Absorbing Perforated Gypsum Board

Sound absorbing perforated gypsum board is the common name of sound absorbing perforated thistle board and sound absorbing perforated decorative gypsum board. It takes decorative gypsum board and thistle board as basic materials, and is composed of perforated gypsum board, covering material, sound absorbing material and the air layer behind the board. The surface form is shown in Figure 4.1. Gypsum board itself does not have excellent sound absorption function, but after it is perforated and punched, each hole constitutes a resonating sound absorption structure with the air layer on its back, meanwhile in order to prevent sundries from falling down into the holes, a layer of membranous material (such as goffered paper, mulberry paper and micro-pore glass-fabric cloth etc.) is stuck to the back of the board, which performs a function of membrane resonating sound absorption. Fixing some porous sound absorption material (such as glass wool, mineral wool, foam plastics and so on) behind gypsum board, the sound absorption effect, especially the absorption of high frequency sound, can be further improved. Therefore, the sound-absorption function should be firstly considered in selection, followed with the sizes and dimensions, and then the colors and patterns.

**1. Shapes and Dimensions**

Sound absorption perforated gypsum board is square, and the shape of its seamed edge is divided into two types: right angle and chamfer angle. Dimensions are length 500 mm×500 mm and 600 mm×600 mm; thickness 9mm and 12mm, which does not include chamfer angle of the seamed edge, holes and the embossed patterns.



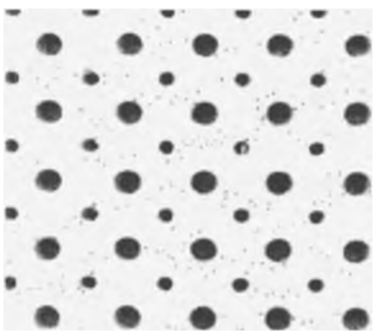


Figure 4.1 Sound absorption perforated thistle board

**2. Product Label**

The sequence of product label of sound absorption perforated thistle board is product name, covering material, basic board type, side length, thickness, bore diameter, pitch-row and standard code. For example, sound absorption perforated gypsum board with covering material, its side length is 600mm×600mm, the thickness is 12mm, the bore diameter is 6mm and the pitch-row is 18mm, is labeled as: sound absorption perforated gypsum board YC600X12-6-18GB11980. In addition, product mark, quality grade, name of the manufacturer and the production date should be clearly labeled on the packing case. And the quality certificate should be attached to the packing case.

### 3. Properties and Technical Requirements

Sound absorption perforated gypsum board can be divided into common board, water proofing board, water resistant board and fire resistant board etc. according to its different base-plates. Sound absorption material (such as mineral wool and mineral cotton etc.) or covering material (poromeric material stuck to the back of gypsum board) can be stuck on the back of the board. With better sound absorption, sound absorption perforated gypsum board should meet the requirements in "*Sound Absorption Perforated Gypsum Board*" (JC/T 803-96), Sound absorption perforated gypsum board with different gypsum board as its base-plate also has the properties of its base-plate, but its bending resistance, impact resistance and breaking load are lower than the base-plate, which must be taken into consideration in application.



### 4. Applications of Sound Absorption Perforated Gypsum Board

Sound absorption perforated gypsum board achieves the effect of sound absorption by making use of the blind holes, the perforated holes in the board and the sound absorption materials on its back, as well as the embossed patterns of certain thickness, so different structures of perforations, materials and embossed patterns develop different sound absorption effects. To buildings with ordinary sound absorption demand, it is suitable to use decorative sound absorption gypsum board. When higher sound absorption is required, sound absorption perforated gypsum board should be selected, and embossed panel coincided with perforated board can also be adopted.

Sound absorption perforated gypsum board is mainly used in the sound absorption structure of indoor ceilings and wall bodies. In installation, the arrow on its back should be in the same direction with the white line in order to keep the integration of the patterns. Proper moisture proofing, water resistant or fire resistant base plate should be adopted in humid environments or when higher fire resistance is required. Sound absorption perforated gypsum board has such properties as light weight, fire proofing, sound insulation, heat insulation, good vibration resistance, and can be used to adjust indoor humidity. With good process-ability, it is convenient in application and fit for dry operation, which saves labor and results in higher construction efficiency.

Sound absorption perforated gypsum board is used as the primary sound absorption decorative material for the decoration of suspended ceilings and walls at places where higher acoustic quality is required or where noises are severely limited, such as broadcasting studios, concert halls, theaters and conference rooms etc.

## 4.2.5 Other Gypsum Products

Art decorative gypsum product is produced by taking high quality building gypsum powder as base material, adding fiber reinforcing material and cementing compound etc., and mixing with water to make well-proportioned slurry, which then is poured into moulds of various moldings, patterns and decorative figures and then is hardened, dried and demolded.

Art decorative gypsum product is processed to meet the requirements of indoor decorative designs. Such product mainly includes anaglyphic gypsum line angles, line plates, patterned angles, lamp rings, fireplaces, roman pillars, round columns, square columns, twisted columns, lamp holders and curlicues etc. As to color, it is advised to adopt the elegant and spotlessly white color of high quality building gypsum board itself as well as the impression made by gold-powder or color-painting . As to its molding, it is preferable to adopt types from all over the world and of every age in history, which will provide new decorative connotations to the traditional material——gypsum.



### 1. Anaglyphic Gypsum Line Angle, Line Board and patterned Angle

Anaglyphic gypsum line angle, line board and patterned angle have many advantages such as smooth and clean surface, spotless white and elegant color, clear streaks and pattern designs, strong stereoscopic impression, stable size, high strength, no poison, fire proofing, easy application and so on. They are widely used in the ceiling decoration in luxury hotels, restaurants, office buildings and residential buildings as a kind of ideal decorative and finishing material with the advantages of low cost, good decorative effect, indoor humidity adjustment and fire proofing. They can be directly fixed and installed with glued gypsum putty and screws.

There are various patterns and designs of anaglyphic gypsum line angle. The section usually takes the shape of an obtuse angle, which also can be the shape of a flat plate, named anaglyphic gypsum board line or straight line. The widths of the two sides of gypsum angle line (or called wing edge) can be equal or unequal in various sizes, generally around 120-300 mm, the thickness of the wings is about 10-30 mm. Gypsum angle line is generally made to a strip of 2300 mm long. There are many patterns and designs of gypsum board lines, though they are simpler than those of angle lines. The width of gypsum board line is commonly 50-150 mm, the thickness is 15-25 mm, and the length of each strip is around 1500 mm. The patterns and designs of various anaglyphic gypsum line angles are shown in Figures 4.2 to Figure 4.5.

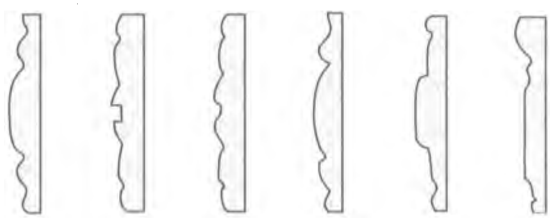


Figure 4.2 Anaglyphic gypsum board lines (straight)

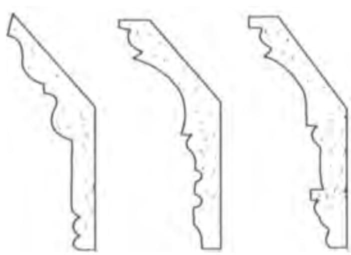


Figure 4.3 Anaglyphic gypsum ceiling angle lines

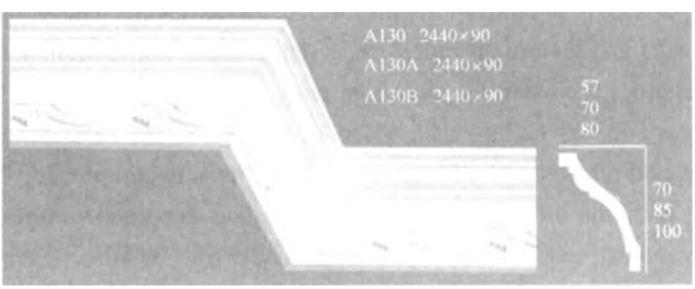



Figure 4.4 Colored anaglyphic gypsum ceiling angle lines

Figure 4.5 Shape of anaglyphic gypsum angle line

**2. Anaglyphic gypsum Lamp Ring**

As a great ceiling decorative material, anaglyphic gypsum lamp ring can be integrated with the lamp ornaments to bring out the best of each other and present the best decorative atmosphere. Gypsum lamp rings are generally processed to be circular, and also can be oval or petaling according to the requirements of indoor decorative designs and the favorites of the users. It has various diameters ranging 500–1800 mm, the thickness is 10–30 mm. Various ceiling chandeliers or ceiling lamps are matched with different anaglyphic gypsum lamp rings, which lead people into a kind of elegant and great decorative artistic conception. Figure 4.6 shows colored (colored drawing with gold powder) anaglyphic gypsum lamp rings.



Figure 4.6 Colored (colored drawing with gold powder) anaglyphic gypsum lamp rings

**3. Gypsums Curlicue and Wall Hanging**

Gypsum curlicue is a kind of decorative board of 15-30mm thick, which is produced by firstly making cavity block (soft mode) according to the design, pouring gypsum hemp thread slurry to be shaped, and then getting it hardened, demoulded and dried. There are all kinds of patterns and designs and dimensions of gypsum curlicues. Its surface can be the natural white of the gypsum itself and also can be gold-plated, ivory white, dark-red and pale yellow to present various colored drawing effects. It is available for the decoration of indoor ceilings or wall surfaces, as is shown in Figure 4.7. Building gypsum can also be made into embossed wall hangings, the surface of which can be painted with different colored coatings. It is another new art product used for interior decoration.

Figure 4.7 Gypsum curlicues

## Cases of Materials Selection



Application examples of decorative gypsum board and thistle board in interior decoration projects:

### 1. Name of Project

Interior decoration project of the office building in Xingqi Paper Manufacturing Plant

### 2. General Introduction of the Project

Building area: $5000m^2$

Structure of the building: Four-floor brick and concrete structure

Application requirements: On the first floor: reception hall, conference room, duty room and dining hall; on the second floor: president's office, manager's office, conference room and financial room; on the third floor: offices, laboratory and monitoring room; on the fourth floor: multi-functional hall, product exhibition room.

#### 3. Material Selection

(1) Selection of thistle board

For suspended ceilings and partitions, Beijing Dragon Brand thistle boards are selected, the dimension is 1200mm×3000mm, the thickness is 9.5mm, and the price is 35.00Yuan per piece.

The suspended ceilings of president's office, manager's office, meeting room, multi-functional hall and product exhibition room, taking the actual effects into consideration are decorated with light-gage steel joisting thistle boards, sealed with gypsum puttying perforated paper strips, puttied with gypsum and painted with emulsion varnish on the surface. The designs and shapes of the ceilings should meet the needs of different applications by taking into consideration the functions of the ceilings, the requirements for acoustics and lights, and should be properly combined with the arrangement of lights to create such atmosphere as to satisfy the requirements in service.

Interior non-bearing partitions adopt light steel keel thistle board, sealed with gypsum puttying perforated paper strips, puttied with gypsum and painted with emulsion varnish on the surface, and filled with thermal preservation and sound absorption material to sufficiently meet the requirements of fire proofing and other functions.

(2) Selection of Decorative Gypsum Board

For suspended ceilings, Beijing Dragon decorative gypsum boards (with carpenterworm surface) are selected, the dimension is 600mm×600mm, the thickness is 9.5mm, and the price is 22.50 Yuan /$m^2$.

For the suspended ceilings of the offices, laboratory, monitoring room, conference room, duty room and dining hall, T type light steel keel carpenterworm decorative gypsum boards are adopted to create concise and decent decorative effects. Inlaid grating ceiling lamps are installed to make a concise and light office environment. Moisture proofing decorative gypsum board is applied to the ceilings in washrooms, laboratory and dining hall to meet the related requirements.



## Summary

This chapter mainly introduces the components, categories, properties and applications of gypsum decorative materials. In teaching, to gypsum decorative boards and gypsum curlicues, students are required to master the properties and components of various gypsum decorative materials and to explain their properties and application cautions with what they have learned in theoretical teaching course; in practical teaching course, students are to master the names, properties, applications and operating requirements of commonly used gypsum decorative materials. It is a must to master the name, specifications, properties, prices and functions of every kind of gypsum material, combined with its applications in practical projects.

## Questions for Reviewing and Thinking

4.1 What properties does building gypsum have in the process of hydration and hardening?

4.2 How is building gypsum applied?

4.3 How many commonly used gypsum decorative boards are there? What are they? What properties does each of them have?

4.4 What are the properties and application requirements of decorative gypsum boards?

4.5 What are the properties and application requirements of thistle boards?

4.6 What are the technical requirements and applications of sound absorption perforated gypsum boards?

4.7 What are the properties and application requirements of commonly-used gypsum curlicues?

# 5

# Building Decorative Cement

Cement is in powder, when mixed with certain amount of water it becomes plastic paste, after physical and chemical process the paste becomes solid and stone-like, which can bind non-coherent grains into an integral solid body. Cement paste can be hardened both in the air and in water, where it retains and develops its strength. So cement is a good hydraulic gelled material. It plays an important role in gelled materials and is one of the most important building materials.

In building and decorative projects, decorative cement such as white cement and colored cement are usually adopted to produce colored cement paste, decorative mortar and architectural concrete, which serve for the internal or external facing decoration of buildings by utilizing the texture and the color of the decorative material itself to beautify structures. Sometimes cement is adopted as gelled material made by taking marble and granite as aggregates, and mixing them together to produce granitic plaster and terrazzo-concrete for architectural facing decoration.



## 5.1 Common Cement

### 5.1.1 Silicate Cement

According to the specifications in national standard "*Silicate Cement and Ordinary Silicate Cement*" (GB175-1999), hydraulic cementing material made by grinding and milling silicate cement clinker, 0-5% limestone or grained blast-furnace slag, and certain amount of gypsum is called silicate cement (called Portland cement in foreign countries). Silicate cement is classified as two types: the one without admixtures is called I-type silicate cement, code P.I.; the other one added with limestone or granulated blast-furnace slag but no more than 5% of the cement mass is called II-type silicate cement, code P.II.

Lime and clay are the main raw materials for the production of silicate cement. Lime raw materials (such as limestone, chalk stone and lime volcanic tuff etc.) mainly provide CaO; clay raw materials (such as clay, argillaceous shale and loess etc.) mainly provide $SiO_2$, $Al_2O_3$ and $FeO_3$. Sometimes the chemical compositions of the above two types can not meet the requirements, then it is required to add in some adjusting materials (such as iron ore powder, pyritic slag and sand stone etc.) for adjustment.

The production technique of silicate cement: mix several sorts of raw materials in proportion and grind them to tiny powder as raw meal; fire it to clinker in the kiln at high temperature (around 1450 ℃); mix the clinker with certain amount of gypsum and admixtures, grind and mill them to tiny powder which is silicate cement. This procedure is summed up as "two grindings and one burning".

## 1. Mineral Compositions of Cement Clinker

The major compositions of silicate cement are: CaO derived from lime, and silicon oxide ($SiO_2$), aluminum oxide ($Al_2O_3$) and ferric oxide ($Fe_2O_3$) derived from clay. After high temperature burning, the above four chemical compositions are combined chemically into the main chemical compositions in the clinker as follows:

Tricalcium silicate ($3CaO{\cdot}SiO_2$, skeleton symbol C3S, content 37%-60%);

Dicalcium silicate ($2CaO{\cdot}SiO_2$, skeleton symbol C2S, content 15%-37%);

Tricalcium aluminate ($3CaO{\cdot}Al_2O_3$, skeleton symbol $C_3A$, content 7%-15%);

Tetracalcium aluminoferrite ($4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$, skeleton symbol is $C_4AF$, content 10%-18%).

Of the above several clinker minerals, the overall content of $C_3S$ and $C_2S$ is more than 70%, and the overall content of $C_3A$ and $C_4AF$ is around 25%, that is why it is called silicate cement. Apart from major clinker minerals, cement also contains a little amount of free calcium oxide, free magnesium oxide and alkali, but their overall content is no more than 10% of the cement mass.

## 2. Hydration, Setting and Hardening of Cement Clinker Minerals

(1) Hydration, Setting and Hardening of Silicate Cement

After reacting with water and serial physical and chemical changes, silicate cement finally is set and hardened to artificial stone, which is called setting and hardening. The major hydration products derived from setting and hardening are hydrated calcium silicate, gel of hydrated calcium ferrite, calcium hydroxide, hydrated calcium aluminate and hydrated calcium sulpho-aluminate crystal. In completely hydrated cement, the content of hydrated calcium silicate is around 50%; calcium hydroxide is around 25%.

(2) Main Factors Affecting the Setting and Hardening of Silicate Cement

The purpose of learning about the factors affecting the setting and hardening of cement is to adjust cement performances in practical production and to use it correctly in construction. The factors include mineral compositions, fineness degree, the needed amount of water, maintenance period, environmental temperature and humidity as well as the amount of gypsum added.

**3. Technical Properties and Requirements of Cement**

National standard "*Silicate Cement and Ordinary Silicate Cement*" (GB175-1999) has promulgated the following requirements for the technical properties of silicate cement.

(1) Fineness of Cement

Cement's fineness is defined as the size degree of cement particles, which directly affects cement's performances and usage. If the size of cement particles is smaller, the contact area between cement and water is larger, and hydration action becomes more complete and adequate and hydration speed becomes faster.

(2) Water Consumption for Normal Consistency of Cement Paste

In order to make comparison of the measuring results of cement's setting time and stability, both of the tests should adopt pure cement paste in normal consistency. It is specified in ISO standard that the consistency of pure cement paste should be measured with a consistometer (Vicat apparatus). When the test bar sinks into the pure cement paste and is 6mm±1mm from the glass base, the pure cement paste is defined as "pure paste with normal consistency"; the amount of water consumed for mixing at this time is the water consumption for normal consistency of cement paste (*P*), which is counted in percentage of the cement mass. Cement clinkers with different compositions consume different amount of water for normal consistency; finer cement consumes more water. Generally the water consumption for normal consistency of silicate cement ranges 24%-30%.

(3) Setting Time

Setting time is divided as initial setting time (pre-setting time) and final setting time. The former is the period from cement receiving water to cement paste starting to lose plasticity; the later is the period from cement receiving water to cement paste completely losing its plasticity.

National standard has specified that the setting time of cement is measured with a setting time apparatus. The initial setting time of silicate cement should not be less than 45min; the final setting time should be no longer than 6.5h. If the initial setting time of a product does not meet the specifications in national standard, it is classified as waste and it is unqualified if the final setting time does not meet the specifications.

Cement's setting time is important in construction. Its initial setting time should be long enough to ensure sufficient time for such procedures as concrete molding; the final setting should not be too late to ensure that the concrete sets and hardens as soon as possible after casting to expedite the next working procedure.

(4) Volume Stability

Volume stability of cement is defined as the evenness of volume change during cement's setting and hardening. If the volume changes evenly, its volume stability is deemed as qualified, otherwise unqualified. Unqualified volume stability may cause expansive cracks to cement products and concrete components, which affects the construction quality and even worse leads to serious engineering accidents. Therefore, cement with unqualified volume stability must be disposed as waste product, and should not be adopted in construction.



(5) Strength and Strength Level

The strength of cement is defined as its bonding capacity, which is the important index for evaluating cement quality, also it is what strength grading is based on.

National standard "*Cement Mortar Strength Test Method* (ISO method)" (GB/T 17671-1999) has specified that the strength of cement is measured with plastic mortar method. The method is in this way: make a 40mm× 40mm× 160mm sample by mixing a portion of cement in mass counting, three portions of ISO standard sand and plastic mortar mixed according to 0.50 water-cement ratio, take the test sample including its mould for 24h curing in moisture condition, then demold it and cure it in water of standard temperature

(20±1)℃, respectively measure the 3d and 28d compressive strengths and the folding strengths, then compare the test results with national standards and decide the strength level of the silicate cement.

Silicate cement is in six strength levels as 42.5, 42.5R, 52.5, 52.5R, 62.5 and 62.5R. R stands for high-early strength cement. The strength of cement at each age should not be lower than what is specified in national standard, otherwise should reduce its use level. Strength requirements for silicate cement at each age are given in Table 5.1.

**Table 5.1 Strength Requirements of Silicate Cement at Each Age**

| Strength level | Compressive strength (MPa) | | Folding strength (MPa) | |
|---|---|---|---|---|
| | 3d | 28d | 3d | 28d |
| 42.5 | 17.0 | 42.5 | 3.5 | 6.5 |
| 42.5R | 22.0 | 42.5 | 4.0 | 6.5 |
| 52.5 | 23.0 | 52.5 | 4.0 | 7.0 |
| 52.5R | 27.0 | 52.5 | 5.0 | 7.0 |
| 62.5 | 28.0 | 62.5 | 5.0 | 8.0 |
| 62.5R | 32.0 | 62.5 | 5.5 | 8.0 |



(6) Hydration Heat of Cement

Heat released out from the hydration reaction when cement meets water is called cement's hydration heat. Most of the heat from cement hydration has been released out in its early period of setting and hardening, for instance, 50% of total hydration heat of silicate cement is released out during 1-3days ages, 7d age up to 75%, 6 month up to 83%-91%. To ordinary cement, higher strength level means more hydration heat; smaller grain size results in faster hydration speed; more hydration heat will be released out in early period when accelerating agent is added.

(7) Alkali Content

Alkali content is defined as the content of sodium oxide ($Na_2O$) and potassium oxide ($K_2O$) in cement. In recent years, many occurrences of alkaline aggregate reaction have been found in concrete construction, i.e., the reaction between the alkali in cement and the active silica in aggregates, which creates expansive alkali silicate gel and makes the concrete crack. Therefore, when active aggregates are adopted, low-alkali cement should be chosen. As specified in national standard, the total alkali content in cement (calculated by "$Na_2O$+0.658$K_2O$") should be no more than 0.60%, or based on bilateral agreements.

## 4. Corrosion and Prevention of Hardened Cement

(1) Corrosion of Hardened Cement

In normal conditions, along with its hardening, silicate cement's strength becomes stronger. But in particular environmental conditions, the strength of hardened cement may be decreased, which, even worse, may lead to the breakage of concrete. Such kind of phenomenon is called the corrosion of cement. Corrosion types mainly include soft water corrosion, acid corrosion, salt corrosion and alkali corrosion etc.

1) Soft Water Corrosion (dissolving corrosion)

Soft water corrosion is also called fresh water or dissolving corrosion. Soft water includes rainwater, snow water, distilled water, industrial condensation water and water from rivers and lakes containing less bicarbonate. After long-term contacting with water, calcium hydroxide in cement could be dissolved out (each liter of water can dissolve more than 1.3g of calcium hydroxide).

In construction practice, cement components that will later meet with water should previously be hardened in the air for certain period of time to produce a covering of calcium carbonate which helps to prevent dissolving corrosion.

2) Carbonic Acid Corrosion

Usually there is a lot of carbon dioxide dissolved in industrial sewage and groundwater. Carbon dioxide in water reacts with calcium hydroxide in hardened cement and creates calcium carbonate; if calcium carbonate continues to react with carbonic water, it will create calcium bicarbonate which is easy to dissolve in water. With the dissolution loss of calcium bicarbonate and the dissolution of other yields in cement, hardened cement may suffer structural breakage.

3) General Acid Corrosion

In industrial waste water, ground water and swamp water, there is certain amount of inorganic and organic acids which have different corrosion influences to hardened cement. The chemical compounds created when the acid reacts with calcium hydroxide in hardened cement either dissolves in water or leads to volume expansion, which may result in the breakage of hardened cement. Moreover, due to the seriousot lose of calcium hydroxide, the alkalinity of the hardened cement declines and other hydrates decompose greatly, therefore the cement's strength decreases sharply.

4) Strong Alkali Corrosion

Generally the corrosion is very slight when alkali solution is not in high concentration, and is deemed harmless. But when silicate cement with higher content of aluminate meets with strong alkali (NaOH, KOH), it will be corroded and damaged.

5) Sulfate Corrosion

Most sulfate (excluding barium sulfate) has strong corrosion influences to hardened cement, mainly due to the replacement reaction between sulfate and calcium hydroxide in hardened cement, which creates calcium sulfate (dehydrate gypsum), then calcium sulfate will react with the solid calcium aluminate hydrate in hardened cement and create high-sulfur calcium sulfo-aluminate hydrate with a volume of more than 1.5 times of its original volume.

6) Magnesium Salt Corrosion

Usually there are some magnesium salts such as magnesium chloride and magnesium sulfate in underground water, sea water and other industrial waste water. These magnesium salts may react with calcium hydroxide in hardened cement and create dissoluble calcium salt and non-coherent magnesium hydroxide. Their chemical equations are:

$$2H_2O + Ca(OH)_2 + MgCl_2 = CaCl_2 + Mg(OH)_2$$

$$Ca(OH)_2 + MgSO_4 = CaSO_4 \cdot 2H_2O + Mg(OH)_2$$

In conclusion, magnesium sulfate has double corrosions of both magnesium salt and sulfate salt to hardened cement.

(2) Prevention of the Corrosion of Hardened Cement

From the above six types of corrosion to hardened cement, we can conclude that it is mainly because the internal compositions (such as calcium hydroxide and calcium aluminate hydrate) and hardened cement is not dense and compacted enough that corrosive media intrudes and creates corrosion. To prevent such cases, it is necessary to take the following approaches.

1) Scientific Selection of Cement

Selecting cement scientifically is to adopt suitable types according to the characteristics of corrosive environments. If hardened cement is to suffer soft water corrosion, cement with hydrates containing less calcium hydroxide should be chosen (e.g., cement with lower content of tri-calcium silicate); if it is to suffer sulfate salt corrosion, sulfate-resistant cement with less tri-calcium aluminate is preferable; cement with admixtures has its corrosion resistance enhanced.

2) Increase the Compactness of Cement

Increasing construction quality and the compactness of cement are important measures to prevent corrosion to hardened cement. Hardened cement with higher compactness has stronger impermeability, and corrosive media is hard to intrude in. Therefore, in construction practice, such measures can be taken as adopting reasonable mixture ratio, decreasing water cement ratio, improving aggregate size gradation and adding in additives etc. In addition, carbonizing the concrete surface to make it denser also reduces the chances of corrosive intrusion.

3) Surface Protective Covering

In case that the corrosion is so stronger that the above approaches fail to work, it may help to cover the hardened cement with a layer made of corrosion-resistant material, such as acid-resistant stone, glass, ceramic, asphalt, paint and plastic etc.

**5. Applications, Transportation and Storage of Cement**



(1) Applications of Cement

As silicate cement clinker has higher content of tri-calcium silicate and tri-calcium aluminate, it has the features such as fast setting and hardening and higher strength, especially higher early strength, which makes it available for important structures requiring high-strength, pre-stressed and high early strength concrete projects, and for concrete projects in cold and freezing regions suffering frequent freezing and thawing cycles; due to its higher anti-carbonization performance, it is applicable to concrete projects requiring carbonization; as silicate cement has strong wear resistance, it is also applicable for cement projects in the construction of roads and airfield runways.

As silicate cement clinker has greater content of tri-calcium silicate and tri-calcium aluminate and its hydrated product contains a lot of calcium hydroxide and hydrated tri-calcium aluminate which are easy to catch corrosion, silicate cement is not applicable for the long term use in environments with varieties of corrosive media; with high hydrated heat and intense heat release, it is inapplicable to massive-concrete construction and inapplicable to concrete constructions with heat-resistance requirements due to its weak heat-resistance.

(2) Transportation and Storage of Cement

Measures should be taken in the transportation and storage to prevent silicate cement from water or moisture. When cement reacts with water, it will set and harden, and lose part of its cohesive force. The strength is weakened and even worse it may become inapplicable to construction.

Cement is stored based on difference types, strength levels as well as the date of production, and should be labeled. Bulk cement should be stored in different warehouses; the piling height of sacked cement should be no more than 10 sacks. Generally "come-first-go-first" rule should be followed in use. The strength of cement stored for a long time should be re-tested and it should be used based on its current strength. Cement stored in normal conditions tends to decrease in strength by 10%-20% after 3 months, 15%-30% after 6 months and 25%-40% after 1 year. Generally, cement's validity storage period is 3 months.

### 5.1.2 Silicate Cement with Admixtures



#### 1. Admixture

The purpose of adding certain amount of admixtures in cement clinker is to improve certain performances of the product, adjust its strength level, save cement clinker in production, increase the output of cement, reduce cost and utilize industrial waste etc. According to different performances, admixtures are classified to two main types: active and inactive admixtures, the former of which is more consumed.

(1) Active Admixture

Active admixture is the material that has hydration reaction with lime, gypsum or silicate cement after being ground to powder and mixed with water, and creates hydraulic cementing material at normal temperature. Commonly-used active admixtures are granulated blast furnace slag, pozzolanic material and fly ash etc.

After silicate cement with active admixtures blending with water, first cement clinker is hydrated, then clinker's hydrated product $Ca(OH)_2$ has hydration reaction with active $SiO_2$ and active $Al_2O_3$ (also called secondary reaction) in the material and creates hydrated product. Therefore, silicate cement with admixtures has lower hydration speed, so its early-strength is lower. But due to the relatively less content of clinker in cement, its hydrated heat is lower.

(2) Inactive Admixture

Inactive admixture is artificial or natural mineral with no or very tiny activeness, after being ground to powder and mixed with lime, gypsum or silicate cement and water, none or very few of hydraulic cementing material is created. The major purposes of adding inactive admixtures are: increase the output of cement, reduce cement strength level and hydration heat, reduce cost and adjust certain properties of cement etc. Commonly-used inactive admixtures are: quartz rock, limestone, sandstone, clay and hard slag etc. Unqualified granulated blast furnace slag and pozzolanic mixture also can be adopted as inactive admixtures.

## 2. Ordinary Silicate Cement

According to specifications in national standard "*Silicate Cement and Ordinary Silicate Cement*" (GB175-1999), hydraulic cementing material made by grinding and milling silicate cement clinker, 6%-15% admixtures and certain amount of gypsum tiny powder is called ordinary silicate cement (shortened as ordinary cement), code P·O. The maximum amount of active admixtures in cement should be less than 15%, and they can be replaced by kiln ash less than 5% or inactive materials less than 10% of the weight of the cement; inactive admixtures in cement should be less than 10% of the weight of the cement. According to the specifications in GB175-1999, ordinary silicate cement is in six strength levels as32.5, 32.5R, 42.5, 42.5R, 52.5 and 52.5R, the strength at each age should not be lower than the value listed in Table 5.2. The initial setting time of ordinary cement must be no less than 45min, final setting time must be no more than 10h.



**Table 5.2 Strength Requirements of Ordinary Silicate Cement at Each Age**

| Strength level | Compressive strength (MPa) | | Folding strength (MPa) | |
|---|---|---|---|---|
| | 3d | 28d | 3d | 28d |
| 32.5 | 11.0 | 32.5 | 2.5 | 5.5 |
| 32.5R | 16.0 | 32.5 | 3.5 | 5.5 |
| 42.5 | 16.0 | 42.5 | 3.5 | 6.5 |
| 42.5R | 21.0 | 42.5 | 4.0 | 6.5 |
| 52.5 | 22.0 | 52.5 | 4.0 | 7.0 |
| 52.5R | 26.0 | 52.5 | 5.0 | 7.0 |

Ordinary silicate cement contains a little of admixture, its properties are close to those of silicate cement, therefore they have almost the same application scopes.

### 3. Slag, Pozzolanic and Fly-ash Silicate Cements

(1) Slag Silicate Cement

According to the specifications in national standard "*Slag Silicate Cement, Pozzolanic Cement and Fly-ash Cement*" (GB1344-1999), hydraulic cementing material made by grinding and milling silicate cement clinker, granulated blast-furnace slag and certain amount of gypsum into tiny powder is called slag silicate cement (shortened as slag cement), code name P·S. The mass percent of granulated blast-furnace slag in cement is 20%-70%. Slag can be replaced by any one of the following: lime stone, kiln ash, fly ash and pozzolanic mixture, whose amount should be no more than 8% of the weight of the cement. After replacement, granulated blast-furnace slag in cement should not be less than 20%.

1) Features of Slag Silicate Cement

According to the specifications in GB1344-1999, slag cement is in six strength levels as 32.5, 32.5R, 42.5, 42.5R, 52.5 and 52.5R, and the strength at each age should not be lower than the value in Table 5.3. The requirements of slag cement in fineness, setting time and boiling stability are the same as those of ordinary silicate cement.



**Table 5.3 Strength Requirements of Slag Cement, Pozzolana Cement and Fly-ash Cement at Each Age**

| Strength level | Compressive strength (MPa) | | Folding strength (MPa) | |
|---|---|---|---|---|
| | 3d | 28d | 3d | 28d |
| 32.5 | 10.0 | 32.5 | 2.5 | 5.5 |
| 32.5R | 15.0 | 32.5 | 3.5 | 5.5 |
| 42.5 | 15.0 | 42.5 | 3.5 | 6.5 |
| 42.5R | 19.0 | 42.5 | 4.0 | 6.5 |
| 52.5 | 21.0 | 52.5 | 4.0 | 7.0 |
| 52.5R | 23.0 | 52.5 | 4.5 | 7.0 |

2) Applications of Slag Silicate Cement

Slag silicate cement has the above properties, so it is mainly applied to the following scopes: ①massive concrete projects; ②high temperature workshops and heat-resistance needed concrete projects; ③ steam-curing needed structures; ④ general over-ground, underground and in-water concrete and ferro-concrete projects; ⑤ high corrosion-resistance needed constructions. However, it is neither allowed to use in high early-strength required concrete projects, nor in concrete projects requiring frost resistance and impermeability.

(2) Pozzolanic Silicate Cement

According to the specifications in national standard GB1344-1999, hydraulic cementing material made by grinding and milling silicate cement clinker, pozzolanic mixture and certain amount of gypsum is called pozzolanic silicate cement (shortened as pozzolanic cement), code P·P. The mass percent of pozzolanic mixture in cement is 20%-50%.

The requirements of pozzolanic cement in fineness, setting time, boiling stability and strength are the same as those of slag cement; their major features are mostly the same except for minor differences. Their common features: low early-strength, high later-strength, low hydrated heat, strong corrosion resistance, weak frost resistance, weak anti-carbonization and bigger drying-shrinkage. Their differences: pozzolanic cement is better in impermeability but weaker in frost resistance and wear resistance; its drying shrinkage is bigger, so in dry and heat conditions it may be powdered.



Pozzolanic silicate cement is mainly applicable to the following scopes: ①underground and in-water massive concrete projects; ②impermeability required components; ③steam-curing required components; ④high corrosion resistance required constructions; ⑤general concrete and reinforced concrete projects. But it is not applicable to constructions requiring high early-strength, frost resistance and good wear resistance or concrete constructions in dry and heat environments.

(3) Fly-ash Silicate Cement

According to the specifications in national standard GB1344-1999, hydraulic cementing material made by grinding and milling silicate cement clinker, fly ash (coal ash) and certain amount of gypsum is called fly-ash silicate cement (shortened as fly-ash cement), code P·F. The mass percent of fly-ash in cement is 20%-40%.

The requirements of fly-ash silicate cement in fineness, setting time, volume stability and strength are the same as those of pozzolanic cement; their major features are mostly the same except for minor differences; their common features: low early-strength, high later-strength, low hydration heat, weak heat resistance, strong corrosion resistance, weak frost resistance and weak anti-carbonization. Their differences: fly-ash cement has smaller drying-shrinkage but greater crack resistance.

Fly-ash cement is mainly applicable to the following scopes: ①over-ground, underground and in-water massive concrete projects; ②steam-curing required components; ③high crack resistance required components; ④high corrosion resistance required constructions; ⑤general concrete constructions. But it is not applicable to constructions requiring high early-strength, frost resistance and high wear resistance.

**4. Composite Silicate Cement**

According to the specifications in national standard "*Composite Silicate Cement*" (GB12958-1999), hydraulic cementing material made by grinding and milling silicate cement clinker, two or more sorts of admixtures and certain amount of gypsum is called composite silicate cement (shortened as composite cement), code P·C. Less than 8% kiln-ash is allowed in the cement to partly replace the admixtures in it; The amount of mixtures added in the slag should not be the same as those added in slag silicate cement.



Composite cement has six strength levels as 32.5, 32.5R, 42.5. 42.5R, 52.5 and 52.5R. The strength at each age should not be lower than the value in Table 5.6. Its requirements in fineness, setting time and volume stability are the same as those of ordinary silicate cement.

The main features of composite cement are related to the types and amount of the two or more admixtures in it and are similar to those of slag silicate cement, pozzolanic silicate cement and fly ash silicate cement, i.e., certain admixture provides the cement with features of its own.

As to its application scopes, refers to those of slag silicate cement, pozzolanic silicate cement and fly ash silicate cement. But its performances are affected by the performances of the admixtures, so it should be selected based on the natures of the projects in application.

## 5.1.3 Selection of Common Cement

Presently, there are six types of common cement widely-used in our country. As to the applications of these types of cement in concrete structure projects, refer to Table 5.4.

**Table 5.4 Selection of Common Cement**

| Features or environmental conditions of concrete projects | | Preferable | Applicable | Inapplicable |
|---|---|---|---|---|
| Common concrete | 1. concrete in normal weather environment | ordinary cement | slag cement, pazzolanic cement, fly-ash cement, composite cement | |
| | 2. concrete in dry environment | ordinary cement | Slag cement | pozzolanic cement, fly-ash cement |
| | 3. concrete in high-humidity environment or permanent underwater | slag cement | ordinary cement, pozzolanic cement, fly-ash cement, composite cement | |
| | 4. massive concrete | fly-ash cement, slag cement, pozzolanic cement, composite cement | ordinary cement | silicate cement |
| Special function required concrete | 1. quick hardening required concrete | silicate cement | ordinary cement | slag cement, pozzolanic cement, fly-ash cement, composite cement |
| | 2. high strength concrete | silicate cement | ordinary cement | pozzolanic cement, fly-ash cement |
| | 3. concrete in open-air and concrete at water level fluctuation range in cold area | ordinary cement | slag cement | pozzolanic cement, fly-ash cement |
| | 4. concrete at water level fluctuation range in cold area | ordinary cement | | pozzolanic cement, slag cement, fly-ash cement, composite cement |
| | 5. impermeability required concrete | ordinary cement, pozzolanic cement | | slag cement |
| | 6. wear consistence required concrete | silicate cement, ordinary cement | slag cement | pozzolanic cement, fly-ash cement |

Note: The cement used for steam-curing should be tested, confirmed and selected based on the practical conditions.

## 5.2 White Cement and Colored Silicate Cement

### 5.2.1 White Silicate Cement

White silicate cement, shortened as white cement, is the white hydraulic cementing material made in this way: take the raw meal with certain compositions and burn it until partially melted to create clinkers containing calcium silicate as main component and a little of iron, then add certain amount of gypsum to the clinker, grind them to tiny powder as end product. Its main difference from ordinary cement is that its ferric oxide ($Fe_2O_3$) content is only around 1/10 of the latter. Cement color is related to the iron content; higher iron content leads to deeper color. If ferric oxide content is up to 3%-4%, cement is in dark grey; if ferric oxide content is 0.45%-0.70%, cement is in light green; cement is close to white with ferric oxide content as low as 0.35%-0.40%. Therefore, the strict control of iron content is one of the major technical measures in the production of white cement.



The procedures such as the selection of raw material, production and transportation of white cement should avoid the interfusion of color materials. Its raw material adopts pure kaolin, pure quartz sand, pure limestone and chalk stone etc. Natural gas, coal gas or heavy oil are adopted to replace coal for burning, and the burning temperature generally ranges between 1500-1600℃. Siliceous stone and white ceramic are taken as backing board and grinding body instead of cast steel plate and steel ball to grind the raw meal and the clinker. It is costly to produce white cement.

White cement has the features of high strength and whiteness in color and gloss. It is available to produce: all kinds of color mortar and color paint, both of which serve for decorative plastering in constructions; artistic decorative structural components of all sorts of white and colored concrete or reinforced concrete; products granitic plaster, terrazzo concrete and artificial marble in all colors; varieties of colored cement. White cement has almost the same technical performances as silicate cement. According to the specifications in "*White Silicate Cement*" (GB/T 2015-2005), white cement is divided into three strength levels as 32.5, 42.5 and 52.5.

### 5.2.2 Colored Cement

Colored silicate cement, shortened as colored cement, is a kind of hydraulic cementing material made in these two ways: mix white silicate cement clinker, super white gypsum, mineral pigment and additives (water proofing agent, water retaining agent and plasticizer etc.) together and grind them to tiny powder as end product; or directly add metallic oxide coloring material to white cement raw meal and burn them to create end product.

Previously, colored cement used to be made by mixing alkali-resistant mineral material with white cement on the construction site. The method was simple but more pigments were needed to produce cement with uneven colors and glosses. Later on, the technique has gradually developed to the above two ways. Another producing method is to add a little amount of metallic oxide to white cement raw meal and directly burn them to create colored cement. Colored cement has the features of even color and gloss, high weather resistance and stability and strong alkali-resistance etc. It is applicable for decorating and plastering structures, carving man-made hills and landscapes, producing colored concrete and mortar, making terrazzo-concrete, granite plaster, artificial marble and figured floor tiles etc.



## Case of Materials Selection

【Case】 Some concrete project has to be completed in a short construction period. There are silicate cement and slag cement with the same strength level as 42MPa. Please analyze which one has more advantages as the project schedule is concerned?

【Analysis】 Though silicate cement and slag cement with the same strength level have the same 28d strength index, but they are different in 3d strength indexes (silicate cement 17.MPa, slag cement 15.0MPa); as to 3d folding strength, slag cement is lower than silicate cement with the same strength level. Silicate cement has higher early-strength. If other performances meet the construction requirements, silicate cement is more helpful to save time.

## Summary

This chapter mainly introduces the mineral compositions, setting and hardening principles and its technical performances of silicate cement and briefly introduces the features and applications of admixture cement, white cement and colored cement.

## Questions for Reviewing and Thinking

5.1 What are the major compositions of silicate cement? What are their features when reacting with water separately?

5.2 Why certain amount of gypsum must be added in when silicate cement is produced?

5.3 What is the setting time of cement?

5.4 What are the factors affecting the setting and hardening of silicate cement?

5.5 Try to choose the right type of cement for each of the following concrete projects, and elaborate the reasons?

①Concrete requiring high early-strength and strong frost resistance; ②concrete requiring strong resistance to soft water and sulfate corrosion; ③high permeability concrete; ④concrete with strong sulfate-corrosion resistance, little dry-shrinkage and strong crack resistance; ⑤massive concrete; ⑥in-water and underground structures; ⑦producing colored concrete.

5.6 What are the features of white cement and colored cement?

5.7 The following is the mineral compositions of A type and B type silicate cement clinker. Please analyze the differences between their early-strengths and hydration heat?

| Mineral composition | $C_3S$ (%) | $C_2S$ (%) | $C_3A$ (%) | $C_4AF$ (%) |
|---|---|---|---|---|
| Cement A | 60 | 15 | 16 | 9 |
| Cement B | 47 | 28 | 10 | 15 |

# Building Decorative Concrete and Mortar

Concrete is a kind of artificial stone made up of cementing material, coarse and fine aggregates as well as other admixtures proportionally, which are processed through blending, moulding and curing as well as a certain period of hardening. It is the most largely consumed constructional material in the world. Mortar is made by mixing cementing material, water and fine aggregates together.

## 6.1 Introduction of Concrete

### 6.1.1 Classifications and Features of Concrete

**1. Classifications of Concrete**



Classified based on cementing material: ordinary concrete (cement concrete), asphalt concrete, sodium silicate concrete and polymer concrete.

Classified based on performance characteristic: impervious concrete, asphalt concrete, sodium silicate concrete and polymer concrete.

Classified based on volume density: heavy concrete (apparent density more than 2500kg/ $m^3$), normal concrete (apparent density ranging 1950-2500kg/$m^3$) and light concrete (apparent density less than 1950kg/$m^3$).

**2. Features of Concrete**

Concrete is widely used in construction projects and has many advantages compared with other materials, but of course it has some disadvantages.

Advantages: ①rich sources of raw material, low cost; ②good plasticity before setting, adaptive to different forms and dimensions to make articles and components according to construction requirements; ③higher compressive strength and good durability; ④reinforced concrete combined with steel bar with strong bonding force is powerful and durable; ⑤concrete with special functions can be produced by adjusting formula proportions.

Disadvantages: big apparent density, low tensile-strength, heavy self-weight, long maintenance time, bigger heat conductivity coefficient and weak high-temperature resistance.

### 6.1.2 Components of Concrete

Ordinary concrete is composed of four basic materials as cement, water, natural sand (fine aggregate) and stone aggregate (coarse aggregate), as well as certain amount of admixtures and additives. Water and cement are mixed into cement paste, which covers stone aggregates and fills up all gaps among them. In this way, concrete is made. Sand and stone aggregates serve as primary elements in concrete, so they are called aggregates, which resist the shrinkage of cement paste. Cement paste takes the functions of lubricating and fluidity before hardening, which facilitates the construction; and after hardening, it plays the role of cohesion, strongly binding sand and stone aggregates to create solid artificial stone with high strength.



**1. Cement**

Cement, the bonding agent in concrete, is an artificial material and the main factor deciding the cost, strength and durability of concrete. So, the selection of cement is especially important in concrete making, of which the main concerns are type and strength level. Its type is selected mainly based on the specific conditions of concrete projects and construction environments. Its strength level is selected based on the designed strength level of concrete, as too high or too low strength level brings negative influences to the technical performances and economical efficiency of concrete. For cement selection, please refer to Table 5.4.

**2. Aggregate**

Aggregate includes coarse aggregate (gravel) and fine aggregate (sand).

Coarse aggregate is defined as rock particles with diameter more than 4.75mm, usually called gravels. Commonly-used coarse aggregates in concrete are gravels and pebbles.

Fine aggregate is defined as rock particles with diameter less than 4.75mm, usually called sand. The most commonly-used fine aggregate in concrete is natural sand and man-made sand. Natural sand includes river sand, lake sand, sea sand and mountain sand. It will be restricted to use natural sand due to the decreasing of natural resources. Man-made sand includes machine-made sand and blended sand. Machine-made sand is rock particles made by crushing and screening with machine. The application of man-made sand effectively utilizes natural resources and simultaneously protects the environments.

The technical performance requirements for aggregates used in concrete are as follows:

(1) Clay Content and Harmful Impurities

Clay content is the content of rock debris, silt, clay particles with granular diameter less than 0.075mm contained in sand and gravel aggregate. These particles adhere on the surface of sand and gravel aggregate, affect the cementing function of cement paste and aggregates and reduce the strength of concrete. Harmful impurities are defined as mica, light stuff, sulfide, sulfate, chlorate salt, plastic, leaves, slag and organic substance etc. contained in sand and gravels. All these harmful impurities bring negative effects to concrete on its technical performances.

The content of harmful impurities in sand and gravels should meet the specifications in "*Standards for the Amount of Sand in Ordinary Concrete and the Test Methods*" (JGJ52-92) and "*Quality Standards for Gravels and Pebbles in Ordinary Concrete and the Test Methods*" (GB/T14685-2001).



(2) Particle size distribution

Particle size distribution is defined as the collocation of particles in different sizes in aggregate. Good distribution ensures the reasonable composition of different sizes of aggregate particles and minimizes the porosity and total surface area, which saves the consumption of cement, increases the workability of concrete mixture and improves the solid-volume ratio of concrete, therefore enhances its strength and durability.

Concrete requires the total surface area of fine aggregate (sand) to be small, that is, to be as coarse as possible.

Concrete requires the total surface area of coarse aggregates (gravels) to be small and different sizes of particles are well composed.

Coarse aggregates are in continuous distribution or intermittent distribution. Continuous distribution is defined as gravel particles of each size, from small size to big size, take up a certain proportion in concrete. Such distribution is usually adopted in construction projects. Intermittent distribution is defined as that gravel particles of some sizes are taken away purposely from the continuous distribution, then the small sizes are directly mixed with the big sizes. Such distribution reduces the pores in aggregate, saves the consumption of cement, but segregation is likely to happen to the concrete mixture, therefore, it is rarely adopted in construction.

When choosing coarse aggregates, on condition of meeting the requirements for size distribution, aggregates in bigger nominal sizes are preferable so as to reduce the specific surface area, therefore lessen the consumption of cement. However, the maximum diameter of coarse aggregates should not be too big.

(3) Strength of Coarse Aggregate

Coarse aggregate serves as primary material in concrete. In order to secure the strength of concrete, coarse aggregate must have sufficient strength. The strength of gravels is represented with the cube compressive strength or crushed index value of rock.

Cube compressive strength is defined as the ultimate compressive strength of cube test sample in dimensions of 5mm× 5mm× 5mm in water saturated state. Crushed index is the compressive strength of coarse aggregates tested with indirect method, which is take 10-20m size gravel samples in air-dry state, put them in a standard cylinder-shaped barrel, apply the specified pressure; after discharging the pressure, calculate the percentage ratio of the weight of particles in diameter less than 2.5mm to the overall weight of the samples. This percentage is crushed index. Smaller crushed index means stronger strength of coarse aggregate.



### 3. Mixing and Curing Water

Generally, any tap water or natural water is applicable for mixing and curing concrete. Ground surface water and underground water is adopted after being tested to be qualified based on standard specifications. When the quality of water is not decided, the water and the pure water should be adopted respectively to produce concrete test samples, and strength comparison test should be carried out. Water selection: domestic water meeting national standard (tap water, stream water, river water and lake water) can be directly adopted for mixing and producing all sorts of concrete; sea water is only applicable for mixing and producing plain concrete; to firstly used ground surface water and underground water, test should be carried out on harmful substance content based on the standard specified in JGJ63-1989.

### 4. Concrete Admixture

Concrete admixture is defined as the material added to concrete mixture to improve concrete performances. Though in small amount, it improves the mixture's workability, adjusts setting and hardening time, controls strength progress and enhances durability etc. Commonly-used admixtures are water reducing agent, air-entraining agent, early-strength admixture, accelerating agent, retarder, water-proofing agent and anti-freezing agent etc.

(1) Early-strength Admixture

Admixture that can accelerate the progress of the early strength of concrete is called early-strength admixture, which expedites the hydration, setting and hardening of cement, shortens the maintenance cycle of concrete and speeds up the construction progress. Especially in low temperature or sub-zero temperature (not lower than −5℃) conditions, its performances are more outstanding.

(2) Retarder

Retarder is the admixture that prolongs the setting time of concrete mixture without affecting its later strength. In concrete construction, retarder is adopted to prevent such case that, due to high temperature and long distance transportation, concrete mixture may set and harden too early to affect the casting quality, and at the same time it is to retard the hydration of massive concrete.

(3) Water reducing agent

Water reducing agent is an admixture that keeps the workability of concrete mixture, but simultaneously reduces water consumption for mixing. According to water reduction efficiency, it is divided into ordinary and high efficiency. It is one of the most widely and largely consumed admixtures in the world.

(4) Notices for admixture usage

1) Strict inspection on product quality.

2) Selection of admixture type: based on "*Technical Code for Application of Admixture in Concrete*" (GB50119) and relevant national regulations for environment protection.

3) Admixture amount: the amount of admixture is related to cement type, environmental humidity and mixing conditions etc., generally no more than 5% of the mass of the cement.

4) Mixing method: make the dissolved powder or liquid admixture into solution with certain concentration, then add certain amount of solution to the mixing water, and blend them together in a mixer.

### 6.1.3 Technical Properties of Concrete Materials

The main technical properties of concrete include three aspects: workability of fresh concrete; concrete strength after hardening and concrete durability. Except for meeting the above performance requirements, the cost needs to be reduced to achieve good economical efficiency.

**1. Workability of Newly-mixed Concrete**

(1) Definition of Workability

Workability is defined as the nature that concrete mixtures, in certain constructional conditions, are easy to operate (blending, transportation, concreting and tamping) to produce even and dense concretes. Workability is a comprehensive technical property, which includes such three aspects as fluidity, cohesion and water retention.

1) Fluidity is defined as the nature that concrete mixtures, under the influence of self-weight and mechanical vibration, start to flow and fill every corner of the mold-board evenly and densely. Fluidity reflects the consistency of the mixtures and the dense status of molding concrete. Therefore, slump test value is usually taken as the index for estimating the fluidity of newly-mixed concrete.



2) Cohesion is defined as the amount of cohesive force among the components in concrete mixture, which can ensure no occurrence of sandwich and segregation during transportation and pouring, and retain concrete being integral and even. In mixture with weak cohesion, mortar and gravel are easy to get separated, and after vibrating and blending, honeycombs and pock marks are likely to appear in the mixture.

3) Water retention property is defined as the ability of retaining water in concrete mixture, which ensures no serious bleeding phenomenon during construction.

(2) Measuring Method of Workability

As the workability of concrete is a comprehensive technical property, presently there is no index or measuring method that is simple, fast and accurate to give an integrated report of workability. Through practical analysis, fluidity is considered to have a great influence on the properties of concrete mixture. Therefore, it is decided whether or not the workability of newly-mixed concrete meets requirements by measuring the fluidity of concrete mixture and observing its cohesion and water retention status. Slump test and Vebe consistency test are applied to measure the workability of concrete admixture.

1) Slump test (slump test value no smaller than 10mm): Fill plastic concrete mixture into the slump-cone according to specified method, vertically lift up the slump-cone, then the mixture molded in slump-cone will slowly slump down due to its own weight; then the slump height is taken as slump test value (mm), refer to Figure 6.1. When slump height is measured, the concrete mixture's cohesion and water retention status should be observed at the same time.

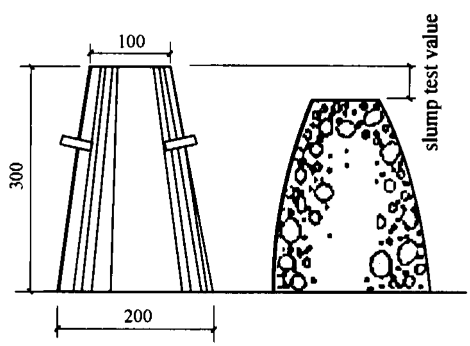



Figure 6.1 Slump Test

2) Vebe consistency test (slump test value less than 10mm): for dry and hard concrete mixtures, Vebe consistometer is adopted (See Figure 6.2).

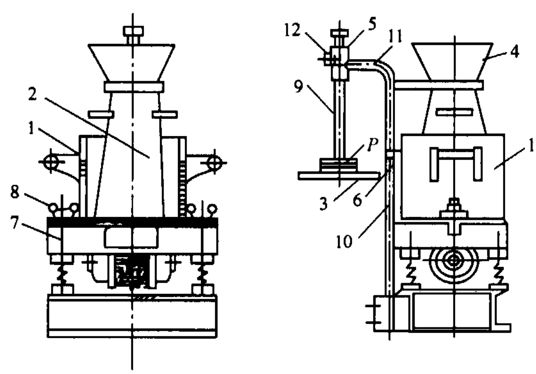



Figure 6.2 Vebe Consistency Test

1. container; 2. slump-cone; 3. circular-tray; 4.feeder; 5.jacket; 6.screw; 7. platform, vibrator(vibrostand); 8.screw; 9.measuring bar; 10.pillar; 11.rotating mount; 12. screw

3) Measurement of workability. The method is: fully fill the slump-cone with concrete mixture, lift up the slump-cone, put a transparent circular-tray on the top of the test mixture; turn on the platform vibrator and time with the stopwatch at the same time. The reading on the stopwatch at the time when the bottom of transparent circular-tray is totally covered with cement paste is the value of Vebe consistency.

**2. Main Factors Affecting Workability**

Main factors affecting the workability of concrete mixture: the amount of cement paste, water cement ratio, sand ratio, properties of components and additives etc.

1) Fluidity of concrete admixture depends on the amount of cement paste. When water cement ratio is constant, if there is more cement in unit volume of concrete, the fluidity of concrete mixture is bigger. If cement paste is excessive, overflowing of paste and bleeding will happen, which brings negative influence to the strength and durability of concrete, and wastes more cement. If cement paste is too less and can't fully fill up the gap among aggregates or can't tightly cover the aggregates, collapse will happen. And the resulted weak fluidity and cohesion will severely affect its strength.

2) If water cement ratio is too big, cement paste has less consistency, the mixture's cohesion force and water retaining ability decreases; if water cement ratio is too small, cement paste becomes dry and thick, the mixture's fluidity decreases and will affect construction work. As a matter of fact, what is decisive to the fluidity of concrete mixture is the amount of water consumption.

3) Sand ratio is defined as the percentage of the weight of sand contained in concrete to the overall weight of sand and gravels. If sand ratio is too big, cement paste is absorbed in and adhered to sand, then the mixture becomes too dry and thick, and its fluidity decreases. If sand ratio is too small, sand is not able to fully fill up the gap among gravels and the gaps must be filled with cement paste, which leads to the decrease of fluidity and the weakening of cohesion and water retaining ability, subsequently loosening and collapsing will take place. In conclusion, appropriate sand ratio should be taken in production to achieve ideal workability with less cement consumption.

### 3. Strength of Concrete

The strength of concrete after setting includes compressive strength, tensile strength and bending strength etc. Among them, compressive strength is the highest and tensile-strength is the lowest. Usually concrete strength is taken for granted as the short form of the compressive strength of concrete.

(1) Strength Level of Concrete

The strength level of concrete is decided based on the standard value of cube compressive strength, which is the value of compressive strength measured with a standard cube test sample (side length 150mm) cured for 28d in standard conditions (temperature 20℃±3℃, relative humidity more than 90%), represented with $f_{cu}$. Cube compressive strength with 95% of assurance is called the standard value of cube compressive strength, represented with $f_{cu,k}$. According to the standard value of cube compressive strength (by MPa), concrete is divided to 12 strength levels: C7.5, C10, C15, C20, C21, C30, C35, C40, C45, C50, C55 and C60. C40 stands for the standard value of cube compressive strength of concrete $f_{cu.k}$=40MPa. Different concrete strength level shows different acceptable load it bears.

(2) Main Factors Affecting Concrete Strength

1) Cement strength level and water cement ratio: both of them are the most important factors affecting concrete strength. Concrete strength mainly depends on the strength of hardened cements and the binding force between cements and aggregates, wherein both depend on the cement strength level and water cement ratio. At the same water cement ratio, cement with higher strength level is made into concrete with higher strength. When using the same cement, bigger water cement ratio results in lower concrete strength.

2) Curing temperature and humidity: after the pouring and molding of concrete, certain temperature and sufficient humidity should be retained to secure the adequate hydration of cement and develop concrete strength.

In the condition of retaining certain humidity, higher curing temperature quickens the speed of cement reaction and concrete strength will grow faster; and vice verse. When temperature decreases to 0℃, concrete strength stops growing, even may be damaged by freezing.

Certain humidity can ensure the sufficient progress of cement hydration. If humidity is smaller, concrete will lose water and the hydration stops, which results in loose internal structure, crack and dry-shrinkage surface and decreased strength. In order to ensure the normal hardening of concrete after molding, concrete surface must be covered and watered to keep it in sufficient moisture state for a certain period of time according to specifications and procedures of construction.

3) Age: it is the time needed by concrete to reach certain strength in normal curing conditions. In normal curing conditions, concrete strength grows faster in the first 3-7d, later it slows down and reaches the designed strength in 28d. After that, it slows down notably. In long-term proper humidity and temperature condition, the strength growth of concrete will last for decades.

4) Durability: it is the ability to resist internal and external negative influences. Concrete durability includes impermeability, frost-resistance, corrosion resistance, anti-carbonization and alkali-aggregate reaction etc.

① Impermeability. Impermeability is the ability of concrete to resist the permeation from hydraulic liquid (water and oil etc.). It is the most important factor deciding the durability of concrete, especially in the construction of house roofs, washroom floors, basic facilities and other structures (oil tanks and ponds etc.). The impermeability of concrete is represented with impermeability level, which is divided into five levels as P4, P6, P8, P10 and P12. They respectively stand for being capable of standing the hydrostatic pressure of 0.4 MPa, 0.6 MPa, 0.8 MPa, 1.0 MPa and 1.2 MPa. In construction practice, the major measures to enhance the impermeability of concrete are reducing water cement ratio, selecting aggregates with good size distribution, adequate vibrating and curing and adding in air entraining agent etc.



② Frost-resistance. The frost-resistance of concrete is defined as the ability that under saturated status, concrete remains unbroken after experiencing many times of freezing-and-thawing cycles, simultaneously its strength suffers no apparent decrease. It is represented with frost-resistance level, which is determined by the times of freezing-and-thawing cycles experienced by the standard cube test sample of 28d-age concrete under saturated status. Frost-resistance has nine levels as F10, F15, F25, F50, F100, F150, F200, F250 and F300, wherein the Arabic number stands for the maximum times of freezing-and-thawing cycles that concrete can stand.

③ Corrosion resistance. The chemical corrosion to concrete is mainly caused by the destruction that hardened cement received from the reaction of external corrosive media. Therefore, concrete corrosion resistance is related to the cement type and its own density. Dense concrete with closed pores has greater corrosion resistance as it is hard for corrosive media to intrude in.

④ Anti-carbonization and alkali-aggregate reaction. Alkali-aggregate reaction is defined as: alkali($Na_2O$, $K_2O$) in cement has a chemical reaction with active silicon dioxide in aggregates, which forms complex alkali-silicate gel on the surface of the aggregates, then the volume of the gel expands (may be more than triple) after absorbing water, which leads to the crack and breakage of concrete.

In construction practice, relevant measures must be taken to prevent the damage from alkali-aggregate reaction. Measures are controlling alkali content in cement; adopting inactive aggregates; reducing the amount of cement in concrete; adding air entraining admixture to concrete; preventing water intrusion and retaining dry concrete etc.

### 6.1.4 Ornamental Concrete

Ornamental concrete takes advantage of the outstanding plasticity of ordinary concrete, adopts proper constituent materials to endow the concrete surface with decorative line styles, grains, textures, and color effects after molding, which meets the different requirements of building facade decoration.



#### 1. As-cast Finish Concrete

As-cast finish concrete acquires its decorative effect by taking advantage of the streaks or the geometric shapes of concrete structure or components. It creates simple, lively and elegant façade decorative effect. Also concave-convex unevenness patterns can be made with moldboards on the surface of components to create luxurious facade textures and achieve artistic decorative effect. There are three molding ways.

1) Front-press Molding Technique

Front-press molding technique is mostly adopted for precasting the wall-panel of large panel building. It is carried out in this way: around the initial setting time after the pouring of concrete wall-panel, press on the concrete surface to create different line styles and patterns. According to different face-finishing technique, there are two ways of front-press molding: impressing and scraping. Impressing technique includes raising and dimpling. Raising technique is to press the mold carved with patterns on the surface of newly concreted wall-panel to create raising patterns. Scraping technique is to scrap and brush the surface with tools such as hard scrubbing brush etc. to create hair-side tactile sensation. Front-press impressing and front-press scraping techniques are very simple and easy to operate, but the wall surface it made has less concave-convex unevenness effect, less stereoscopic stratification and is lack of tactile sensation.

2) Bottom-press Molding Technique

Bottom-press technique is carried out in this way: make grooves on the bottom surface of concreting moldboard, or pad a liner-moldboard with certain patterns and designs on the bottom-mold, after demoulding, concrete surface will acquire line styles and stereoscopic decorative patterns.

3) Formwork Erection Technique

Both front-press and bottom-press molding techniques are adopted in precast situation. Formwork erection technique is for cast-in-place face-finishing. It is carried out in this way: install liner-moldboard inside the external mold with wall panel formwork-lifting technique, when demoulding, horizontally move the moldboard and make it leave the newly-concreted wall surface and then lift it up. Therefore, along with the lifting of the moldboard, the ornamental concrete with vertical stripes and the unique style of façade effect are created.



**2. Colored Concrete**

Colored concrete is produced by adding certain tinting pigment to ordinary concrete. Commonly-used methods for concrete coloring: add certain amount of color admixture, inorganic oxide pigment and chemical coloring material etc., or scatter coloring hardener directly, etc.

**3. Exposed Aggregated Concrete**

Exposed aggregated concrete is produced in this way: before hardening or after hardening, expose the aggregate appropriately with certain technique and method, to achieve certain decorative effect with the natural gross and irregular distribution of aggregate.

Methods for producing exposed concrete are: water-washing, retarder, pickling process, water-rubbing, sandblasting, ball-blasting, chisel chopping, fiery blasting, and splitting etc. ① water-washing technique: water-washing is to expose the aggregates by washing out the slurry before the hardening of cement. This method is only applicable to front-press technique for precast wall-panel, i.e., 1-2h after pouring and molding of concrete, just before the cement is setting, lift up one end of the moldboard, wash out the slurry from the surface with water with certain pressure and expose the aggregate; after curing, exposed ornamental concrete is created. ②retarder technique: for on-site construction, when adopting formwork erection concreting or precasting bottom-press technique, the working face is sheltered by moldboard and the slurry can't be washed away in time. Then retarder is needed to retard the hardening progress of cement and delay the washing time until after demoulding. Retarder is plastered on the bottom mold before concreting.

## 6.2 Mortar

Mortar is made by mixing cement, lime paste, sand and water proportionally. According to different cementing material adopted in it, building mortar is divided into cement mortar, cement lime mortar, lime mortar and gypsum mortar etc; according to the main applications, it is divided to masonry mortar and finishing mortar. Building mortar applied to masonry brick, masonry stone and building block etc. is called masonry mortar, which takes the function of cementing and transmitting load. Finishing mortar is also called plastering mortar and is used to plaster the surface of structures and structural components, with the functions such as protecting the substrate, satisfying operational requirements and improving artistic appearance.



### 1. Components of Mortar

To masonry mortar, the strength level of adopted cement generally is 4-5 times of that of mortar, commonly-used cement is in 32.5 and 42.5 strength level. To improve the workability of mortar and lessen the consumption of cement, when mixing mortar, certain amount of lime, gypsum or clay is added in. The maximum granular diameter of sand in mortar should not be more than 1/4-1/5 of the thickness of the mortar joint.

### 2. Selection and Applications of Mortar

Newly mixed mortar has good workability. Mortar with good workability is easy to lay and plaster into an even and thin mortar layer on the coarse base surface of block-form masonry material, and the laying mortar is able to be tightly combined with the base surface, which is not only easy to operate and increases production efficiency, but also ensures the quality of construction. Workability of mortar includes two aspects as fluidity and water retention.

(1) Fluidity

The fluidity of mortar, also called "consistency", is defined as the performance of flowing motion created by its self-weight or external force. It is measured with mortar consistometer, taking the sinking depth (mm) as mortar's consistency index. Mortar consistency varies along with these factors: the amount of water consumption, types and the amount of the adopted cementing material and the amount of mortar itself.

The consistency of masonry mortar mainly depends on the block type, construction condition and weather condition. Brick (block) mortar's sinking degree is 70-100mm; masonry stone (concrete block and slab) mortar's sinking degree is 50-70mm. In dry and heat weather, maximum value is taken, and in moisture cold weather minimum value is taken to show its consistency.

(2) Water Retention

The ability of newly-mixed mortar to retain its internal water from leakage loss is called "water retention", which is measured with mortar lamination cone and represented with lamination degree (mm). Bigger lamination degree shows that mortar is easy to delaminate and separate, which has negative influence to construction or cement hardening. The lamination degree of cement mortar should be no more than 30mm, for cement lime mortar it should be no more than 20mm. If lamination degree is too small, desiccation fissure is likely to happen, so lamination degree of all kinds of mortar should be no less than 20mm.

(3) Strength and Strength Level

Mortar takes compressive strength as its strength index. Its compressive strength is decided by the mean value of the compressive strength of a group (6 pieces) of standard test samples after being cured for 28 days. Mortar has six strength levels such as M2.5, M5.0, M7.5, M10, M15 and M20. To a water absorbing substrate, mortar strength mainly depends on the strength and amount of its cement content.

In ordinary building constructions, M5.0-M10 mortar is suitable for projects of office buildings, school buildings and multi-floor stores etc.; M1.0-M5.0 for one-floor houses and stores etc.; M2.5-M10 for dining halls, warehouses, basements and industrial factories etc.; M5.0 mortar is for inspection chambers, catch basins and cesspools etc. For structures requiring higher durability, mortar above M10 is adopted.

Different from masonry mortar, the main technique requirement of plastering mortar is not strength, but workability and the binding force with the base material. Finishing mortar is usually employed two or three layers in construction. The bottom layer plastering is to bind tightly with the base material; the middle plastering is to make it even, sometimes this step is neglected. The surface layer plastering is to achieve a flat and appealing surface effect.

For the bottom layer plastering on brick walls, lime mortar or lime furnace ash mortar is usually adopted; for the bottom layer plastering on battened walls or lathed ceilings, hair lime mortar is usually adopted; cement lime mortar is usually adopted for the bottom layer plastering on concrete walls, beams, pillars and ceilings etc.; middle layer plastering usually adopts cement lime mortar or lime mortar; surface layer plastering usually applies cement lime mortar, hair lime mortar or paper-pulp lime mortar.

Cement mortar is suitable for places easy to suffer collision or moisture. E.g. 1:2.5 cement lime mortar is generally applied to places such as dados, baseboards, floors, awnings, windowsills and wells etc.

Reference mixing ratios of masonry mortar are given in Table 6.1; reference mixing ratios of ordinary lime mortar are shown in Table 6.2; for the selection of mortar type, refer to Table 6.3.



**Table 6.1 Reference Mixing Ratios of Masonry Mortar**

| Mortar strength level | Weight mixing ratio | |
|---|---|---|
| | Cement mortar (cement: sand) | Cement lime mortar (cement: lime: sand) |
| M2.5 | - | 1:0.96:11.6 |
| M5.0 | 1:5 | 1:0.55:8.1 |
| M7.5 | 1:4.4 | 1:0.36:6.6 |
| M10 | 1:3.8 | 1:0.19:5.4 |

**Table 6.2 Reference Mixing Ratios of Ordinary Plastering Mortar**

| Material | Volume mixing ratio | Material | Volume ratio |
|---|---|---|---|
| Cement: sand | | Lime: gypsum: sand | |
| Lime: sand | - | Lime: clay: sand | |
| Cement: lime: sand | 1:5 | Gypsum: hair | |

**Table 6.3 Selection of Mortar Type**

| Mortar type | Application scope |
|---|---|
| Cement lime mortar | Supporting and non-supporting brickwork and stonework above ground surface |
| Cement mortar | Rubble footing, brick footing and general underground structure<br>Brick flat arch, reinforced brick lintel etc, water tower, smokestack and vaulting requiring high mortar strength level |
| Lime mortar | One-floor house or temporary structure. |

# Decorative Materials Test

## Test on Mortar Consistency

### 1. Test Objective

Evaluate the fluidity of mortar. Control mortar consistency in construction to lessen mortar consumption.

### 2. Mortar Sample Mixing and Mixture Sampling

(1) General Regulations for Producing Mortar and Carrying out Test in Laboratory

When mixing mortar and carrying out test in laboratory, the test material should be consistent with on-site material, and should take indoors in advance for air-drying; when blending, house temperature should range (20±5)℃ (laboratory material temperature should be the same as the onsite temperature if it is necessary to simulate the mortar in construction conditions); lumps in cement should be blended adequately to an even distributed state as to pass through the sieve with holes of diameter 0.9mm. Sand is sieved through holes of diameter 5mm. When making mortar, the accuracy of the material weight: (1±0.5)% for cement and additives; (1±1)% for sand, lime putty and clay puddle etc.

(2) Mixing of Mortar Test Sample

In building constructions, numerous amount of cement lime mortar is adopted. Its sample mixing method is: according to calculated mixing ratio, prepare cement and air-dried sand for making 5L mortar counted in weight mixing ratio. Firstly, put the cement and sand in a mixing-pan and mix them to even state (for around 1.5min); then make a groove in the middle with a mixing-spatula, put the prepared lime putty into it, and pour certain amount of water to mix it thinner, then blend it together with the cement and sand, continue adding water gradually and mixing them generally for 5min until the mixture has the same color and gloss. When workability meets the requirements according to observation, it is ready for consistency test.

(3) Mixture Sampling

Building mortar test material is taken from the mortar of the same mixture or the same delivery according to different requirements; when sampling in laboratory, the sample is taken from the mixed mortar, and the test samples must be 1-2 times more than that of the test material.

### 3. Major Instruments and Equipments

Mortar Consistometer (See Figure 6.3), tamper, platform balance, mixing-pan, mixing steel-plate and stopwatch etc.

Test method and procedures are: ① put the prepared mortar inside the cone until mortar surface is around 10mm to the cone opening, tamp with the tamper for 25 times, first 12 times should touch the bottom of the cone, then slightly vibrate the mortar cone on the table for 5-6 times to make the mortar surface flat, then place it on the platform of mortar consistometer; ② loosen the fixing-screw, let the sharp end of the body-cone touch the mortar surface, accurately pointing to the surface center, then fasten the fixing-screw, read the value on the staff gauge; then loosen the screw suddenly, 10s after the body-cone automatically sinks to the mortar, read the sinking depth (by mm), which is the consistency value of the mortar.



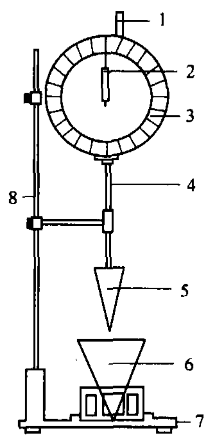



Figure 6.3 Mortar Consistometer

1. rack rod; 2. pointer; 3. dial scale; 4. sliding rod; 5. body-cone; 6. container-cone; 7. pedestal; 8. stand

### 4. Test Result Conclusion

1) Carry out two tests and take the arithmetic mean value of the two results as the measured result of mortar consistency, if the difference of the two measured values is more than 20mm, the test should be redone.

2) If mortar consistency does not meet the requirements, add water or lime putty according to need, and test again until the requirements are met. But it should not be more than 30min counted from the time of mixing with water, otherwise redo it.

## Summary

This chapter introduces the technical properties of ordinary concrete materials; mainly focuses on the performances of ornamental concrete, building decorative mortars and the applications of such materials. Learn about the technical properties of ordinary concrete materials.

## Questions for Reviewing and Thinking

6.1 What are the main types of mortar?

6.2. What indexes are adopted to represent the fluidity and water retention of mortar?

6.3 What are the major factors affecting the strength of ornamental concrete?

# 7

# Building Decorative Ceramic

## 7.1 Introduction of Ceramic

### 7.1.1 Definition and Classification of Ceramic

**1. Definition of Ceramic**

Ceramic is a product made of clay, feldspar and quartz as basic raw materials which are processed through mixing, molding, drying and burning. When it is applied to building projects, it is called building ceramic, which has been a kind of great building decorative material in China since long time ago. With the development of science and technology and the improvement of people's living quality, it has greatly changed in designs, colors, types and performances. Ceramic applied to modern building decoration projects primarily are ceramic wall-floor tiles, sanitary ceramic, garden ceramic and terracotta products, among which ceramic wall-floor tiles take up the largest output.



**2. Classifications of Ceramic**

According to types of products, ceramic is classified to: earthenware, porcelain and stoneware.

Earthenware product needs low degree of sintering and in porous structure. It includes unglazed and glazed types, and has such features as high water absorption (10%-22%), low strength, weak frost resistance, rough and no luminous fracture surface and hoarse knocking sound. It is suitable for interior application. According to the different contents of impurities in raw material, it is classified to two types: coarse earthenware and fine earthenware. Coarse earthenware is not glazed, most commonly-used products of which are fired clay bricks and tiles, daily-used ceramic pots and crocks; fine earthenware generally requires technique procedures of biscuit firing, glazing and glaze firing, and different glazing statuses result in different colors as white, milky white and light green etc. Commonly-used construction glazed tiles, sanitary wares and faience wares are of this type.

Porcelain product needs high sintering degree, so is hard and almost free from water absorption (water absorption<1%) with features of dense structure, fine and glossy fracture surface, high strength, hard and high wear resistance. The glazing layer provides the product with certain translucence. According to different chemical compositions in raw material and different production techniques, it is classified to two types: coarse and fine porcelains. Wall and floor tiles in building decoration belong to coarse porcelain products; most daily-used tableware and tea sets, artistic handicrafts and electric ceramic products are fine porcelain products.

Stoneware product is the moderation of the above two main types, also called semi-porcelain. Its structure is denser than earthenware with less water absorption (1%-10%), but is not as white and clean as porcelain. The body is colorful without translucence. According to different degrees of fineness and density of the body, it is classified to coarse and fine stoneware. Exterior wall tiles, floor tiles and ceramic mosaic tiles in building decoration are coarse stoneware, whose water absorption is usually 4%-8%. House wares and ceramics used in chemical industry and electric industry are fine stoneware, whose water absorption is less than 2%. Stoneware has higher mechanical strength and thermal stability than porcelain ware, and is allowed to adopt low quality clay as raw material, so it is less costly.



## 7.1.2 Components of Ceramic

There are a lot of raw materials for ceramic production. As to the sources, its raw material includes natural mineral and chemical material processed with chemical method. Natural mineral raw material, the main raw material for ceramic production, is mainly clay, which is composed of multiple types of mineral. The quality and performances of ceramic are primarily decided by the compositions in clay. Glaze is defined as the continual vitreous layer adhered to the surface of ceramic body. The purpose of glazing is to improve the surface performance of the body and enhance its mechanical strength.

**1. Clay**

(1) Compositions of Clay

Clay is the result of natural rock after long time of weathering. It is the mixture of many sorts of fine minerals, in colors as white, grey, yellow, black and red etc. Generally, clay minerals are kaolinite, turface and hydromica etc., whose main chemical composition is hydrous aluminosilicate in laminated structure; clay also contains many impurities such as quartz, feldspar, iron mineral, carbonate and organic substance, whose types and contents have a great influence to clay performance. i.e. more quartz decreases clay's plasticity; the iron and titanium oxide in it is the primary factors deciding the colors of sintered body; the calcium and magnesium compound in it decreases its fire-resistance and narrows its sintering range and the excessive content of the compound will cause bubbles; when containing more organic impurities, clay with high water absorption may increase its plasticity and strength after drying, but will shrink more greatly.

(2) Types of Clay

According to the different contents of impurities in clay, different fire-resistance and applications, clay is classified to the following four types:

1) Kaolin. Kaolin is high-purity clay without coloring impurities such as ferric oxide etc., and looks white after burning. Its grain is coarse with low plasticity and high sintering temperature is needed in production. It is the primary raw material for producing porcelains, also called porcelain clay.

2) Fusible clay. It contains a lot of impurities such as fine sand, dust, organic substance and iron mineral etc. It looks red after firing and is the main raw material for producing tiles and heavy clay products, also called silica.

3) Infusible clay. Such kind of clay, also called montmorillonite, contains little impurities. It is highly pure and looks grey, light yellow or red after firing. As the primary raw material for producing earthenware, it is also called earthenware clay.

4) Fire-resistant clay. It contains less impurities and its fire resistance is as high as 1580℃. The color ranges from light yellow to yellow after firing and is the primary raw material for producing fire-resistant and acid-resistant ceramics, also called fireclay.

## 2. Glaze

(1) Functions of Glaze

Generally, the surface of sintered ceramic body is rough and lackluster, which not only affects its esthetic appearance and mechanical properties, but makes it easy to get stained and moistened. After the body surface is glazed and fired in high temperature, the glaze and body surface will react mutually and form on the body a vitreous layer, which is glass-like glossy and transparent, and makes the surface of the body flat, bright, water tight and airproof, thus enhances the artistic quality and mechanical strength of the product. Meanwhile it plays perspective and protective functions to the patterns underneath the layer, prevents the dissolution and leakage of toxic element in coloring materials, and covers the unappealing colors and defects on the body, as a result, enlarges the application scope of ceramics.

(2) Types and Features of Glaze

1) Feldspar glaze. It is produced by mixing materials such as quartz, feldspar, limestone, kaolin, clay and fine powder of ceramic waste. High sintering temperature is needed in production, so it belongs to high temperature transparent glaze, which serves as the raw material for producing the glaze layer of porcelain, stoneware and hard fine earthenware. It has the features as strong hardness, transparency, high glossiness, gentle sensation and broad range of sintering temperature etc.

2) Talc glaze. It is made by adding talc powder to feldspar glaze. Such kind of glaze is pure white with good transparency. Crack and fume smoking are not likely to happen to it. Its disadvantages are weak adhesion and low brightness after firing.

3) Admixture Glaze. The glaze is made by adding fusing agents such as talc, dolomite, calcite and zinc oxide to feldspar, quartz and kaolin. The fusing agents are mixed based on their different features. Admixture glaze adequately combines the advantages of different agents and glazes, decreases the disadvantages of each kind of glaze to a maximum degree to achieve the most satisfying service performances.

4) Color glaze. It is made by adding coloring oxide or some salt compounds to glaze. According to different sintering temperatures, color glaze is classified to high temperature and low temperature color glazes, with the dividing point 1250℃. Earthenware often adopts low temperature color glaze, but stoneware and porcelain adopt high temperature glaze. Color glaze covers unappealing places on the body and creates certain decoration effect. Furthermore, it is convenient in operation and at low cost, so is widely applied to produce ceramic arts and crafts.

5) Salt glaze. Salt glaze is not to glaze directly on the surface of ceramic green body, but to put salt in the kiln when the product is fired to a certain temperature. At high temperature and in vapor, salt is dissolved to sodium oxide and chloride hydride which are distributed inside the kiln in gas state;

such two sorts of substance will react with the clay and silicon oxide on the body surface and create a vitreous glaze layer. Salt glaze is solid and not likely to fall off or crack, and has the feature of high acid-resistance etc.

# 7.2 Glazed Interior Tile

Glazed interior tile is shortened as glazed tile, interior tile or tile, which is made in this way: make the body with white fired clay, pyrophyllite or kaolin as raw materials, cover it with glaze surface layer and sinter it in high temperature.

## 7.2.1 Features and Applications of Glazed Interior Tile

### 1. Features

Glazed tile is flaky fine earthenware serving as the building material for interior wall decoration. It is composed of the body and the surface color glazed layer. It has features such as delicate color and gloss, elegant and attractive appearance, clean and smooth surface, wear resistance, fire resistance, corrosion proof and good thermo-stability etc., and is an advanced interior decorative material. Buildings with their interior walls decorated with glazed tiles show the present special sanitation and beautiful decoration effect, and they are easy to wash and clean. Main types and features of glazed tiles are given in Table 7.1.



**Table 7.1 Main Types and Features of Glazed Tiles**

| Types | | Features |
|---|---|---|
| White glazed tiles | | Pure white, bright glazed surface, clean and elegant |
| Color-glazed tiles | Luster color-glazed tiles | Glazed surface is crystal-bright, colorful, fine and elegant |
| | Lackluster color-glazed tiles | Glazed surface is lackluster and not glittering; color and gloss is consistent and mild |
| Ornamental Glazed tiles | Fancy glazed tiles | Paint different color glazes on the same tile and fire it in high temperature; color glazes mix together, create many wonderful patterns and good ornamental effect |
| | Crystalline glazed tiles | Crystalline shining, plentiful texture styles |
| | Dappled glazed tiles | Dappled glazed surface, plentiful and vivid appearances |
| | Marble glazed tiles | Having the patterns of natural marble; colorful, beautiful and elegant |

Continued

| Types | | Features |
|---|---|---|
| Pattern tiles | White pattern tiles | Create different decorative patterns on the surface of white glazed tiles and fire them in high temperature; the patterns look very clear and appealing |
| | Color-ground pattern tiles | Create different patterns on the luster or lackluster surface of color-glazed tiles and fire them in high temperature; having the effects of reliefs, satins, color paintings etc |
| Hand-painting glazed tile | Ceramic tile painting | Combine different glazed tiles to form different ceramic pictures, or fire and create glazed tiles complying with the prepared pictures, then compose them to form different ceramic pictures; clear and attractive and unfading |
| | Color-glazed ceramic calligraphy | Made by firing different color glazes and porcelain clays; colorful, bright and attractive appearance, unfading |

### 2. Application

Glazed tiles have features such as good thermo-stability, fireproof, moisture-proof, acid and alkali resistance, they have smooth and polished surfaces and are easy to wash and clean, so they are mainly applied to the decoration of interior wall surfaces and table tops etc. in kitchens, bathrooms, washrooms, laboratories and hospitals etc.

Glazed tiles have porous body of fine earthenware, whose water absorbing capacity is around 18%-21%. Exposed to air especially serving in moisture environment for a long time, it absorbs great amount of water and appears the phenomenon of moisture expansion. Because glaze has very tiny moisture expansion, when the expansion degree of the body grows big enough to make the glaze surface in tensile stress state and the stress is stronger than the tensile strength of the glaze, cracks will appear on the glaze surface. Therefore, glazed tiles are not applicable to exterior walls or out-door construction. Otherwise due to the action of wind and sun, hot and cold weather, they will crack and shatter.

## 7.2.2 Technical Requirements for Glazed Interior Tiles

### 1. Types and Specifications of Glazed Tiles

According to glaze colors, glazed tile is classified to monochromatic (including the white), multicolor and pattern tiles; according to product shapes, it is classified to square, rectangle and special shaped auxiliary tiles, etc. In order to enhance its bonding power with the base, there are grooves on the backside of glazed tile, whose depth should be no less than 0.2mm. Glazed tile is in many dimensions such as 300mm×200mm×5mm, 150mm×150mm×5mm, 100mm×100mm×5mm, 300mm×150mm×5mm and so on. Special shaped auxiliary tile includes internal angle, external angle, coping tile, stringcourse tile, internal coconut piece, external coconut piece, internal corner foot and external corner foot etc. There are more shapes and dimensions adopted according to different requirements in practice.

**2. Technical Performances of Glazed Tile.**

Glazed tile should comply with the standards in "*Ceramic Tiles*" (GB/T 4100.5-1999). According to appearance quality, it is classified to superior quality and good quality. Superior quality: at least 95% of tiles have zero defects on their surface based on vertical observation from 0.8m away; good quality: at least 95% of tiles have zero defects based on vertical observation from 1m away.

The dimensional tolerances of glazed tiles are given in Table 7.2; Table 7.3 shows the edge straightness, squareness and surface flatness of glazed tiles; as to the main physical and chemical performances, refer to Table 7.4.



**Table 7.2 Allowed Dimensional Tolerances of Glazed Tiles (%)**

| Type dimensional allowed tolerance | | No spacer lug | Spacer lug |
|---|---|---|---|
| Length and width | The allowed tolerance of the average edge length of each block of tile (2 or 4 edges) to its working dimension | $L \leqslant 12$cm: ± 0.75<br>$L \leqslant 12$cm: ±0.50 | +0.60<br>−0.30 |
| | The allowed tolerance of the average edge length of each block of tile (2 or 4 edges) to the average edge length of 10 blocks of tiles (20 or 40 edges)[1)] | $L \leqslant 12$cm: ±0.50<br>$L \leqslant 12$cm: ±0.30 | ±0.25 |
| Thickness | The maximum allowed tolerance of the average thickness of each block of tile to its working thickness | ±10.0 | ±10.0 |

Note: 1) There is one or several glazing edges on a tile. The joint width in nominal dimension of the modular tiles is 1.5-5mm; the difference between the working dimension and nominal dimension of non-modular tiles should not outrange ±2mm; special requirements for dimensional tolerances can be negotiated by the supplier and the customer.

**Table 7.3 Edge Straightness, Squareness and Surface Flatness of Glazed Tiles**

| Allowed Tolerance (%) | No spacer lug | | Spacer lug | |
|---|---|---|---|---|
| | Superior quality | Good quality | Superior quality | Good quality |
| The maximum allowed tolerance of the edge straightness[1] (front) to its working dimension | ±0.20 | ±0.30 | ±0.20 | ±0.30 |
| The maximum allowed tolerance of the squareness[1] (front) to its working dimension | ±0.30 | ±0.50 | ±0.20 | ±0.30 |
| The maximum allowed tolerance of the surface flatness to the working dimension: ①to the curvature of diagonal center calculated on basis of the working dimension; ②to the curvature of edges calculated on basis of the working dimension | +0.40<br>−0.20 | +0.50<br>−0.30 | +0.70mm<br>−0.10mm | +0.80mm<br>−0.20mm |
| ③to the diagonal warpage calculated on basis of the working dimension | ±0.30 | ±0.50 | $S \leqslant 250cm^2$: 0.30 mm<br>$S > 250\ cm^2$: 0.50 mm | $S \leqslant 250cm^2$:0.50mm;<br>$S > 250cm^2$: 0.75mm |

1) It is not available for bent tiles.

**Table 7.4 Physical and Chemical Performances of Glazed Tiles**

| Items | Performance requirements |
|---|---|
| Water absorbing capacity | Mean value $E > 10\%$, single value no less than 9% |
| Breaking strength | thickness$\geqslant$7.5mm: mean value no less than 600N<br>thickness$<$7.5mm: mean value no less than 200N |
| Modulus of rupture (not applicable to tiles with breaking strength$\geqslant$3000N) | Mean value no less than 15MPa, single value no less than 12MPa |
| Thermal shock resistance | Zero rupture or crackle after 10 times of shock test |
| Crazing-resistance | No crazing or flaking-off of glaze after cracking-resistance test to glazed tiles |
| Frost-resistance | No crazing or flaking-off after freezing test to ceramic tiles |
| Wear-resistance | Wear level and rotating rounds in the report of the wear-resistance of flooring glazed tiles |
| Impact-resistance | The average recovery coefficient of earthenware tile reported after impact test |
| Coefficient of linear thermal expansion (from room temperature to 100℃) | The coefficient of linear thermal expansion of ceramic tile reported after test |
| Moisture expansion (mm/m) | The mean value of moisture expansion of ceramic tile reported after test |
| Small color difference | The value of color difference of ceramic tile reported after test |
| Friction coefficient | The friction coefficient of flooring ceramic tile reported after test |

Continued

| Items | | Performance requirements |
|---|---|---|
| Chemical corrosion resistance | Resistance to low-concentration acid and alkali | Determination and comparison between the tested chemical corrosion resistance level and the manufacturer's stipulated level |
| | Resistance to high-concentration acid and alkali | Chemical corrosion resistance level of ceramic tiles reported after test |
| | Resistance to household chemical reagent and swimming-pool salt | After test, to glazed ceramic tiles not lower than GB level; to un-glazed ceramic tile not lower than UB level |
| Resistance to stains | Glazed tile | Not lower than level 3 after stain test |
| Lead and cadmium dissolved out | | The amount of lead and cadmium released from the surface of glazed ceramic tiles reported after test |

## 7.3 Ceramic Wall and Floor Tile

Wall & floor tile is used for the decoration of exterior walls, interior and exterior floors. Such kind of tile is commonly applicable for both walls and floors, so is called wall & floor tile.

### 7.3.1 Features and Application of Ceramic Wall and Floor Tiles

Wall & floor tile is made of high quality earthenware clay as main raw materials, which is firstly added in other materials to make raw meal, and then after semi-dry pressing molding, fired at a temperature around 1100℃. It is classified to glazed and unglazed types. Some is produced by glazing on the surface of already fired green body and then burning it; some manufacturers carry out both biscuit firing and glaze firing at the same time in production. Wall & floor tile has features such as high strength, high wear-resistance, stable chemical properties, incombustibility, high weathering resistance and acid and alkali resistance, low water absorption, and it is free from light influence, easy to wash and clean, durable and no crazing for long-term use, so it is able to retain fresh patterns and colors of the surface for a long time etc.

### 7.3.2 Technical Requirements for Wall and Floor Tiles

#### 1. Types and Specifications of Wall-floor Tiles

According to facing status, wall & floor tile is classified to glazed and unglazed; according to coloring method, it is classified to natural coloring, artificial coloring and color-glaze coloring etc.; according to its surface texture, it is classified to types such as plane surface, dimple surface, rough surface, burnished surface, polished surface, speck surface, marble-imitating surface and embossed surface etc.

Common dimensions of interior wall & floor tile are 300mm×300mm, 200mm×200mm, 150mm×150mm and 200mm×300mm etc., mostly are 8-10mm thick. Tiles in large sizes are adopted more and more widely in dimensions 400mm×400mm, 500mm×500mm and 600mm×600mm. Most of exterior wall & floor tiles are rectangle in 240mm×60mm and 50mm×75mm etc., generally 6-10mm thick. There are 0.5mm deep grooves on the back side of the tile to enhance its bonding power with the main structure.

## 2. Technical Performances of Wall & floor Tiles

Wall & floor tile should comply with the standards in GB/T 4100.4-1999. According to the appearance quality, it is classified to superior quality and good quality. Superior quality: at least 95% of tiles have zero defects on their surface based on vertical observation from 0.8m away; good quality: at least 95% of tiles have zero defects based on vertical observation from 1m away.

The dimensional tolerances of wall & floor tiles are given in Table 7.5; Table 7.6 shows their edge straightness, squareness and surface flatness; as to the main physical and chemical performances, refer to Table 7.7.



**Table 7.5 Allowed Dimensional Tolerances of Wall & floor Tiles** (%)

| Item | | $S \leqslant 90cm^2$ | $90\ cm^2 < S \leqslant 190\ cm^2$ | $190\ cm^2 < S \leqslant 410\ cm^2$ | $S > 410\ cm^2$ |
|---|---|---|---|---|---|
| length and width | The allowed tolerance of the average edge length of each block of tile (2 or 4 edges) to its working dimension | ±1.2 | ±1.0 | ±0.75 | ±0.6 |
| | The allowed tolerance of the average edge length of each block of tile (2 or 4 edges) to the average edge length of 10 blocks of tiles (20 or 40 edges) | ±0.75 | ±0.5 | ±0.5 | ±0.4 |
| Thickness | The maximum allowed tolerance of the average thickness of each block of tile to its working thickness | ±10.0 | ±10.0 | ±5.0 | ±5.0 |

Note: The joint width in nominal dimension of the modulus tiles is 2-5mm, the difference between the working dimension and nominal dimension of non-modulus tiles should not outrange ±2% ( max.±5mm ); special requirements for dimensional tolerances can be negotiated by the supplier and the customer.

**Table 7.6 Edge Straightness, Squareness and Surface Flatness of Wall & floor Tiles**

| Allowed Tolerance | $S \leqslant 90\ cm^2$ | | $90cm^2 < S \leqslant 190cm^2$ | | $190cm^2 < S \leqslant 410cm^2$ | | $S > 410cm^2$ | |
|---|---|---|---|---|---|---|---|---|
| | Superior quality | Good quality | Superior quality | Good quality | Superior quality | Good quality | Superior quality | Good quality |
| The maximum allowed tolerance of the edge straightness[1] (front) to its working dimension | ±0.50 | ±0.75 | ±0.4 | ±0.5 | ±0.4 | ±0.5 | ±0.4 | ±0.5 |
| The maximum allowed tolerance of the squareness (front) to its working dimension | ±0.70 | ±1.0 | ±0.4 | ±0.6 | ±0.4 | ±0.6 | ±0.4 | ±0.6 |
| The maximum allowed tolerance of the surface flatness to the working dimension | ±0.7 | ±1.0 | ±0.4 | ±0.5 | ±0.4 | ±0.5 | ±0.4 | ±0.5 |

1) Not available for bent tiles.



**Table 7.7 Physical and Chemical Performances of Wall & floor Tiles**

| Item | Performance requirement |
|---|---|
| Water absorbing capacity | Mean value $6\% < E \leqslant 10\%$, single value no bigger than 11% |
| Breaking strength | Thickness ≥ 7.5mm: mean value no less than 800N<br>Thickness < 7.5mm: mean value no less than 500N |
| Modulus of rupture (no applicable to tiles with breaking strength ≥ 3000N) | Mean value no less than 18MPa; single value no less than 16MPa |
| Thermal shock resistance | Zero breakage or crackle after 10 times of shock test |
| Crazing-resistance | Zero crazing or zero flaking-off after cracking test to glazed ceramic tiles |
| Frost-resistance | Zero crazing or zero flaking-off after freezing test to ceramic tiles |
| Wear-resistance | The deep-abrasion-resistance volume of unglazed tiles no bigger than 540 $mm^3$;<br>Wear level and rotating rounds in the report of wear-resistance of flooring glazed tiles |
| Coefficient of linear thermal expansion (from room temperature to 100℃) | The coefficient of linear thermal expansion of ceramic tiles reported after test |
| Moisture expansion | The mean value of moisture expansion of ceramic tile reported after test |
| Small color difference | The value of color difference of ceramic tiles reported after test |
| Friction coefficient | The friction coefficient of ceramic tiles and the adopted test method reported after test |

Continued

| Item | | Performance requirement |
|---|---|---|
| Chemical corrosion resistance | Resistance to low-concentration acid and alkali | Determination and comparison between the tested chemical resistance level and the manufacturer's stipulated level |
| | Resistance to high-concentration acid and alkali | Chemical corrosion resistance level of ceramic tiles reported after test |
| | Resistance to household chemical reagent and swimming pool salt | After test, to glazed ceramic tiles not lower than GB level; to un-glazed ceramic tiles not lower than UB level |
| Stain resistance | Glazed tile | Not lower than level 3 after stain test |
| | Unglazed tile | Report the stain resistance level after stain test |
| Lead and cadmium dissolved out | | The amount of lead and cadmium released from the surface of glazed ceramic tiles, reported after test |

## 7.3.3 New Ceramic Wall and Floor Tiles

### 1. Split Tiles



Split tile is made in this way: take raw materials according to certain mixture ratio, and then after crushing, pug-milling and vacuum-extrusion molding, dry and sinter it at high temperature. The mould is formed with two back-to-back tiles and is split into two after sintering, so it's called split tile.

There are many types of split tiles, whose features are: plentiful of color, natural and soft color tone, glazed or unglazed surface; glazed surface with crystal luster while unglazed surface appears modest and elegant with no dazzling shining. Due to its dense body, split tile has such advantages as high strength, low water absorbing capacity, skid-proof and wear-resistance, thermal-shock resistance and good thermal-stability. The groove pattern on the back-side is able to form wedged binding with the cementing mortar, which ensures the solid binding when laying tiles.

Split tile is applicable to the exterior wall decoration of different structures, also used for interior floors of common buildings, halls, bus terminals, waiting rooms and restaurants etc. Thick split tile is applicable to open air floors of squares and parks, parking lots, corridors and sidewalks etc. It also serves as the facing decorative material for the bottoms and banks of swimming pools.

There are a lot of types of split tiles with major dimensions as 240mm×52mm×11mm, 240mm×115mm×11mm, 194mm×94mm×11mm, 190mm×190mm×13mm and 240mm×115mm×13mm etc.

**2. Colored-body Tiles**

Colored-body tile is an unglazed porcelain facing tile made in this way: make a mixture with color granular soil as raw material, then press it to colored body and sinter it to the end product. Its surface is covered with colorful fine patterns and natural marble specks in light color tones of many basic colors such as yellow, red, green, blue, grey and brown etc. It has advantages such as high strength, low water absorbing capacity and good wear resistance. It is especially suitable for the flooring decoration of public places often crowded with many people such as commercial buildings, theatres, hotels and restaurants etc. Beautiful and durable, it is also applicable for the decoration and renovation of residential floors.

There are two types of colored-body tiles: plane and relief colored-bodies, which are further classified to lackluster, burnished and polished. Its main quality requirements are: folding-strength not less than 27MPa, water absorbing capacity not less than 1%; main dimensions are 200mm×200mm, 300mm×300mm, 400mm×400mm, 500mm×500mm and 600mm×600mm, minimum dimensions 95mm×95mm, maximum dimensions 600mm×900mm.

**3. Dimpled Tiles**

Dimpled tile is a stoneware facing tile made in this way: make mixture with raw materials in imitating color of natural rock, press it to body with dimpled surface, that is, concave-convex unevenness surface, and then produce the tile through one-time sintering. The tile surface looks like manual-chiseled natural rock surface with natural texture in boorish and antique rustic style, and in many colors such as white, yellow, grey and black etc. Major dimensions are 200mm×100mm, 200mm×75mm and 100mm×100mm etc. Dimpled tile has advantages such as low water absorbing capacity (less than 1%) and high strength; folding strength no less than 20MPa, skid-proof and wear-resistance. Based on thickness, it is classified to thin and thick tiles. Thin tile is applied to the exterior wall decoration of structures; thick tile is applicable for the floor paving of squares, parking lots, wharfs and sidewalks etc. When used in squares, there are also products in trapezoid and triangle, which are combined to create different designs and patterns to increase the artistic sensation of the ground.

**4. Ceramic Artistic Tiles**

Ceramic artistic tile is a ceramic product with different embossed patterns on the surface. It is produced by molding, drying and firing at high temperature quality clay and other minerals. Ceramic artistic tile can be combined to create different wall paintings with abstract or concrete image designs according to geometric combination principle of point, line and surface etc. therefore, it achieves strong artistic effect. The tile has advantages such as low water absorbing capacity, high strength, weathering-resistance, corrosion-resistance and unique decorative effect. It is applicable to the wall facing decoration of conference halls, exhibition pavilions, parks and public places.

**5. Large Ceramic Veneers**

Large ceramic veneer has large unit-block surface and creates many effects of pictorial arts, calligraphies and wall paintings etc. Different embossed patterns and designs can be made on its surface, and after glazed to different colors, it creates great decorative effect. It is thin and flat with such advantages as low water absorbing capacity, high frost resistance and corrosion resistance, thermal shock resistance and convenient for construction operation etc. It is applied to the decoration of places such as exterior and interior walls as well as corridor and hall columns etc., and is more suitable for the decoration of public structures such as hotels, airports, bus terminals and wharfs etc. The major specifications are 395mm×295mm, 295mm×295mm and 295mm× 197mm in 4.5mm, 5mm and 8mm thick etc.



**6. Ceramic Wall Paintings**

Ceramic wall painting is the creation of both architectural engineers and artists in modern building decoration art. Ceramic wall painting is a new advanced building decoration with higher artistic value, which is made by laying and combining structural blocks such as ceramic tiles and panels etc. and is the creation made by combing painting and decoration arts in one, i.e. processing relevant materials through a series of technical procedures such as mold lofting, sampling, carving, glaze mixing, glazing and burning etc., and then adopting different sorts of glazing techniques such as dipping, dotting, painting, spraying and filling etc. Ceramic wall painting is legendary, vivid and precious artwork.

Ceramic wall painting is thin, flat and convenient for constructional operation with advantages such as large unit block area, high strength, low water absorbing capacity, frost-resistance, corrosion-resistance, thermal shock resistance. It is applicable to the decoration of public structures such as hotels, restaurants, airports, waiting rooms of railway stations, guest rooms, conference rooms, metros and tunnels etc. It gives people the feeling of beauty and art.

# 7.4 Ceramic Flooring Tiles

Ceramic flooring tile, shortened as flooring tile or floor tile, is block-like ceramic material for floor paving. It is mainly applied to places such as interior and exterior floors, steps, footboards and stairs etc. but does not serve as interior or exterior wall facing material.

## 7.4.1 Types and Specifications of Ceramic Flooring Tile

According to material quality, ceramic flooring tile is classified to ordinary ceramic flooring, full-porcelain and vitreous tiles etc; according to finishing status, is classified to glazed, unglazed tile, polished and soluble-salt tiles etc.; according to applications and functions, classified to ordinary flooring, stair, skid-proof, wear-resistant, moisture-proof and square paving tiles etc. They are in many shapes such as square, rectangle, octagon and round-angle trapezoid etc. Tile surfaces are in different colors and pattern styles such as mono-color, multi-color, specks and imitation stone textures etc.

Major dimensions of ceramic flooring tile: 100 mm×100mm, 150 mm×150mm, 200 mm×200mm, 200 mm×100mm and 300 mm×300mm etc.



## 7.4.2 Technical Performances of Ceramic Flooring Tile

Product quality should comply with the standards in "*Unglazed Ceramic Floor Tile*" (JC501-1993). The dimensional allowed tolerances are given in Table 7.8; The specifications of surface quality and deformation are shown in Table 7.9; as to physical performance indexes, refer to Table 7.10.

**Table 7.8 Dimensional Allowed Tolerances of Unglazed Ceramic Flooring Tiles**

| Item | Basic dimension (mm) | Allowed tolerance (mm) |
|---|---|---|
| Side length $L$ | $L<100$ | ±1.5 |
| | $100\leqslant L\leqslant 200$ | ±2.0 |
| | $200<L\leqslant 300$ | ±2.5 |
| | $L>300$ | ±3.0 |
| Thickness $H$ | $H\leqslant 10$ | ±1.0 |
| | $H>10$ | ±1.5 |

**Table 7.9 Specifications of Surface Quality and Deformation of Unglazed Ceramic Flooring Tiles**

| Defect | | Quality criteria | | |
|---|---|---|---|---|
| | | Superior quality | First quality | Good quality |
| Surface quality | Spot, bubble, fusion hole, chip, body powder, pocked, flaw, blur pattern | No apparent defect on eye observation, 1m from the tile surface | No apparent defect on eye observation, 2m from the tile surface | No apparent defect on eye observation, 3m from the tile surface |
| | Crazing | Not allowed | | Overall length no bigger than 6% of the relevant side length |
| | Crack | | | Front face, no bigger than 5mm |
| | Color difference | No apparent color difference on eye observation, 1.5m from the tile surface | | No severe color difference on eye observation, 1.5m from the tile surface |
| Deformation (%) | Flatness | ±0.5 | ±0.6 | ±0.8 |
| | Edge straightness | ±0.5 | ±0.6 | |
| | Squareness | ±0.6 | ±0.7 | |
| Back pattern | | Both the height and the depth of concave back-pattern no less than 0.55mm | | |
| Interlayer | | No interlayer is allowed for any quality level unglazed tile | | |

**Table 7.10 Physical Performance Indexes of Unglazed Ceramic Flooring Tiles**

| Water absorbing capacity (%) | Thermal shock resistance | Bending strength (MPa) | Frost resistance | Wear resistance ($mm^3$) |
|---|---|---|---|---|
| 3-6 | After 3 times of thermal shock cycles, no breakage or crazing | Mean value≥25 | After 20 times of freezing and thawing cycles, no breakage or crazing | Mean value of wear loss≤345 |

## 7.4.3 Other Types of Ceramic Flooring Tiles

### 1. Skid-proof and Wear Resistant Flooring Tile

Wear resistant flooring tile is made by processing natural sand and stone through crushing, ball milling, molding and high temperature sintering. It is highly vitrified and in stone-like hardness, so it has good wear resistance and corrosion resistance. Tile sintered with different concave-convex patterns and designs on the surface is skid-proofing, called skid-proof flooring tile. With elegant and harmony colors and natural and rustic textures, it is especially applied to places often crowded with many people such as halls, conference rooms, theaters, office buildings and places requiring skid-proof.

**2. Moisture-proof Tile**

Moisture-proof tile is made by sintering earthenware clay. It looks red and is also named red ground tile. It has such features as high strength and light weight, pressure resistance and wearing resistance, moisture-proof and skid-proof, and is applicable to floors, gate porches and gate steps etc. in public places such as theaters, office buildings, schools, hotels and other public structures as well as residential buildings, especially suitable for bathrooms and washrooms.

Moisture-proof tile is in shapes as square, rectangle and hexagon etc., and in different dimensions.

**3. Square Paving Tiles**



Square paving tile is a ceramic product imitating the textures and grains of stone, generally in shapes such as triangle, trapezoid, square and hexagon etc. Its surface is boorish and rustic, wear resistant and skid-proof and has natural and clear textures. It is applied to the grounds of public places, wharfs, bus terminals, sidewalks and courtyard-structures and is combined to create patterns of circles, rings or fish-scales, which show unique appearances and styles.

# 7.5 Ceramic Mosaic

## 7.5.1 Features and Applications of Ceramic Mosaic

Ceramic mosaic, also called ceramic mosaic tile, is ceramic tile combination made up of many small unit-blocks (surface area no bigger than $55cm^2$), which is used to decorate and protect building floors and walls.

Ceramic mosaic has features such as hard texture, beautiful color, elegant design, corrosion-resistance, wear-resistance and fire-resistance. It is easy to wash and clean and fade-proofing. It is primarily applied to the facing decoration of interior and exterior walls and the floor paving in structures such as workshops, control laboratories, entrance halls, corridors, kitchens and washrooms etc., and also for mounting and combining wall paintings, calligraphies and trimmings etc.

## 7.5.2 Technical Requirements for Ceramic Mosaic

### 1. Types, Shapes and Specifications of Ceramic Mosaic

According to surface nature, ceramic mosaic is classified to glazed and unglazed; according to tile-combination, is classified to three types such as mono-color, multi-color and patterned; according to dimensional allowed tolerance and appearance quality, classified to superior quality and good quality.

The side length of unit-block should be no more than 95mm; surface area is no more than $55cm^2$; the shapes of tile-combination are square, rectangle and others. Special requirements can be negotiated by the supplier and demander. According to dimensional allowed tolerance and appearance quality, it is classified to superior quality and good quality.

The basic shapes of ceramic mosaic are square, rectangle, symmetric-corner, right trapezoid, symmetric-ribbon, pentagon, half-octagon and hexagon etc. The specifications are shown in Table 7.11; Different shapes can be combined together to create various patterns, refer to Figure 7.1 and Table 7.12.



**Table 7.11 Specifications of Ceramic Mosaic**

| Name | Type | Dimension (mm) | | | | Name | Type | Dimension (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *a* | *b* | *c* | *d* | | | *a* | *b* | *c* | *d* |
| Square | Large square | 39.0 | 39.0 | — | — | Right trapezoid (oblique angle) | | 36.4 | 11.9 | 37.9 | 22.7 |
| | Medium large square | 23.6 | 23.6 | — | | Symmetric-ribbon | | 7.5 | 15 | 18 | 20 |
| | Medium square | 18.5 | 18.5 | — | — | Pentagon | Large pentagon | 23.7 | 23.7 | — | 35.6 |
| | Small square | 15.2 | 15.2 | — | — | | Small pentagon | 18.5 | 18.5 | — | 27.8 |
| Rectangle (long ribbon) | | 39.0 | 18.5 | — | — | Half-octagon | | 15 | 15 | 18 | 40 |
| Symmetric-corner (corner cut) | Large symmetric-corner | 39.0 | 19.2 | 27.9 | — | Hexagon | | 25 | — | — | — |
| | Small symmetric-corner | 32.1 | 15.9 | 22.8 | — | | | | | | |

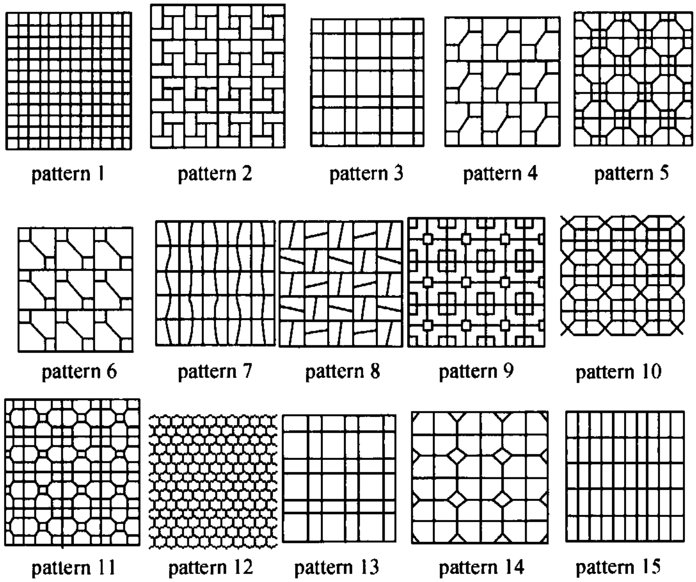



Figure 7.1 Primary Combination Patterns of Ceramic Mosaic



**Table 7.12 Description of Some Primary Combination Patterns of Ceramic Mosaic**

| Pattern code | Pattern description | Pattern code | Pattern description |
|---|---|---|---|
| P1 | Different squares combined together | P8 | Different right trapezoids combined together |
| P2 | Square combined with rectangle | P9 | Symmetric-ribbon combined with small square |
| P3 | Large square, medium square combined with rectangle | P10 | Square combined with pentagon |
| P4 | Medium square combined with large symmetric-corner | P11 | Half-octagon combined with small square |
| P5 | Small square combined with small symmetric-corner | P12 | Different hexagons combined together |
| P6 | Medium square combined with large symmetric-corner; small square combined with small symmetric-corner | P13 | Large square, medium square and rectangle combined together |
| | | P14 | Small symmetric-corner combined with medium large square |
| P7 | Different right trapezoids combined together | P15 | Different rectangles combined together |

## 2. Technical Performances of Ceramic Mosaic

Ceramic mosaic product should meet the standards in "*Ceramic Mosaic*" (JC/T 456-2005). Its dimensional allowed tolerances, physical performance indexes and appearance quality requirements are given in Table 7.13, Table 7.14 and Table 7.15; as to the quality requirements for ceramic mosaic tile combination, refer to Table 7.16.

**Table 7.13 Dimensional Allowed Tolerances of Ceramic Mosaic**

| Item | | Allowed tolerance (mm) | |
|---|---|---|---|
| | | Superior | Good quality |
| Unit block | Length and width | ±0.5 | ±1.0 |
| | Thickness | ±0.3 | ±0.4 |
| Each tile combination | Joint line | ±0.6 | ±1.0 |
| | Combination length | ±1.5 | ±2.0 |

Note: Special requirement can be negotiated by the supplier and customer.

**Table 7.14 Physical Performance Indexed of Ceramic Mosaic**

| Item | Performance Index |
|---|---|
| Water absorbing capacity | Unglazed ceramic mosaic: no bigger than 0.2%; glazed ceramic mosaic: no bigger than 1.0% |
| Wear-resistance | The deep-abrasion-resistance volume of unglazed ceramic mosaic no bigger than $175mm^3$;<br>Wear level and rotating rounds in the report of surface wear-resistance of flooring glazed ceramic mosaic |
| Thermal shock resistance | Zero breakage or crazing after 5 times of thermal shock test |
| Frost resistance, chemical corrosion resistance | Be negotiated by the supplier and customer |

**Table 7.15 Appearance Quality Requirements for Ceramic Mosaic**

| Name of defect | | | Defect allowed range | | | | Remark |
|---|---|---|---|---|---|---|---|
| | | | Superior quality | | Good quality | | |
| | | | Front | Back | Front | Back | |
| Interlayer, crazing, crack | | | Not allowed | | | | |
| Spot, adhesive scar, bubble, body powder, pocked, crinkle, cut glaze, orange peel, pinholes, ash contamination, fusion hole | | | Not apparent | | Not severe | | |
| Maximum side length less than 25mm | Broken corner | Sloping side length (mm) | <2.0 | <4.0 | 2.0-3.5 | 4.0-5.5 | Broken corner is not allowed to appear on both the front and the back of the same corner; only one broken corner is allowed on the front |
| | | Depth (mm) | No more than 2/3 of the tile thickness | | | | |

Continued

| Name of defect | | | Defect allowed range | | | | Remark |
|---|---|---|---|---|---|---|---|
| | | | Superior quality | | Good quality | | |
| | | | Front | Back | Front | Back | |
| Maximum side length less than 25mm | Broken edge | Length (mm) | <3.0 | <6.0 | 3.0-5.0 | 6.0-8.0 | Broken edge is not allowed to appear on the front and the back of the same wing-side; each wing-side is not allowed to have 2 pcs of broken edge; only 2 pcs of broken edge are allowed on the front |
| | | Width (mm) | <1.5 | <2.5 | 1.5-2.0 | 2.5-3.0 | |
| | | Depth (mm) | <1.5 | <2.5 | 1.5-2.0 | 2.5-3.0 | |
| | Deform-ation | Warp | Not apparent | | | | |
| | | Big end and small end (mm) | 0.2 | | 0.4 | | |
| Maximum side length bigger than 25mm | Broken corner | Sloping side length (mm) | <2.3 | <4.5 | 2.3-4.3 | 4.5-6.5 | Broken corner is not allowed to appear on both the front and the back of the same corner; only one broken corner is allowed on the front |
| | | Depth (mm) | No bigger than 2/3 of tile thickness | | | | |
| | Broken edge | Length (mm) | <4.5 | <8.0 | 4.5-7.0 | 8.0-10.0 | Broken edge is not allowed to appear on the front and the back of the same wing-side; each wing-side is not allowed to have 2 pcs of broken edge; only 2 pcs of broken edge are allowed on the front |
| | | Width (mm) | <1.5 | <3.0 | 1.5-2.0 | 3.0-3.5 | |
| | | Depth (mm) | <1.5 | <2.5 | 1.5-2.0 | 2.5-3.5 | |
| | deforma tion | Warp (mm) | 0.3 | | 0.5 | | |
| | | Big end and small end (mm) | 0.6 | | 1.0 | | |

**Table 7.16 Quality Requirements for Ceramic Mosaic Tile Combination**

| Item | Quality requirements |
|---|---|
| Color difference | The color difference of mono-color ceramic mosaic and the color difference of the same color tiles in tile combination: superior quality, almost identical on eye observation; good quality, a little color difference on eye observation |
| Bonding performance of cementing backing material | After bonding test to ceramic mosaic and cementing backing material, mosaic is not allowed to fall off |
| Peeling of cementing backing material | After laying and pasting ceramic mosaic, the peeling time of mosaic is no more than 40 min |
| Exposal of cementing backing material | After laying and pasting ceramic mosaic on the front and the back, cementing backing material is not allowed to expose |

# 7.6 Building Terracotta

## 1. Features and Applications of Building Terracotta



Building terracotta is a conventional building material with Chinese national cultural features and styles. It is not only applicable to traditional structures, but also to national style modern structures. Terracotta is made in this way: make the body with infusible clay, and then process it through drying, biscuit firing, glazing and glaze firing.

Building terracotta is solid and durable, beautiful and colorful in antique and simplicity style and with features such as dense texture, smooth and bright surface and stain resistance. Common colors are golden, emerald green, sapphire blue, cyan, black and purple. It is primarily applied to palace-style structures with national characters and some monumental buildings, and also used to build kiosks, stages, lofts and walls etc. in gardens.

## 2. Technical Performances of Terracotta

Building terracotta is classified to three types: tiles (flat tile, drip tile, round tile and eave tile etc.), ridges (main ridge round tile etc.) and ornamental pieces (eaves tile with patterns, roof-end tile with beast head etc.).

There are no specifications for dimensions of terra-cotta in "*Building Terra-cotta*" (JG/T 765-1996). Its dimensions are negotiated by the supplier and customer, but the dimensional allowed tolerances have already been stipulated.

According to appearance quality, building terracotta is classified to superior quality, first quality and good quality. Its water absorbing capacity is required no more than 12%; superior quality and first quality are required being capable of resisting more than 15 times of freezing and thawing cycles, and for good quality, more than 10 times; bending failure load no less than 1177N; resisting more than 3 times of thermal shock cycles; mean value of glossiness is generally required more than 50 degree.

## Materials Selection

【Case】 Glazed interior tiles were applied to the interior walls of a kitchen. Several years later, some pieces of crazing appear on tiles near the stove. Please analyze the reasons.

【Analysis】The temperature near the stove varies more greatly. The glaze on the tile has larger expansion coefficient than the tile body. Temperature rises and falls down before and after cooking. During the hot and cold alternations, the deformation of the glaze is bigger than that of the body, therefore, stress is created. When the stress is too big, it will cause crazing on the glazed surface. It is reasonable to adopt high quality glazed interior tiles for the place.



## Test on Decorative Materials

Test 1: Test on thermal shock resistance of ceramic tile (refer to GB/T 3810.9-1999)

This test adopts the test method for thermal shock resistance of all types of ceramic tiles under normal service conditions.

### 1. Test Principle

Thermal shock resistance is determined by 10 cyclic tests on whole tiles at temperatures of 15℃ and 145℃.

### 2. Test Equipments

1) Low temperature water tank. Adopt low temperature water tank with flowing cool water of 15℃±5℃, for instance, water tank of length 55cm, width 35cm and depth 20cm, water flow speed 4L/min; or other suitable equipment.

Immersion test: The test is used on ceramic tiles with tested water absorbing capacity no more than 10% according to GB/T 3810.3; water tank don't need to be covered, but the water should be deep enough to cover the whole tiles vertically placed in the tank.

Non-immersion test: The test is used on glazed tiles with tested water absorbing capacity more than 10% according to GB/T 3810.3. The large water tank is covered with a 55mm thick aluminum panel contacting with water surface. Then cover the aluminum panel with aluminum grains in diameter ranging 0.3mm to 0.6mm, the layer is 5mm thick.

2) Baking box with working temperature ranging 145℃ to 150℃.

**3. Test Sample**

At least 5 blocks of full tiles are adopted for the test.

**4. Test Procedures**



1) Preliminary checking of test sample. First, in the light condition of illuminating value 300lx, observe the tile surface with eyes from 25mm to 30mm away. All test samples should have no defect before test. Methylene blue solution is applied in the checking before measuring.

2) Immersion test. Adopt low-porosity tiles with water absorbing capacity no more than mass-fraction 10%, vertically immerge them in 15℃±5℃ cold water, keep them separating from each other.

3) Non-immersion test. Adopt glazed tiles with water absorbing capacity no bigger than mass-fraction 10%, keep the glazed surface downward to touch aluminum grains laid on the tank filled with 15℃±5℃ cold water.

4) After keeping the above two procedures at low temperature for 5min, move the test samples immediately to the 145℃±5℃ baking box, heat and preserve it at the temperature (usually 20min), then shift them immediately to low temperature environment. Repeat this procedure cycle for 10 times. Then visually study if there is any visible defect on the test samples 25mm to 30mm away in the light condition of illuminating value around 300lx. It betters the check to brush proper staining solution (such as 1% methylene blue solution with a little wetting agent) on the glazed surface of test samples and wipe it off 1min later with wet cloth.

### 5. Test Report

Test report includes the following: ① description of the tiles; ② water absorbing capacity of the tiles; ③ test type (immersion test and non-immersion test); ④ the quantity of test samples with visible defect.

Test 2: Test on surface wear-resistance of glazed tiles (refer to GB/T 3810.7-1999).

This test is to measure the surface wear-resistance of all glazed tiles.

### 1. Test Principle

The surface wear-resistance of glazed tile is measured in this way: lay grinding media (meet GB/T 308 requirements) on the glazed surface and rotate them, then study and compare the worn test samples with the unworn ones and evaluate the wear-resistance of ceramic tiles.

### 2. Grinding Media

Grinding media for each piece of sample: 70.0g of 5mm diameter steel balls; 52.5g of 3mm diameter steel balls; 43.75g steel balls 2mm in diameter; 8.75g steel balls 1mm in diameter; No.80 white fused alumina must meet the specifications in GB/T 2479; de-ionized water or distilled water, 20mL.



### 3. Test Equipments

1) Abrasion wear test machine. It is composed of steel chassis with built-in motor drive horizontal bearing disk, the minimum dimension of the test sample is 100mm×100mm. The distance between the bearing disk center and each test sample center is 195mm. There is equal distance between each two adjacent sample holders. Bearing disk rotates at a speed of 300r/min and creates 22.5mm of eccentric distance. Therefore, each sample is doing circular motion of 45mm in diameter, and is fixed with the rubber-sealed metallic holder. The inside diameter of the holder is 83mm, which provides a test area of 54cm$^2$. The rubber is 9mm thick and the height inside the holder is 25.5mm. After the machine reaches the preset revolutions, it stops automatically. Holders supporting the test samples should be covered in operation. Other devices providing the same test result are also applicable.

2) Visual evaluation: Inside the device box, vertically fix a fluorescent lamp with color temperature ranging 6000-6500K and illuminating value around 300lx above the surface of the tiles. The dimension of the box is

61cm×61cm×61cm, there is natural light inside the box. Direct lighting from light source should be avoided during observation.

3) Baking box should be able to work at temperature 110℃±5℃.

4) Balance (adopted when abrasion-wear is required).

## 4. Test Sample

1) Types of test samples. Test must be typical. To ceramic tiles in different colors or with surface decorative effects, samples should include all the special features. The dimension of test samples is usually 100mm×100mm. Small size test samples should be firstly fixed to a certain bearing material, the influence of small joints is allowed to neglect.

2) Sample quantity. The test needs 11 blocks of test sample, 8 of which are for eye observation and evaluation after testing. One block is taken away at each grinding stage, and then is compared with the other 3 blocks to study the visible abrasion-wear traces.

3) Preparation. Test samples should be washed, cleaned and dried.



## 5. Test Procedures

1) Hold the test samples tightly to the metallic holders with their glazed surface upward, then input grinding media from the feed inlet at the top of the holder and cover the inlet to prevent the loss of grinding media. The preset revolutions for test samples are 100, 150, 600, 750, 1500, 2100, 6000 and 12000 (r/min). After reaching each of the preset revolutions, take away one sample and wash it in flowing water and dry it in the 110℃±5℃ baking box. If test samples are stained by iron rust, scrub them with hydrochloric acid with volume-fraction 10%, then immediately wash them in flowing water, and dry them. In dim light room, put test samples in the observation box, under illuminating value 300lx, visually study then in a distance of 2m and a height of 1.67m, and compare and find out if there is any difference between the glazed surfaces of the unworn and the worn tiles. Be aware of the difference on glazed tile surfaces which experienced different revolutions. At least three study conclusions must be provided.

2) Visually study inside the observation box and make comparison. When visible abrasion-wear of the test samples experienced higher level revolutions and those experienced lower level revolutions are close to each other, test

should be done again to check the result. If the result is different, take the two higher levels as end result for classification.

3) Ceramic tiles that have passed through 12000 revolutions should be taken to stain resistance test. According to specifications in GB/T 3810.14 standard, after the test, steel balls should be washed in flowing water, cleaned with methyl alcohol and absolutely dried to avoid rusting.

## 6. Classification of Test Results

Based on table 1, test samples are classified to 5 types. Ceramic tiles having passed 12000 revolutions should be taken to surface stain resistance test on the worn glazed surface according to GB/t 3810.14 standard. The standard has been revised as follows:

1) Take only one block of worn tile (more than 12000r/min), observe and distinguish carefully, make sure the stain classification is accurat (e.g. before carrying out stain resistance test, cut off part of the worn tile).

2) If not following A, B and C procedures to wash and clean the tile, then D procedure specified in GB/T 3810.14 standard is taken.

3) If no abrasion-wear trace appears after 12000 revolutions, but stain can't be cleaned with any method listed in GB/T 3810.14 standard, the tile is classified as type 4.

### 7. Test Report

Test report should include the following: ①description of ceramic tiles, including preparation method of test samples; ②classifications based on Table 7.17; ③the grinding level of visible abrasion-wear trace.

**Table 7.17 Classifications of Glazed Ceramic Tiles**

| Visible abrasion-wear trace level (r/min) | Classification |
|---|---|
| 100 | 0 |
| 150 | 1 |
| 600 | 2 |
| 750, 1500 | 3 |
| 2100, 6000, 12000 | 4 |
| >12000r then it requires to pass the stain resistance test in GB/T 3810.14 | 5 |

## Practice

7.1 Take a building with its exterior walls decorated with glazed tiles on campus. Study the application status carefully.

(1) Tasks

1) Investigate the service life of glazed tiles, observe the surface cleanliness and find out if there is any flaking-off or crazing problems.

2) Think over and discuss the existed problems according to what is learned in this chapter.

(2) Requirements

Write a paper of no less than 1500 words.

7.2 Carry out market research on building decorative ceramics in the local decorative material markets.

(1) Tasks

1) Find out what decorative ceramic products are mainly sold in the decorative material markets.

2) Find out the prices, features and manufacturers of several types of ceramic introduced in this chapter and collect the samples.

3) Collect information about the application of these ceramic products in local decoration projects.

(2) Requirements

1) 3-4 students in a group to complete the above research tasks;

2) Each team hands in a research record and a research report which include:

① Information about the ceramic products in the market, including the material components, features, applications and so on;

② Make a list of the production origins and prices of several ceramic products and make comparisons;

③Make discussions on how to scientifically select and apply decorative ceramic according to what is learned in the chapter and the research.



## Summary

This chapter introduces the classifications and material components of ceramics and the features, applications and technical requirements of several

types of ceramic products commonly-used in building decoration projects, such as glazed interior tiles, ceramic wall-floor tiles and ceramic mosaic; Thermal shock resistance test and wear resistance test are also important contents in this chapter.

## Questions for Reviewing and Thinking

7.1 Which three types of ceramic are there according to product category? What kind of features does each of them have?

7.2 What are commonly-used decorative ceramic products? What application does each of them have?

7.3 Why are glazed interior tiles only applicable indoors?

7.4 What are mainly included in the quality requirements for glazed interior tiles, ceramic wall-floor tiles and ceramic mosaic?

7.5 What are new ceramic wall-floor tiles? What features does each of them have?

# 8

# Building Decorative Glass

## 8.1 Introduction of Glass

Conventionally glass was only used for light-picking. With the development of modern architecture, glass is adopted for decoration in many buildings. At the same time, it is required to have such functions as light controlling, heat adjusting, energy saving and noise controlling, and to decrease the dead load of buildings, improve building environments and enhance architectural art effects etc. Therefore, glass has become one of the important decorative materials for building decoration projects.



### 8.1.1 Components of Glass

The main raw materials of glass are quartz sand, pure alkali, feldspar and limestone etc., which are made into glass, a transparent amorphous inorganic material, after fusing, melting, cooling and curing. The primary chemical compositions in ordinary glass are oxide materials such as $SiO_2$, $Na_2O$, $K_2O$, $Al_2O_3$, MgO and CaO, which have notable functions in glass (refer to Table 8.1). In addition, some auxiliary raw materials are added in the production of glass to improve the performances as pigmenting and modification to meet the requirements of different applications. Common auxiliary materials are solutizer, decolourant, clarifier, colorant and opacifier.

**Table 8.1 Affections of Oxides to Glass Performances**

| Name of Oxide | Affection | |
|---|---|---|
| | Increase | Decrease |
| $SiO_2$ | Fusing temperature, chemical stability, thermal stability, mechanical strength | Density, heat expansion coefficient |
| $Na_2O$ | Heat expansion coefficient | Chemical stability, heat resistance, fusing temperature, tendency towards devitrification, annealing temperature, ductility |

Continued

| Name of Oxide | Affection | |
|---|---|---|
| | Increase | Decrease |
| CaO | Hardness, mechanical strength, chemical stability, tendency towards devitrification, annealing temperature | Heat resistance |
| $Al_2O_3$ | Fusing temperature, chemical stability, mechanical strength, annealing temperature | Tendency towards detrivification |
| MgO | Chemical stability, heat resistance, mechanical strength | Tendency toward detrivification, ductility |

## 8.1.2 Basic Performances of Glass

### 1. Density

The apparent density of glass is related to its chemical compositions, so it varies greatly and decreases when temperature rises. The apparent density of ordinary silicate glass is about 2500kg/m$^3$ at normal temperature.

### 2. Mechanical Properties

The mechanical properties of glass are decided by its chemical compositions, the shape, surface features and processing method of the product. Stress concentration which hugely decreases its mechanical strength is likely to happen to products with un-molten debris, concretions, knots or other micro crazings. In construction practice, glass often receives bending, stretching, impact and shock but seldom receives pressing, therefore, its mechanical properties mainly include tensile strength and fragility index. The actual tensile strength of glass is 30-60MPa. The fragility index of ordinary glass (ratio of the elastic modulus over the tensile strength $E/R$) is 1300-1500 (rubber, 0.4-0.6). Higher fragility index means higher fragility.

### 3. Thermal-physical Properties

Glass has weak thermal conductivity, at normal temperature its coefficient of thermal conductivity is only 1/400 of that of copper, but it increases when temperature rises, and is also affected by its color and chemical compositions. The heat expansion of glass depends on its chemical compositions and purity. Higher purity leads to smaller heat expansion coefficient. Thicker and larger glass products have weaker thermal stability.

**4. Chemical Stability**

Though glass has high chemical stability, it is likely to deteriorate and get broken after long period of corrosion by corrosive media.

**5. Optical Performances**

Glass can be penetrated by light and also reflects and absorbs light, therefore, thick or multilayer glass is often not easy for light to get through. The ratio of reflected light energy to projected light energy is called reflection coefficient which depends on factors such as smoothness of reflection surface, refractive index, size of incidence angle of the projection light, the coating on glass surface and its type etc. The ratio of absorbed light energy of glass to its projected light energy is called absorption coefficient. The ratio of transmitted light energy over projected light energy is called transmission coefficient.

Reflection coefficient, transmission coefficient and absorption coefficient sum up to 100%. Under vertical sunlight projection, the reflection coefficient of 3mm-thick ordinary window glass is 7%; its absorption coefficient is 8%; the transmission coefficient, 85%. Taking solar radiation energy that passes through the standard 3mm-thick transparent glass as 1.0, the relative value of solar radiation energy that passes through other glass in the same condition is called sheltering coefficient. Smaller sheltering coefficient shows that less solar radiation energy enters the house through glass, the cooling effect becomes better and the light becomes gentler.



## 8.1.3 Classifications and Applications of Glass

There are many types of glass, which is classified based on its chemical compositions, product structures and performances, production techniques or functional features.

**1. Classified Based on its Chemical Compositions**

Soda ash glass, potassium glass, aluminum magnesium glass, lead glass, borosilicate glass and quartz glass.

**2. Classified Based on its Product Structures and Performances**

1) Regular plate glass: including ordinary sheet glass and float glass.

2) Toughened glass.

3) Surface-processed plate glass: including polished glass, frosted glass, sandblasted glass, embossed glass, patterned glass, ice-flower glass and etched glass etc.

4) Plate glass with special compositions: including colored glass, heat-absorbing glass, photochromic glass and solar glass etc.

5) Laminated plate glass: including wired glass, laminated glass and electric heated glass.

6) Multi-coated plate glass: regular mirror glass, coated heat-reflecting glass, laser glass, glazed glass, coated glass and filmed glass (glass covered with film) etc.

**3. Classified Based on its production techniques and functional features. (Refer to Table 8.2.)**

**Table 8.2 Classifications and Features of Glass**

| Classification | | Feature | Application |
|---|---|---|---|
| Plate glass | Regular plate glass | Produced with processing techniques as up-drawing and horizontal drawing etc.; staple product, with slight glass wave | General construction projects |
| | Heat-absorbing plate glass | Absorb heat (infrared) | Sun-proofing buildings etc. |
| | Polished plate glass | Flat surface, no glass wave, no optical distortion | Mirror making, advanced buildings |
| | Float plate glass | Produced with float process; Same features as polished plate glass | |
| | Wired plate glass | With wire mesh embedded in the middle of glass; Safe and fireproofing | Security enclosure walls, light transmission buildings |
| | Patterned(or figured) plate glass | Transmit diffused light; not perspective; good decorative effect | Doors, windows and decorative screens |
| Decorative glass | Glazed glass | Glazed surface; decorated with colorful patterns and designs; have reflection function | Decorative doors and windows and screens |
| | Mirror glass | Have reflection function | Mirror making and decoration |
| | Combined-patterned glass | Assemble and combine patterns and designs with I-shaped lead bars | Decoration, doors and windows |

Continued

| Classification | | Feature | Application |
|---|---|---|---|
| Decorative glass | Frosted glass | Transmit diffused light; different patterns according to meet needs | |
| | Stained glass | Different beautiful and fresh colors | Decoration, signals |
| | Color coating glass | Different beautiful colors; Have heat-reflection function | Decoration, energy saving |
| | Laser glass | Generate physical diffracted light when illuminated by light source; seven-color spectral changes | Decoration of façades and entertainment places |
| | Sandblasted glass | Paste patterns on the surface of glass, then cover it with protection layer, and process it with sandblasting technique | Decoration of doors and windows and screens |
| | Carved glass | Made through painting, carving, waxing and acid etching and grinding | |
| | Print Glass | The pattern does not transmit light but the blank does | Doors and windows, partitions, screens |
| | Ice-flower glass | Transmit diffused light; glittering patterns look like ice flake; rich of 3d tactile sensation | Doors and windows, suspended ceilings, screens |
| | Crystallized glass | Plasticity; crystal luster and smoothness; high strength and hardness; reflect its gloss and create special effect | Interior and exterior walls, table tops, columns and corners |
| | Welding glass | Light transmittance is only 1%; good glossiness and hardness | Furniture, wall tiles and photo frames |
| | Ornamental glass | Reflect colorful glosses and reveal different patterns when illuminating or moving. | Decoration, art-wares |
| | Colored split-pattern glass | Different glosses and pattern styles | Doors and windows, decorative lighting |
| Safety glass | Toughened glass | High strength; heat shock resistance; non-sharp angle grains after breaking | Security doors and windows |
| | Laminated glass | High strength; no fall-off glass debris after breaking | |
| | Security glazing | Not likely to break; can't be broken in even if broken; allow to be equipped with alarms | Security doors and windows, shop windows |

Continued

| Classification | | Feature | Application |
|---|---|---|---|
| Safety glass | Explosion-proof glass | Bear certain explosion wave; not fall to pieces; not hurt people | Observation windows etc. |
| | Bulletproof glass | Protection against the shooting from certain caliber of gun; no penetration | Security buildings and watch-houses etc |
| | Fireproof glass | Usually transparent; protect against certain level of fire and remain unbroken in a certain period of time; keep away fire and smoke; can be equipped with fire alarm | Security fireproof buildings |
| | Armored glass of titanium | High resistance to smash; high heat resistance and UV resistance | Security doors and windows, watch-houses |
| | Irregular glass | Transmission of light; heat insulation; sound insulation and high mechanical strength; difficult for on-site processing and cutting | Skylights, roofs and weather sheds |
| New type building glass | Electric heated glass | No water condensation, fogging or ice flake etc. | Doors and windows, observation windows and windshields |
| | Heat-reflecting glass | Reflection of infrared; cooling effect; modulation of light | Glass curtain walls, advanced doors and windows |
| | Low emissivity glass | Small radiation coefficient | Doors and windows of advanced buildings etc. |
| | Selective absorption glass | Selectively absorb or reflect light with certain wavelength | |
| | UV-glass | Absorb or reflect ultraviolet light; protect from damage of ultraviolet radiation | For antiquities, libraries and healthcare etc. |
| | Photochromic glass | Changeable colors under illumination | Sunlight shadings |
| | Double insulating glass | Create effects such as heat preservation, heat insulation, sound absorption and light modulation etc. | Air-conditioning rooms, cold area structures |
| | Electro-chromic glass | Color changes under certain voltage | Sunlight shadings and advertisements etc. |
| | Imitation marble glass | Appearance is like natural marble, but performances are better | Same as marble |

Continued

| Classification | | Feature | Application |
|---|---|---|---|
| New type building glass | Embossed marble glass | Same appearance as marble; easy to process into different shapes and dimensions | Walls, table tops and columns |
| Glass tile | Glass facing tile | Flat; good performance of reflection, frost resistance, acid and alkali resistance | Interior and exterior walls |
| | Colored glass tile | Different colors; acid and alkali resistance; wear resistance | Walls and places requiring high stain-resistance |
| | Extra-thick glass | Glass with thickness more than 12mm | Glass curtain walls and safety glass |
| | Hollow glass block | Made by welding four-form glass; transmit diffused light; high strength | Light transmission walls and roofs etc. |
| | Glass mosaic | Rich colors; combined into different patterns | Large area decoration of interior and exterior walls |
| | Foam glass | Light weight, heat preservation, heat insulation, mould-proofing and moth-proofing | For heat insulation and deep-level heat preservation etc. |



## 8.1.4 Packing, Marking, Transportation and Storage of Glass

### 1. Packing

Glass is packed in wooden boxes or containers (pallets). The boxes (pallets) should be easy for handling and transportation. The packing quantity in each box (pallet) depends on its strength level.

### 2. Marking

Package (box) should be attached with conformity certificate and should be marked with the name of th producer or trademark, grade, dimension, thickness, quantity, date of production, standard code and notice symbols or letters such as correct handling, fragile, rain and temperature attentions etc.

### 3. Transportation

Prevent boxes (pallets) from leaning or sliding. Take measures against weather in transport and handling.

### 4. Storage

Glass must be stored in places without condensation of moisture or rainproof places.

# 8.2 Regular Plate Glass

## 8.2.1 Features and Performances of Plate Glass

Plate glass is flat glass product without other additional processing, also called plain glass or clear glass. It is the traditional glass product mainly applied to transmit light, keep out wind and preserve heat. It is required to be colorless and transparent with smooth and flat surface or defects. Its light reflectivity is around 7%, light transmittance ranges 82%-90%. In glass family, plate glass has the largest output and is most frequently used. It is mainly applied to doors and windows for light-picking (visible light transmittance 85%-90%), enclosing, preserving heat and insulating sound. Moreover, it is the raw material for further processing into other technical glass.



## 8.2.2 Classifications, Specifications and Grades of Plate Glass

According to processing methods, plate glass is classified to regular plate glass and float glass. According to applications, it is classified to window glass and decorative glass. Based on national standard "*Regular Plate Glass*" (GB4871-1995) and "*Float Glass*" (GB11614-89), there are several specifications of glass according to its thickness as follows:

1) Regular plate glass produced with drawing-method: four types as 2mm, 3mm, 4mm and 5mm thick.

2) Float glass: seven types as 3mm, 4mm, 5mm, 6mm, 8mm, 10mm and 12mm thick.

The length-width ratio of glass produced with drawing method is supposed to be no more than 2.5; 2mm and 3mm thick glass should not less than 400mm×300mm; 4mm, 5mm and 6mm thick glass not less than 600mm×400mm. The size of float glass is required not smaller than 1000mm×1200mm; for 5mm and 6mm thick glass, the maximum dimension is up to 3000mm×4000mm.

Based on national standards, plate glass is classified to different grades according to its appearance quality. Regular plate glass is classified to three grades: premium, first-grade and second-grade. Float glass is classified to three grades: premium, first-grade and sound-grade. Meanwhile the bending distortion of glass is required to be no more than 0.3%.

Regular plate glass is counted in standard case, actual case or weight case. For 2mm thick glass, each 10 meter is counted as 1 standard case; other plate glass is counted by converting its thichness to standard case. Actual case serves as the unit for counting pieces in transport. For glass in different thicknesses, the packing quantity in each actual case is different. Actual case is converted into standard case by multiplying the total square meters of glass of the same thickness and the same thickness coefficient. Weight case is defined as the weight of 2mm thick plate glass in each standard case. Other glass is counted by converting its weight to weight case according to certain coefficient.

## 8.2.3 Technological Quality Requirements for Plate Glass

### 1. Thickness Deviation

Thickness deviation must meet requirements in Table 8.3.

**Table 8.3 Thickness Deviation**

| Thickness (mm) | Allowed deviation | Thickness (mm) | Allowed deviation |
|---|---|---|---|
| 2 | ±0.20 | 4 | ±0.20 |
| 3 | ±0.20 | 5 | ±0.25 |



### 2. Dimensional Deviation

Length within 1500mm (including 1500m), not outrange ±3mm, length more than 1500mm, not outrange ±4mm.

### 3. Size Deflection

Length 1000mm, not outrange ±2mm.

### 4. Bending Distortion

Bending distortion should be no more than 0.3%.

### 5. Edge protrusion or Edge Fault

Edge protrusion or edge fault should be no greater than 3mm; one piece of glass only allows one broken corner no greater than 5mm measured along the angle bisector line of the corner.

**6. Transmittance of Visible Light**

Transmittance of visible light is required not less than the value specified in Table 8.4.

**Table 8.4 Transmittance of Visible Light**

| Thickness (mm) | Transmittance of visible light (%) | Thickness (mm) | Transmittance of visible light (%) |
|---|---|---|---|
| 2 | 88 | 4 | 86 |
| 3 | 87 | 5 | 84 |

### 8.2.4 Applications of Plate Glass

Plate glass is a conventional glass product and mainly applied to doors and windows to transmit light, keep out wind and preserve heat. It is required to be colorless and with good transparency, flat and smooth surface without defects. Its reflectivity to visible light is around 7%, transmittance ranges between 82%-90%. 3-5mm thick plate glass is directly applied to doors and windows for light-picking, 8-12mm thick glass is applied to partitions. Another important application is to serve as raw material to produce toughened, laminated, coated or insulated glass products etc.



## 8.3 Decorative Glass

### 8.3.1 Colored Plate Glass

Colored plate glass is classified to transparent and non-transparent. Transparent colored glass is made by adding certain amount of metallic oxide to the raw material. Non-transparent colored glass is a facing glass made through annealing processing, which can be cut, but after toughened processing it is no longer available for cutting.

Colored plate glass is in varieties of colors such as tea brown, sea blue, sapphire blue and emerald green etc. It can be joined together to create different patterns and has such features as corrosion resistance, anti-scour and easy-cleaning, and mainly used in the decoration of interior and exterior walls, doors and windows as well as places having special requirements for light.

### 8.3.2 Frosted Glass

Frosted glass is also called mat glass, which is made by sandblasting the surface of plate glass mechanically, then manually grinding or processing with hydrofluoric acid denudation etc. to create evenly rough surface. Due to its rough surface, it transmits light but is not perspective, so is primarily applied to privacy-required places or interference-proof rooms such as bath rooms, wash rooms, office doors and windows etc., and also serves as blackboards.

### 8.3.3 Glass with Patterns

**1. Patterned Glass**

Patterned glass is made by pressing the molten glass with figured roll-shaft during its cooling procedure. Thus various patterns in different depths are rolled and pressed on the surface of patterned glass. Because of such concave-convex uneven surface, light diffuses in the course of transmitting. Seen from one side of the glass, the object image on the other side looks blur and unclear, so it transmits light but is not perspective. Furthermore, with different patterns and designs on its surface, patterned glass can both transmit light and block eyesight, i.e. it is light-transmitting but non-transparent, which results in better artistic and decorative effects.

There are types of patterned glass: ordinary patterned glass, vacuum coated patterned glass and colored patterned glass etc. It is the ideal material for interior decoration and partitions in public structures, mainly applied to places such as doors and windows, indoor intervals, bathrooms and washrooms etc., and also to doors and windows of living rooms. It plays the role of light-picking but blocking visual sight.

**2. Sandblasted Patterned Glass**

Sandblasted patterned glass, also called glued-patterned glass, is made in this way: paste patterns on the surface of glass, cover it with protection layer, and then create transparent and non-transparent patterns with sandblasting process. Sandblasted patterned glass has elegant and beautiful appearance, and is applicable for interior doors and windows, partitions and for light-picking. Its thickness is usually 6mm; the maximum working dimension is 2200mm× 1000mm.

**3. Alabaster Glass**

Alabaster Glass is a new decorative glass and its appearance is close to that of glued-patterned glass. It is made by pasting patterns on one side of plate glass, covering it with protection layer, and then chemically processing and etching. Its patterns are clear, beautiful and full of decorativeness. Its thickness ranges between 3-5mm; maximum working dimension is 2000mm×1500mm.

**4. Ice-flower Glass**

Ice-flower glass is a kind of glass with natural ice flower patterns, which is made by processing plate glass with special technique. It diffuses the penetrated light. When applied to doors and windows, it looks like a veiling curtain blurring the interior scene but having good transmission performance. Ice-flower glass is made of colorless plate glass and also can be made of colored glass such as tea brown, blue and green glass etc. Its decoration effect is better than that of patterned glass, which gives people clear and fresh feelings. It is a new interior decorative glass and is applicable for the doors, windows, partitions and screens in hotels and restaurants as well as for home decoration. Presently its maximum dimension is 2400mm×1800mm.



## 8.3.4 Mirror Glass

Mirror glass is also called coated glass or film glass. It takes organic or inorganic compounds of gold, silver, copper, iron, tin, titanium, chromium or manganese as raw materials to create oxide coating on glass surface by adopting methods such as jetting, sputtering, vacuum deposition and vapor deposition etc. The coating layer of mirror glass is in all colors including golden, silver, grey and antique bronze. Such coated glass has one-way vision penetration, i.e. only allows vision from the coated side to non-coated side. Simultaneously, it is able to expand the interior space and the vision of buildings, or reflect the seasonal changes of the surroundings, which favors people with a delighting and cheerful feeling. Mirror glass has strong reflecting ability to light, which is 4-5 times more than that of plate glass. It increases interior brightness, creates mild and comfortable light, and feels cool in summer and warm in winter inside the room. Especially, it helps to save energy remarkably in buildings with air-conditioners. Such glass is applied to interior walls or columns, entrance halls, corridors, glass barriers etc. of public buildings, and to the exterior wall decoration (glass curtain wall) of hotels, restaurants and bars.

### 8.3.5 Laser Glass

Laser glass, also called laser-light glass or optical-wave glass, is the latest generation of laser decorative material, which adopts glass as basic material and is processed through surface microlithography. According to modern high-tech laser holographic optical principle, features of photographic art and carving are combined together, and with Bragg conditions, ordinary glass shows colorful prismatic 3d stereoscopic images and becomes more beautiful than people can take in.

#### 1. Main Features of Laser Glass

According to different needs, Laser glass is made by adopting computer design, laser surface processing, different colors and images, as well as various color modes to form physical diffraction spectroscopic and holographic gratings or other gratings on the surface of ordinary glass. The surface looks crystal-like, with concave and convex parts forming the reciprocal distribution or diffusion distribution of all sides, which creates lens with different textures, space feelings and façades. Moreover, with the color of the glass itself and the incident light source, countless of small lens generate multiple times of refractions, which creates the most colorful radiance and fantastic, esthetic, elegant and magnificent scenery, companied with reflecting and glittering of cool, warm and inter-medium colors. Unconventional and unorthodox, vagary and novelty, it is one of the latest stylish decorative glass products with brand new enjoyable value and is the creation of high and new technology and art.



#### 2. Functional Performances and Applications of Laser Glass

(1) Performances of Laser Glass

Laser glass has good impact-resistance and skid-proof performance, its corrosion resistance is better than that of marble, mosaic or vacuum coated glass etc. Its service life and holographic grating is highly stable.

(2) Applications of Laser Glass

Laser glass is applied to the decoration and renovation of public structures, restaurants, hotels as well as different commercial, cultural and entertainment halls, official buildings, scriptoriums and lobbies (saloons, halls) and to the beautification of residential houses. It is a finishing decorative material for such places as interior and exterior walls, commercial facilities, façades, signboards, billboards, ornamental boards, gates, stairs, columns, roofs, sculpture faces, elevator doors, artistic screens, luxurious fountains, hairdresser's, light-changing fishbowls, color-changing lamps, clocks and watches, as well as other electronic products.

**3. Specifications of Laser Glass**

(1) Standard Dimensions of Laser Glass (5mm thick)

Standard dimensions: 300mm×300mm, 400mm×400mm, 500mm×500mm and 500mm×1000mm.

(2) Dimensions of Floor-tile Laser Glass

Standard dimensions: 500mm×500mm and 600mm×600mm.

Nonstandard specifications: triangle, round and fan shapes.

(3) Irregular Laser Column Glass

Standard specifications include those with diameter of 150mm, 600mm, 700mm, 800mm, 900mm, 1100mm and 1200mm; other specifications are non-standard columns.

### 8.3.6 Glazed Glass

Glazed glass is made by painting easily-fused color glaze on the surface of glass in certain sizes, processing it through procedures such as sintering, annealing or tempering etc. to make the glaze layer bind tightly with the glass itself to produce the end product with beautiful colors or patterns. Usually it takes plate glass as basic material. With features as beautiful pattern, unfading, no discoloring and easy cleaning, it can be produced according to customer requirements or artistic designs. Glazed glass has good chemical stability, so it is widely used for interior facing decoration, the facing decoration of entrance halls and stair wells of ordinary buildings.

## 8.4 Safety Glass

Compared with ordinary glass, safety glass has higher mechanical strength and stronger impact-resistance. Its major types are tempered glass, wired glass, laminated glass and titanized glass. When safety glass is broken, its fragments won't hurt people, so it has anti-burglar and fireproof functions. By adopting different glass plate, safety glass also create certain decorative effects.

### 8.4.1 Tempered Glass (or Toughened Glass)

Tempered glass is also called reinforced glass, toughened glass or strengthened glass. Physical or chemical approaches are adopted to create a compressive stress layer on the surface, so it is able to avoid stress damage due to the high compressive strength of itself. When glass receives external forces, this stress layer is able to partly counterbalance the tension stress, thus avoid its breakage. Though the interior of tempered glass is in high tension stress state, self-destruction doesn't happen due to its zero interior defect, thus the strength of glass is enhanced. Tempered glass is the secondary product of plate glass. The processing methods include physical tempering and chemical tempering processes.

Physical-tempered glass is also called chilled glass. It is made by heating ordinary plate glass in the heating-furnace to softening temperature (600℃) to remove its internal stress by its self deformation, then taking the glass out of the heating-furnace and quickly cooling it down to room temperature by blowing high pressure cold air to both sides of the glass with a multi-nozzle. Such kind of glass is in the state of bearing both internal tension stress and external compressive stress at the same time. Even a tiny breakage releases its stress and leads to fragmentation to countless little bits which have no sharp edges or corners and won't hurt people.

Chemical tempered glass is made by changing the chemical compositions of glass surface to enhance its strength, commonly adopting ion exchange technique. This method is to immerge silicate glass containing alkali metal ion in molten lithium ($Li^+$)salt, then the $Na^+$ or $K^+$ ions in the glass surface exchange with $Li^+$ ions, which creates $Li^+$ ion-exchange layer on the surface. Because the expansion coefficient of $Li^+$ is smaller than that of $Na^+$ and $K^+$ ions, the external layer shrinkage is smaller than that of the internal layer during cooling procedure. Cooling to normal temperature, glass is also in the state of bearing both internal tension stress and external compressive stress and the effect is similar to that of physical tempered glass.

Tempered glass has high strength, and its compressive strength is more than 125MPa, which is 4-5 times of that of ordinary glass. Its impact strength is also very high. When measured by steel ball method, hit by a 0.8kg steel ball falling off from 1.2m height, glass retains unbroken. The elasticity of tempered glass is much greater than that of ordinary glass. A block of 1200mm×350mm×6mm tempered glass is able to reach a bending deflection of 100mm when receiving externl forces, whereas the bending deflection of ordinary glass is only several millimeters. Moreover, after the removal of the external forces, it recovers to its normal form. It also has good thermal stability. When receiving thermal shock, it is hard to get broken because its compressive stress is able to counterbalance part of the tensile stress created by the thermal shock. As to thermal shock resistance, its maximum working temperature is 288℃ and it is able to bear 204℃ temperature difference.

As tempered glass is better in mechanical strength and thermal stability, it is widely applied in the field of building construction, vehicles and other areas. Flat tempered glass is usually adopted for doors and windows, partitions, curtain walls, showcases and furniture etc; curved glass is applied to automobiles, trains as well as aircrafts etc. It should be noticed that tempered glass is not allowed to be cut, ground or chiseled and its edges and corners are not allowed to be hit or compressed. Users should select from the ready-made dimensions or make orders based on specific design-drawings. For a large surface curtain wall, the strengthened degree of tempered glass should be controlled. Semi-strengthened glass is preferable to avoid self-destruction due to excessive stress when receiving wind load or shaking. Different glass plates can be produced into ordinary tempered glass, heat-absorbing tempered glass, color tempered glass or tempered insulating glass etc.



### 8.4.2 Laminated Glass

Laminated glass is made by pasting PVB (polyvinyl butyral) resin glue film between two or more pieces of glass sheet, then heating, pressing and bonding them together to create flat or curved compound glass product. The glass sheet for making laminated glass can be ordinary glass, float glass, tempered glass, colored glass, heat-absorbing glass or heat-reflecting glass etc. The layer quantity is 2, 3, 5, 7, up to 9. For double-layer laminated glass, the common thickness of glass sheet is (mm) 2+3, 3+3 and 3+5 etc. Laminated glass has good transparency, and its impact resistance is several times higher than that of ordinary sheet glass. Bullet-proof glass is made by compounding multiple layers of ordinary glass or tempered glass.

Due to the adhesion of PVB glue film, even when the glass breaks, its fragments keep binding on the thin film and will not hurt people, and the surface of the fragmented glass remains clean and smooth, which effectively prevents fragments from penetrating or falling, thus ensures human safety. Laminated glass made of different sheet glass has different features such as durability, heat resistance and moisture resistance etc.

In Europe and America, laminated glass is applied to most buildings to avoid dangerous accidents because of its strong anti-shocking and anti-break-in abilities. The glue film in the middle is able to resist the consecutive striking by lethal weapons such as hammers and wood-cutting blades, and to resist the penetration of bullets for a certain period of time, so it is of high security level.

Sound-insulation effect is one of the important factors to evaluate the quality of modern residential buildings. Glass with PVB interlayer films is able to block sound wave and retain calm and comfortable office ambient. Its special UV filtering function not only protects human skin, but also prevents important and precious furniture and exhibiting artworks from fading. It also reduces the transmission of light and saves refrigerating energy.



Due to so many advantages, laminated glass creates unimaginable unique effects in household decoration. For instance, now frosted glass is applied to home doors, including kitchen doors, and oily smoke is easy to stick to the surface; however, if laminated glass is taken instead of frosted glass, such trouble will disappear. Moreover, large surface partitions at home are always a hidden trouble to the safety of active kids; if laminated glass is applied, parents will feel released about the safety of the children.

Laminated glass is safe to people even it is broken. Hit by a heavy ball, it is likely to break into fragments, but the whole block of glass retains consistent, and its debris and small sharp fragments keep binding with the glue film in the middle. Laminated glass is safer, so it is generally applied to doors, windows and skylights of high buildings, and showcases and partitions in stores, banks and jewelry shops etc.

### 8.4.3 Wired Glass

Wired glass, also called shatter-proof glass or ferro-glass, is made with rolling method; that is, pressing pre-heated steel wires or steel meshes into the middle of glass in molten state, then annealing and cutting the glass into end product.

The surface of wired glass can be patterned or polished, transparent or colorful.

Wired glass has the features as high safety and good fire resistance. Its strength is greatly enhanced due to the skeleton of wire meshes in the middle. When receiving destruction from impacts or sudden changes of temperature, its fragments will not fly away or strike to hurt people. When a fire breaks out and spreads, wired glass receives heat and gets broken, but due to the metallic wire meshes, glass retains fixed and firm and separates fire flame, so it's also called fireproof glass.

Based on national industry standard "*Wired Glass*" (96) (JC433-91), the thickness of wired glass is classified to: 6 mm, 7 mm and 10mm; its size generally not less than 600mm×400mm and not bigger than 2000mm×1200mm. Presently there are two types of wired glass made in China: patterned wired glass and polished wired glass, which is applicable for places such as doors and windows, skylights, light-picking roofs and balconies etc.



### 8.4.4 Fireproof Glass

Glass meeting the requirements for fire-resistant integrity, fire-resistant thermal insulation and heat radiation intensity is called fireproof glass. Fire-resistant integrity is defined as the ability of glass to prevent fire from penetrating or to prevent fire from spreading to the fireless side in the condition of standard fire-resistance test; fire-resistant thermal insulation is defined as its ability to retain its fireless side temperature no greater than the specified value for a certain period of time when one side of the building separation is on fire; heat radiation intensity is defined as the radiance value of the fireless glass side within certain distance and certain period of time. Fireproof glass is classified to level I, level II and level III according to fire resistance grade; according to structure, it is classified to two types:

Compound fireproof glass (FFB): a special type of glass made by combining two or more layers of glass or of a glass layer combining with organic material and simutaneously meeting the requirements of fire resistance level.

Monolayer fireproof glass (DFB): a special type of glass made of a single layer of glass and meeting the requirements of fire resistance level.

### 8.4.5 Titanized Glass

Titanized glass, also called never-broken armor foil glass, is a new type of glass made by tightly pasting titanium foil on the surface of any basic glass and combining them to one integral block. Titanized glass has functions such as high anti-breaking ability, high heat-resistance and UV resistance etc. Different basic glass material and different titanium foil are combined to form titanized glass in different colors and with different performances and specifications. It is usually colorless transparent, tea brown, glittering-brown or glittering-bronze etc.

## 8.5 Energy-saving Decorative Glass

Traditional glass is applied primarily for light-picking. As building doors and windows are getting larger, higher performances of heat-preservation and heat-insulation are required. Energy-saving decorative glass combines energy-saving and decorative functions together and well meets such requirements. It has gorgeous appearance and colors with special properties such as light and heat absorption, transmission and reflection. Applied to windows and exterior glass curtain walls, it significantly enhances the energy-saving effect. Presently, it has been widely applied to different luxurious buildings. Commonly-used energy-saving glass includes heat-absorbing glass, heat-reflecting glass and hollow glass etc.



### 8.5.1 Heat-absorbing Glass (or anti-solar glass)

Heat-absorbing glass is plate glass that absorbs large quantity of infrared radiation energy and retains high transmittance of visible light. It is produced in two ways: one is to add certain amount of coloring agent with heat-absorbing function to the raw material of ordinary soda-lime glass; another is to spray and coat a layer or multiple layers of thin film of metal or metal oxide on the surface of plate glass.

Heat-absorbing glass is in colors as grey, brown, blue, green, antique bronze, bronze, pink or golden yellow etc. Presently the first three colors with the thickness of 2mm, 3mm, 5mm and 6mm are mainly produced in China. Based on composition, it is classified to silicate, phosphate, photochromic heat-absorbing glass and coated glass etc. Heat-absorbing glass can be further processed to polished, tempered, laminated or insulated glass products. Compared with ordinary sheet glass, it has features as follows:

**1. Absorbing Solar Radiation Heat**

Take 6mm thick transparent float glass. In sunshine, its total transmitted heat is 84%, while that of heat-absorbing glass is 60% in the same condition. Glass in different colors and thicknesses have different absorption abilities to solar radiation heat.

**2. Absorbing visible sunlight, reducing light intensity and anti-dazzling**

**3. Certain transparency and UV absorption**

Heat-absorbing glass, with such functions as heat insulation, anti-dazzling, light-picking and decoration etc., has been widely applied to doors and windows, exterior walls of buildings, the windshields of vehicles and ships etc. It can be processed into polished, laminated, mirror and insulated glass to meet different applications. In exterior enclosing structures, it is applied to colored glass windows; in interior decoration, to mounted glass partitions and furniture decoration to increase aesthetic feelings. Colorless phosphate heat-absorbing glass is able to absorb large amount of infrared radiation heat and is applied to movie copying, movie projecting, slide projecting and color printing etc.



## 8.5.2 Heat-reflecting Glass

Heat-reflecting glass is plate glass both with better ability of heat-reflection and retaining good transmittance. It is made with methods such as pyrolysis, vacuum evaporation and cathode sputtering process to coat the glass surface with gold, silver, copper, aluminum, chromium, nickel and iron metallic or metallic oxide film, or by adopting ion exchange technique such as electric-float to exchange its metal ions with the ions in glass surface layer to create heat-reflecting coating. Heat-reflecting glass is also called mirror glass, which is in colors such as gold, tea brown, grey, purple, brown, bronze and light blue etc.

Heat-reflecting glass has higher heat-reflectance. For instance, the total reflecting heat of 6mm thick float glass is only 16%, the total reflecting heat of heat-absorbing glass is 40%, while that of heat-reflecting glass is as high as

61% in the same condition. Therefore, it is often adopted to produce insulated glass or laminated glass to enhance their heat insulation performance.

Metallic coating heat-reflecting glass is one-way perspective glass, that is, in daytime people inside room can see the outside scenery whereas people outside are not able to see the scenery inside. That is why it is widely used in constructions, mainly for producing insulated glass or laminated glass to improve their heat insulation performance. Heat-reflecting glass is mainly applied to buildings which are requied to prevent the increase of heat from solar radiation and buildings equipped with conditioners. Moreover, it is applicable to doors and windows in different structures, glass windows of auto vehicles and ships, glass curtain walls and many kinds of artistic decoration. Many types and specifications of color-coated heat-reflecting glass are produced in Ningxia glass manufacturer in China. The maximum size is 2600mm×1200mm, 3mm and 6mm thick.

### 8.5.3 Hollow Glass



As the building standard has been improved, large surface windows are adopted in buildings, which leads to the increase of energy consumption for seasonal heating and cooling. Therefore, it becomes more necessary and popular to adopt hollow glass and special functional glass in construction practice to reduce energy consumption.

The main functions of hollow glass are heat and sound insulation, so it is also called insulating glass. Generally it reduces noise by 30-40db. With the function of high frost-resistance, its frost condensing temperature is lower than that of ordinary glass by 15℃. Its heat transmission coefficient is 3.09W/($m^2 \cdot K$), whereas that of ordinary glass (3mm thick) is 7.19 W/($m^2 \cdot K$). Its heat consumption is twice as much as that of insulated glass. The service life of quality insulated glass is up to 25 years. Insulated glass is more widely used in foreign countries. In 1990, it had been applied to 90% of residential buildings in America. Some European countries even have specified that all buildings adopt insulating glass and ordinary glass be forbid to serve as window glass. In recent years, as people have increasingly noticed the importance of energy-saving of structures, the application of insulating glass becomes more and more important in our country.

With many premium properties, hollow glass has been used widely. Different components of raw material result in different performances and different application scopes of hollow glass. Colorless transparent hollow glass is mainly applied to common residential houses, rooms and trains with air-conditioners, commercial refrigerators etc.; colored hollow glass is mainly applied to buildings requiring greater architectural artistry, such as theaters, exhibition pavilions and banks etc.; special-type hollow glass should be used according to its design requirements, e.g. anti-solar insulating glass; heat-reflecting hollow glass is mostly applied to buildings in tropical regions; low-radiation hollow glass is applicable in cold areas and solar-energy projects etc.; laminated hollow glass mostly for anti-burglar showcases etc.; tempered hollow glass and wired hollow glass are for security purposes, mainly applied to glass curtain walls and places such as light-picking roofs etc.

## 8.6 Other Decorative Glass Products

### 8.6.1 Glass Mosaic



Glass Mosaic is also called glass mosaic tile. The name is derived from Latin; English name is MOSAIC. In the past, mosaic referred to mounted artwork; later on it refers to plane decoration mounted together with different colors of small blocks. Glass mosaic is a decorative material made by placing and pasting on paper glass blocks with length no greater than 45mm in different colors and shapes. Its main differences from ceramic mosaic are: glass-like texture, in opacification or semi-opacification, containing a few bubbles or un-molten grains; unit block section surface is in cuneiform, with serration or cascade wrinkles on the back for stronger cohesion.

**1. Features of Glass Mosaic**

1) Beautiful colors and glosses, elegant and appealing.

There are all colors of products such as red, orange, yellow, green, cyan, blue and purple. Users can make choices according to their needs. Starry glass mosaic made in recent years not only has ordinary mosaic features, but also reflects different colors with the changes of external light, and flickering and dazzling, it looks like shining golden stars. Different colors and patterns of mosaic can be combined and assembled to form different colorful wall paintings with impressive decorative effects.

2) Hard texture and stable performances such as heat resistance, frost resistance, weather resistance, acid and alkali resistance etc. Because its fracture section surface is more improved than that of ordinary ceramic, it can be bound more strongly and is less likely to fall off, so it has better durability. It is dust-proof and can be cleaned by natural rain, so remains new and fresh for a long period of time.

3) Low price.

Commonly the price of ceramic mosaic is 9-11 yuan/$m^2$, while glass mosaic costs only 7.50-10.00 yuan/$m^2$.

4) Convenient for construction.

Less pileup of material saves labor and increases construction efficiency.

**2. Specifications**

Common dimensions of glass mosaic are 20mm×70mm, 30mm×30 mm and 40mm×40 mm etc.; thickness ranges 4-6mm, in transparence, translucence, golden half-spot, silver spot or silver stripe etc. It is generally produced with one side smooth and wrinkles on the other for stronger cohesion in construction.



**3. Applications of Glass Mosaic**

Glass mosaic is suitable for the facing decoration of exterior walls of buildings such as hotels, hospitals, office buildings, halls and residential houses etc.

### 8.6.2 Glass Brick

Glass brick, also called extra thick glass, is classified to two types: solid brick and hollow brick. Solid glass brick is rectangle block-shape product made of molten glass mold-pressed with machine. Hollow brick is square or rectangle hollow product made in two steps: first 凹-shape(concave form) half brick is produced with box-like mold; then two blocks of 凹-shape half brick are molted or bound together into the end product. There are different patterns inside and outside of the brick. According to its internal structure, hollow brick is classified to two types: sole cavity or dual cavity. A glass string is in the middle of the dual cavity brick. Hollow glass brick has dimensions as 115mm, 145mm, 240mm and 300mm etc.; it is made of colored glass or made by painting its internal cavity with transparent coating material. It has low volume weight (800kg/$m^3$), low coefficient of heat conductivity

[0.46W/(m·K)], sufficient light transmittance coefficient (50%-60%) and diffusion coefficient (25%). Different patterns in its inner cavity scatter external light or refract it to given directions, which is a special optical property.

Glass brick is reputed as "light wall", which has features such as high strength, sound insulation, thermal insulation and waterproof etc. and is mainly applied to build transparent partitions, shower partitions, staircases, entrance halls and passages etc. and to places where transmission light, dazzling light or direct sunlight need to be controlled.

## 8.7 Nucleated Glass

Nucleated glass, reputed by scientists as the new decorative material of 21st century, is polycrystalline ceramic new material developed since the 1970s. It has the advantages of both glass and ceramic and has the physical performances that are hard to achieve by ordinary materials. Nucleated glass is made with a production technique different from that of ceramic, and its features are totally different from those of ceramic. Because the features of glass have changed when it is filled with mini-crystals inside (billions of grains per unit cubic centimeter), that is, it changes from a material in amorphous state to a glass crystalline material with metal-like internal crystalline structure. It is like gel which is neither fragile nor fragmental after hardening. It is a kind of transparent or non-transparent inorganic material, so called nucleated glass, also named as mini-crystal glass, glass-ceramic or pyroceramic.



Nucleated glass is harder than high carbon steel and lighter than aluminum; its mechanical strength is 6 times that of ordinary glass; its wear resistance is not less than that of cast stone; it has good thermal stability (no breakage when heated to 900℃ or sudden immersed to 5℃ cold water); its electric insulation performance is close to that of radio-ceramic; with the same chemical stability as that of borosilicate glass, it is acid and alkali resistant. Nucleated glass board is in rich colors and without color difference; with soft and bright gloss, the appearance looks very similar to that of natural stone; moreover, it is better than granite in aspects such as mechanical performance index, chemical stability, durability and surface smoothness and cleanness etc.

## 8.7.1 Features of Nucleated Glass

**1. Beautiful Colors and Glosses and Unique Textures**

Nucleated glass facing material can be produced into different colors, tones or patterns through technique controlling. And different surface processing creates different textural effects. The surface of polished nucleated glass is far smoother than that of natural stone and its beautiful luster makes buildings more luxurious and magnificent. Obscure or matt nucleated glass creates natural and solid, decent and solemn sensations for buildings. Therefore, nucleated glass well meets the designer's requirements in color, gloss and texture.

**2. Even Color Tone**

It is difficult for natural marble to avoid apparent color differences, which is its innate fault. Whereas nucleated glass is easy to achieve even colors and create more brilliant decorative effects. Especially the effects of elegant pure white nucleated glass are almost impossible for natural stone to achieve.



**3. Permanent Water Resistance and Stain-resistance**

After rain and snow, some wetting traces are likely to remain on the wall surfaces decorated with natural stone and won't disappear after months or even longer period of time. This happens because the natural stone has certain extent of water absorption, which allows the intrusion of water and alkali, even mud slurry. Thus affects the primary color and gloss and even causes stain and moist on the stone surface. Whereas nucleate glass has the innate nature of glass that keeps itself free from water, so it is less likely to get stained. Its gorgeous appearance is not only free from rain and snow intrusion, but on the contrary, becomes cleaner and more splendid after being rinsed with such natural water, which enables the building to retain the magnificent outlook for a long time. As being easy to clean, in consideration of structure maintenance and renovation, it is really a cost cutter.

**4. Advanced Mechanical Performances and Chemical Stability**

Nucleated glass is made from inorganic materials through high temperature refining; its structure is even, fine and dense, and is better than natural stone in aspects such as hardness, wear resistance, acid and alkali resistance etc.; even exposed to wind and rain as well as polluted air, it is less likely to deteriorate or fade.

**5. High Safety in Fragmentation**

There are many types of stone-imitation nucleated glass. There is a kind of nucleated glass with marble-like gritty texture internal structure made by a manufacturer in Tianjin, which cracks in the same way as marble even when receiving strong impacts——only Y-shape crack is caused and the crack is blunt.

**6. High Environmental Protection Performance**

Nucleated glass contains no radioactive substance, which ensures no radioactive pollution to the environment. Though polished nucleated glass is similar to glass in smoothness and cleanness, it creates natural soft and mild texture without any light pollution whichever angle light illuminates from.



## 8.7.2 Nucleated Glass Products, Such as Nucleated Glass Decorative panel

Nucleated glass decorative panel has many wonderful features, for instance, it is glass product, but not fragile or broken; its surface is of the texture of natural stone but without color differences; it is as dense as large-dimension polished tile, applicable for flooring and wall hanging, but is less likely to fade like the glazed surface of ceramic tile; it is in all colors with beautiful appearance just like aluminum composite panel, but different from the later, it prevents oxidation or corrosion. It is these special unique performances such as beautiful color gloss, brilliant appearance, permanent wear resistance, permanent unfading and corrosion resistance that make it one of the advanced decorative materials just like decorative glass, natural stone and metal plate. Nucleated glass decorative panel is similar to natural stone in appearance. Crystals form soft patterns on the surface like a picture of flowing cloud. Because it is a glass product, it has some extent of light-transmittance; especially to light-color panel, a mild lamination appears on its whole decorative front surface when light shines from its backside. Like stone, nucleated glass decorative panel is available for exterior wall dry-hanging, thinner than stone by7-12mm; for flooring and for producing into different irregular shapes. It is also applied to suspended ceilings and roofs, which is beyond stone's application because stone has innate cracks and is likely to be ruptured under certain pressure.

### 8.7.3 Production of Nucleated Glass

There are two production techniques for nucleated glass: pressing method and sintering method. Pressing method is to melt raw meal to molten glass, then press it and cut into plates after heat processing. Sintering method is to melt raw meal to molten glass and suddenly cool it down to crushed aggregates, then put them in mold and flatten the surface, finally put the mold inside the kiln for heat processing. Each method has its own assets and disadvantages: the former is favorable for continual line production with low heat-consumption, but ends with single type product; the later ends with different types of product, but the technique is complicated with high requirements for mold, and the main fault is that there are more air bubbles in the product.



### 8.7.4 Applications of Nucleated Glass and Its Products

There is a growing demand and higher requirements for advanced decorative materials in modern building industry. Because traditional decorative materials such as marble and granite have disadvantages such as weak corrosion resistance and weathering resistance, they are no longer suitable to serve as interior and exterior wall decorative materials. Many interior and exterior walls decorated with materials such as granite, diabase and black shale are found to coexist with uranium and thorium etc. and bring about excessive radioactivity. Without such disadvantages, nucleated glass is suitable to serve as decorative material for structures such as advanced metros, large buildings, airports, bus terminals, hotels and large restaurants etc.

## 8.8 Future Development of Building Decorative Glass

### 8.8.1 Multifunctional Composite Decorative Glass

Material should not limit to sole function. Combining multiple functions is able to maximize the utilization of resources and to meet the requirements in various aspects. For instance, coated hollow glass has all functions of sunlight shading, thermal reservation and decoration, which saves 18% more energy than ordinary hollow glass; hollow glass processed from glass coated with photolyzable film not only has the functions of ordinary hollow glass such as heat preservation, sound insulation and frost removing, but also has the function of dirt removing, namely, "self-cleaning" etc.

### 8.8.2 Eco-material Type Decorative Glass

It is a kind of glass material that achieves the ideal service performances or decoration function with features such as less consumption of resource and energy, less pollution to ecological environment, high efficiency of recycling utilization, harmonizing and coexisting with environment. For instance, in sunlight, glass coated with a thin film is able to catalyze and degrade the organic pollution substances from industrial waste gas and vehicle exhausted gas and to restrain and kill microorganism in the environment, thus the dust and oil dirt will be automatically removed from the glass surface to meet the requirements of stain removing or self-cleaning. Such kind of self-cleaning (stain-resistant) glass is applicable to places such as doors, windows, exterior walls and kitchens, especially to interior walls, doors and windows of washrooms and sanitary wares to refrain and kill the surface adhesive microorganism, mildew spots and stains. It is not only used in monolayer, but also made into hollow glass or glass curtain walls. This is how building glass will develop in the future.



### 8.8.3 Intelligent (Smart) Decorative Glass

With the booming of intelligent buildings, such functions of building decorative materials are required as feeling, processing and executing (drive) to play the role of auto-diagnosis, auto-adapting and auto-repairing (auto-restoring), in consideration of communication, office and management automation. Presently the development of intelligent glass window and intelligent material falls behind, only at elementary level. More intelligent building decorative glass will be researched and developed in the future.

## Case of Materials Selection

First Domestic Twisted Surface Glass Curtain Wall.

Adopting advanced structural design and new processing technique, the first domestic warped surface glass curtain wall was completed in Dongguan Library, Dongguan, Guangdong province. Different from any other previous design of exterior decoration of domestic buildings, the façade of Dongguan Library is an irregular curved surface, which fundamentally breaks the technological mode for curtain walls that the arraying of dot, line and surface is in straight or arc line. The technology of warped surface curtain wall has not only set up a brand new type of curtain wall, but also largely enriches the creation space for personalized model designs of domestic building. Meanwhile it has spotlighted the importance of glass in building decoration projects. The whole warped surface curtain wall is made up of five parts: western façade, southern entrance, northern entrance and two interior warped surface curtain walls. Because there was no such type of curtain wall for technological reference, the design principle of warped surface curtain wall of Cam-Art Center in Stuttgart, Germany was introduced and technological research and creation activities had been carried out during the whole process of construction organization and design to ensure the installation accuracy, to avoid structural discrepancy and to prevent glass crack on the same surface and meanwhile to keep the fragile flat glass twisting.



## Summary

Glass is widely used in modern building decoration and renovation. This chapter introduces the compositions, basic performances, types and applications of glass. briefly addresses new types of building decorative glass such as nucleated glass and their future development. The chapter also includes the classifications, dimensions, grades and constructional applications of plate glass, safety glass, new-type glass and glass brick. This chapter mainly focuses on the performances and applications of building decorative glass such as glazed glass, mirror glass, combined-pattern glass, sandblasted glass, colored glass, colored coating glass, laser glass, sandblasted pattern glass, carved glass, screen painting glass, glue -etched glass, crystallized glass, welding glass and colored split-pattern glass etc. The service function of glass is highlighted and its selection method and constructional applications are emphasized.

## Questions for Reviewing and Thinking

8.1 According to the regulations in "Building Safety Glass Management Regulations", 8 of the places where safety glass must be applied are involved in interior decoration and renovation, including roofs (inc. skylight and light-picking roof), suspending ceilings; stairs, balconies, terrace corridors, shower partitions and bathtubs in bathrooms and the doors of bathrooms. Why?

8.2 What are high quality energy-saving types of glass?

8.3 How is tempered glass produced? Where is it applied to? What must be noticed in application?

8.4 What is nucleated glass? What main performances does it have? What kind of decoration projects is it applied to?

8.5 What types of decorative glass are there? What kind of decoration projects is each of them suitable for?

8.6 After the air-tight sealed edge becomes invalid, hollow glass loses its functions. It is neither incapable of energy-saving, nor being clearly seen through in dewy weather. What are the main factors affecting the air-tight sealing of hollow glass? What measures should be taken to prevent such phenomenon?

8.7 What are the main factors leading to the breakage of building glass?

# 9

# Metal Decorative Materials

## 9.1 Building Decorative Steel and Products

### 9.1.1 Introduction of Building Decorative Steel

There is a long history of metal as a building decorative material. It is generally classified to two types: ferrous metal and non-ferrous metal. The basic components of ferrous metal are iron and iron alloy, and non-ferrous metal is the generic term of other metals (such as aluminum, copper, lead, tin and zinc as well as other alloys etc.) except iron. Steel is iron-carbon alloy, which is produced by smelting the iron made from iron ore. The difference between steel and iron is carbon content, which in steel is 0.04%-2.11%. Different percentages of carbon content result in different performances between iron and steel.

Steel is an important material for building construction and decoration. In construction practice, iron ore is smelted to steel ingot, then steel ingot is processed, i.e. rolled and forged, to different types of sectional material, such as angles, I-beams, channels, bars, pipes, plates and wires etc.

Steel has such features as uniformity of quality, tensile resistance, crushing resistance, impact resistance and anti-fatigue etc., and is able to bear certain elastic deformation and plastic deformation, also is available for such processes as welding, riveting, cutting and bending. Therefore, steel section and its products are not only applicable to serve as structural material, but also used as decorative skeletal material for the exterior walls, roofs and different suspended ceiling keels of buildings. Steel products (stainless steel, color steel plate and profiled steel sheet etc.) are endowed with different colors and textures and become advanced decorative materials for interior and exterior decoration of modern buildings.

## 1. Classifications of Building Decorative Steel

(1) Classified Based on Refining Method

1) Based on furnace types, it is classified to open-hearth steel, converter steel (oxygen converter steel, pneumatic steel) and electric steel;

2) Based on degrees of de-oxidation, it is classified to rimmed steel, killed steel, semi-killed steel and special killed steel.

(2) Classified Based on Chemical Compositions

1) Carbon steel: Low carbon steel (carbon content less than 0.25%)
Medium carbon steel (carbon content 0.25%-0.60%);
High carbon steel (carbon content more than 0.60%).

2) Alloy steel: Low alloy steel (alloying element total content less than 5%);
Medium alloy steel (alloying element total content 5%-10%);
High alloy steel (alloying element total content more than 10%).

Steel not only contains iron, but also contains minor elements such as carbon, silicon, manganese, sulfur and phosphor etc. These minor elements have a great influence on the performances of the steel. Steel with less carbon has lower strength but good plasticity and impact toughness, so it is easy for processing; Steel with more carbon has higher strength but less plasticity, thus its brittleness increases, so it is not easy for processing. Silicon and manganese are able to enhance the strength value of steel without decreasing its plasticity and toughness. Sulfur and phosphor will make steel hot-short or cold-short brittle respectively. In production practice, it is necessary to control the content of alloy elements in steel according to actual requirements. In steel selection, the composition and content of different elements in steel should be decided and controlled based on different applications to meet different requirements for the performance indexes of the steel.

(3) Classified Based on Applications

1) Building steel;

2) Structural steel (carbon steel and alloy steel);

3) Tool steel (carbon tool steel, alloy tool steel and high speed tool steel);

4) Special property steel (stainless steel, acid-resistant steel and heat-resistant steel etc.).

## 2. Technical Performances of Building Steel

The mechanical properties of building steel include tensile strength, cold bending and impact toughness etc.

### 3. Standard and Selection of Building Decoration Steel

(1) Ordinary Carbon Steel

Ordinary carbon steel is the short term of ordinary carbon structural steel. It needs simpler refining technique, but has better workability and is at low price, and its performances meet the requirements of general engineering structures, so it is adopted more often and widely. Commonly-used structural steel such as rounds, squares, angles and channels as well as plates are ordinary carbon steel.

(2) Common Low Alloy Steel

Common low alloy steel is the short term of common low alloy structural steel. It is made by adding a little amount of alloy elements (total content no bigger than 5%) to steel. It not only has high strength, good wear resistance and corrosion resistance, but also costs less. It is more suitable for wide-span structures and especially saves more steel than ordinary carbon steel does, soit is widely used in construction projects.



(3) Types of Building Steel

Commonly-used building steel mainly includes bars, wires, strands, shapes (rounds, squares, flats, hexagons, angles, I-beams and channels etc.), plates and pipes etc.

1) Steel Bar.

Based on steel type, steel bar is classified to two types: ordinary carbon steel and common low alloy steel. Based on shape, it is classified to plain round bar and deformed steel bar (screw-thread, herringbone-shape and crescent etc.).

2) Steel Wire.

Steel wire is made by cold drawing 6-10mm steel bar into wire with a wiredrawing machine. Steel wire is classified to two types: cold-drawn low-carbon wire and carbon steel wire.

3) Steel Strand.

Steel strand is made by twisting and stranding seven pieces of 2.5-5.0mm high tensile carbon steel wires to remove their internal stress. With advantages such as high strength, good flexibility, stable quality, coil-unit supply and no joint pieces etc. it is mainly used in wide-span bridges, roads, flyovers and large house structures etc.

4) Formed Steel

Formed steel has different sectional forms made by processing steel ingot under heating condition. There are rounds, squares, flats, hexagons, angles, I-bars and channels etc. Commonly-used types are shown in Figure 9.1.

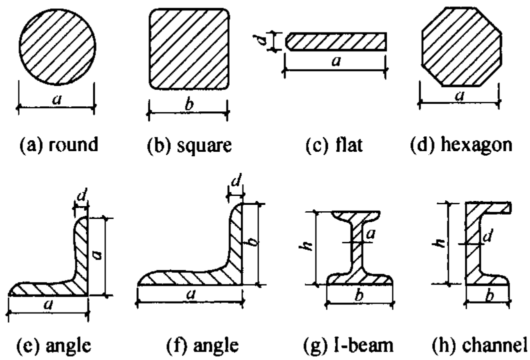



Figure 9.1 Sectional Shapes of Profiled Steel



① Round steel. Diameter "$\phi$" stands for its specification, for instance, $\phi 40$ stands for round steel with diameter 40mm. It is mainly adopted to produce steel bars, rivets, bolts and different machinery parts etc.

② Square Steel. Side length $b$ (mm) stands for its specification. Square steel is mainly applied to different steel structures, bolts, nuts, steel bars as well as different machinery parts etc.

③ Flat Steel. Its sectional form is rectangle. Its specification is showed by its thickness ($a$) mm× width ($b$) mm. Commonly it serves as thin plates, tools, machinery parts, bridge-girders and building trusses etc.; In iron-art decoration projects, it is usually processed into iron-art fittings by bending or twisting etc. It is also applicable for making decorative products such as zipper doors and fences etc.

④ Hexagon Steel. Its specification is showed by the diameter (mm) of its inscribed circle, i.e. the distance between opposite sides "$a$", and it is mainly used to produce nuts, steel drills and crane crowbars etc.

⑤ Angle Steel. It is also called angle iron and is classified to two types: equal angle steel and unequal angle steel. The two sides of equal angle steel are perpendicular and equal. Side width (mm) ×side thickness (mm) stands for its specification, and the model number is decided based on the centimeters of its side width. For instance, No. 4 angle steel means its side length is 4cm, marked as "No. L4".

The two sides of unequal angle steel are perpendicular but unequal. Its specification is represented by long-side width (mm) × short-side width (mm) × thickness (mm). The model number is showed by the ratio of long-side width to short-side width. For instance, unequal angle steel with long-side width as 6.3cm and short-side width as 4cm, customarily it is marked as "No. L6. 3/4".

Angle steel is the most basic steel for structures and is available for solely use or combination. It is widely applied to houses, pylons, machinery components, decorative frameworks and components etc.

⑥ I-shaped beam. It is composed of two flanges and one abdominal plate. Its specification is represented by the height $h$ (mm)× the thickness $d$ (mm) of its abdominal plate. The model number is represented by the centimeters of the height of its abdominal plate. For instance, No. 10 I-beam stands for 10cm height I-steel, marked as "I 10". If I-beam is of the same height and width but with different thickness, it is marked behind the model number such as "I 10a", "I 10b" and "I 10c".

I-shaped beam is widely applied to factory buildings, bridge-girders, ship-crafts as well as structural components etc.

⑦ Channel Steel. Its specification is represented with the same method as that for I-shaped beam, for instance, "channel 120×53×5" stands for channel steel with abdominal plate height 120mm, flange-width 53mm and abdominal plate thickness 5mm.

5) Steel Plate. According to thickness, steel plate is classified to thin steel plate (thickness≤4mm), medium thick steel plate (thickness 4.5-6.0mm) and extra thick steel plate (thickness>6.0mm); according to surface shape, it is classified to flat and patterned plates. Steel plate is generally supplied in sheet or coil. The specification of the sheet is represented by thickness × width × length; coil by thickness × width.

There are two types of thin steel plate: galvanized (named as galvanized sheet) and non-galvanized (named as black sheet). With strong rust-resistance, galvanized sheet is suitable to serve as rainspouts and ventilation pipes etc. Black sheet is largely adopted as roof boards, accessories, stages and passages etc. The plate is also applied to make water tanks, storage bins and storage bunkers etc.

Medium thick and extra-thick steel plates are mainly applied to structural components and decorative components etc.

6) Steel Pipe. According to producing method, steel pipe is classified to seamless and welded steel pipes; according to surface processing status, to galvanized and non-galvanized pipes; according to pipe-wall thickness, to ordinary and thick steel pipes; according to sectional form, to round and square pipes etc.

## 9.1.2 Building Decorative Steel Products

In modern building decoration, metal decorative plate is more and more widely adopted. This is not only because the surface of metal plate shows beautiful and good decorative effect after processing, but also because the plate has such assets as light weight, good shock-resistance, easy processing, quick installation and easy molding, moreover, the sectional shape can be changed to comply with different design needs, easily to meet the modeling requirements. Due to the advantages of metal decorative plate such as wear resistance, durability and corrosion resistance, fire resistance and unique decorative effect, it is widely applied to structures such as hotels, restaurants, ballrooms, exhibitions pavilions and exhibition centers etc., as well as interior decoration and renovation (including façades, entrance halls, awnings, walls, columns, ceilings, local partitions and modeling surfaces etc.)



According to compositions, metal decorative plate is classified to two types: mono-material and composite material plates. There is only one material in mono-material plate, such as steel pate, aluminum plate and copper plate as well as corrosion resistant plate etc.; composite material plate is composed of two or more types of material, such as aluminum alloy plate, enamel steel plate, lacquer board, galvanized plate, color plastic film plate and metal sandwich plate etc. According to the shape of plate surface, it is classified to polished flat plate, flat patterned plate, contour plate, corrugated plate and cubic box plate etc. Steel products adopted in decoration projects mainly are stainless steel, color coated steel plates, color contour plates, steel doors and windows as well as metal frames etc.

### 1. Stainless steel

Stainless steel is defined as the alloy steel added with elements such as chromium, manganese and nickel etc. It contains more than 12% of chromium, and also contains other alloy elements. Besides the properties of ordinary steel, it has excellent corrosion resistance, because of which its surface is smooth and easy to clean. Stainless steel is produced into plates, sections and pipes etc., among which plates are the mostly used. Moreover, it is largely adopted in the production of metal wares, water and heating pieces and curtain-wall joint pieces, etc. Therefore, it is widely applied to the decoration projects of many public buildings (such as office buildings, advanced apartments, commercial buildings and schools etc.)

According to the surface glossiness and its reflecting rate, decorative stainless steel plate is classified to mirror plate and matt plate; according to the color, classified to ordinary and color plates; according to the surface shape, to flat plate and embossed plate etc. The mostly used in building decoration projects is ordinary stainless steel plate.

Several types of commonly-used stainless steel for decoration projects are 1Crl7Ni8, lCrl7Ni9 and 1crl8Nil7Ti etc. The first number of the code stands for the average carbon content in the steel. If carbon content is less than 0.03% or 0.08%, the steel code starts with "00" or "0". The content of alloy element is still presented with the percentage behind its element symbol.

(1) Ordinary stainless Steel

The length of ordinary stainless steel plate, including mirror plate (polished surface), frosted plate (matt surface) and embossed plate, is 1830mm, 2440mm, 3000mm, 3600mm, 4000mm, 5000mm and 6000mm etc., width is 900-1200mm, thickness is 0.35-2.0mm. It is suitable for the surface decoration of walls and columns of shops and hotels, and for the production of elevator doors, door trims, different decorative treadle bars and containers.

1) Mirror plate: Smooth and bright, its reflectance to light illumination is more than 90%, and is able to reflect images but not as clear as glass mirror. Such kind of plate is commonly used at areas of columns and walls requiring higher reflecting rate to light.

2) Matt plate: Stainless plate with reflecting rate less than 50% is called matt plate, which reflects mild and not glaring light and creates gentle art effect in interior decoration. Matt plate is classified to many grades according to different reflecting rates. The reflecting rate of commonly-used steel plate ranges 24%-28%, the maximum value is 8%, which is a bit higher than that of wall paper.

3) Embossed steel plate: There is not only luster but also 3d relief decoration on the surface. It is produced through rolling, grinding, erosion or carving (etching). Generally erosion or carving depth is 0.015-0.5mm. Before

erosion and carving, it requires routine grinding and polishing, which is labor consuming and costly.

There are two types of stainless steel tube: square and round, which are produced to armrests, handrails, stainless steel security doors, isolation fences and flagstaffs etc. Stainless formed steel is used to produce counters and different beads etc. It is also applied to make signboards, ceilings, carriage panels and automatic doors, frameless glass doors and stainless steel doors etc.

(2) Color Stainless Steel

1) Features of Color Stainless Steel Plate

Color stainless steel plate is made by carrying out technical and artistic processes on the surface of stainless steel plate to create different beautiful colors. Wall surface decorated with color stainless steel plates becomes solid and durable, looks beautiful and fresh, and shows pretty strong modern sensation.

Color stainless steel is made by processing ordinary stainless steel plate with chemical coating method. There are many colors such as blue, grey, purple, red, green, golden yellow (titanium plate) and orange, all with high glossiness. The tone of color and luster changes with different illuminating angles. At 200℃ or bending to 180℃, the colored surface layer doesn't change or fall off; the color itself is durable and keeps no fading. Color stainless steel is also better in salt-fog resistance than ordinary stainless steel and its wear resistance and scratch resistance are equivalent to those of foil coating gild.



2) Specifications and Performances of Color Stainless Steel Plate

Color stainless steel plates are usually 0.2-2.0mm thick, its length and width are the same as those of ordinary stainless steel plate, and it can also be processed according to practical needs. Color stainless steel plate is available as elevator cage panels, carriage panels, wall panels of halls, ceilings, building decoration and signboards etc. in advanced buildings. The reflecting rate of commonly-used stainless steel is 24%-28%, the minimum is 8%, which is a bit higher than that of wall paper.

## 2. Color Coating Steel Plate

Color coating steel plate is also called colored steel plate, colored plate or plastic metal plate, which is made in this way: adopt cold-rolled plate or galvanized plate as base, after continual treatments of chemical priming and paint coating on the surface, cover the surface with one or multiple layers of high-performance coating, polyvinyl chloride plastic film or other resin surface coatings. There are inorganic, organic and composite coatings etc., among which organic coating is mostly used.

Color coating steel plate has the performances of both steel plate and surface coating, which enhances the corrosion resistance while keeping the strength and stiffness of steel plate. It has such processability as to be cut, bent, drilled, riveted or edge-curled etc., and also has strong insulation and resistance to temperature-change, corrosion and wear. Moreover, with grain s and textures, its surface is fresh and beautiful in colors such as red, green, milky white, brown and blue etc. It is highly decorative. The performances of color coating steel plates and steel strips are given in Table 9.1.

**Table 9.1 Performances of Color Coating Steel Plate and Steel Strip (GB/T 12754—1991)**

<table>
<tr><th colspan="2">Plate Type</th><th rowspan="2">Coating thickness (μm)</th><th colspan="3">Glossiness (%)</th><th rowspan="2">Pencil hardness</th><th colspan="2">Bending</th><th colspan="2">Reverse impact (J)</th><th rowspan="2">Salt-fog resistance (h)</th></tr>
<tr><th>Application</th><th>Coating Type</th><th>high</th><th>medium</th><th>low</th><th>Thickness ≤0.8 mm 180℃, T*</th><th>Thickness >0.8mm</th><th>Thickness ≤0.8mm</th><th>Thickness >0.8mm</th></tr>
<tr><td rowspan="4">Exterior Use</td><td>Exterior use polyester</td><td rowspan="3">≥20</td><td rowspan="3">>70</td><td rowspan="8">40-70</td><td rowspan="8"><40</td><td rowspan="3">≥HB</td><td>≤8</td><td rowspan="8">90°</td><td>≥6</td><td>≥9</td><td>≥500</td></tr>
<tr><td>Silicon modified polyester</td><td rowspan="2">≤10</td><td colspan="2" rowspan="2">≥4</td><td>≥750</td></tr>
<tr><td>Exterior use acrylic acid</td><td>≥500</td></tr>
<tr><td>Plastisol</td><td>≥100</td><td>-</td><td>-</td><td>0</td><td colspan="2">≥9</td><td>≥1000</td></tr>
<tr><td rowspan="4">Interior Use</td><td>Interior use polyester</td><td rowspan="2">≥20</td><td rowspan="2">>70</td><td rowspan="2">≥HB</td><td rowspan="2">≤8</td><td>≥6</td><td>≥9</td><td rowspan="2">≥250</td></tr>
<tr><td>Interior use acrylic acid</td><td colspan="2">≥4</td></tr>
<tr><td>Organosol</td><td>≥30</td><td>-</td><td>-</td><td>≤2</td><td colspan="2" rowspan="2">≥9</td><td>≥500</td></tr>
<tr><td>Plastisol</td><td>≥100</td><td>-</td><td>-</td><td>0</td><td>≥1000</td></tr>
</table>

Continued

| Plate Type | | Coating thickness (μm) | Glossiness (%) | | | Pencil hardness | Bending | | Reverse impact (J) | | Salt-fog resistance (h) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Application | Coating Type | | high | medium | low | | Thickness ≤0.8 mm 180℃, T* | Thickness >0.8mm | Thickness ≤0.8mm | Thickness >0.8mm | |
| Household Electrical Appliance | Interior use polyester | ≥20 | >70 | | | ≥HB | ≤4 | - | ≥6 | - | ≥200 |

Note: * stands for the quantity of base layers held in the bending-area.

Color coating steel plate is generally 1800mm and 2000mm long, 450mm, 500mm and 1000mm wide, and 0.35mm, 0.4mm, 0.5mm, 0.6mm, 0.7mm, 0.8mm, 1.0mm, 1.5mm and 2.0mm thick. It is suitable to serve as the base plate of interior and exterior wall panels, suspending ceilings, roofing boards and storefront signboards in different buildings, also serves as exhaust tubes, ventilation ducts and other resemble items and equipment jackets requiring corrosion resistance.

When color coating steel plate is applied to building enclosing structures and roofing boards, usually it is combined with insulating materials to produce composite board such as rock wool plate, polystyrene foam board and polyurethane foam board to meet the requirements of thermal preservation and insulation as well as create good decorative effects. Its thermal preservation and insulation performances are better than those of common brick wall. Chinese Antarctic Great Wall Station was constructed and decorated with such kind of thermal insulation sandwich plate.



### 3. Color Profiled Steel Sheet

It's produced by rolling and cold bending different kinds of thin steel plate such as cold-rolled sheet, galvanized sheet and colored coating plate. Its sectional shape is in V form, U form, trapezium or waveform resembling to the above forms. It is called profiled steel sheet (shortened as profiled sheet).

As specified in "*Building Profiled Steel Sheet*" (GB/T12755-1991), no crack that can be seen with a 10-fold magnifier is allowed on the surface. As to profiled sheet made of galvanized and colored coating steel sheet, no defect such as reaming layer, fall-off of coating and clamping damage which affects its service performances is allowed on the surface.

There are 27 different models of profiled steel sheet. Its wave pitch modulus is 50mm, 100mm, 150mm, 200mm, 250mm and 300mm (with exception); wave height is 21mm, 28mm, 35mm, 38mm, 51mm, 70mm, 75mm, 130mm and 173mm; the dimensional series of actual covering width is 300mm, 450mm, 600mm, 750mm, 900mm and 1000mm (with exception). The model of profiled steel sheet (YX) is marked in this sequence: wave height, wave pitch and actual covering width, for instance, YX38-175-700 stands for profiled steel sheet with wave height 38mm, wave pitch 175mm and actual covering width 700mm. Several models of profiled steel sheet are shown in Figure 9.2.

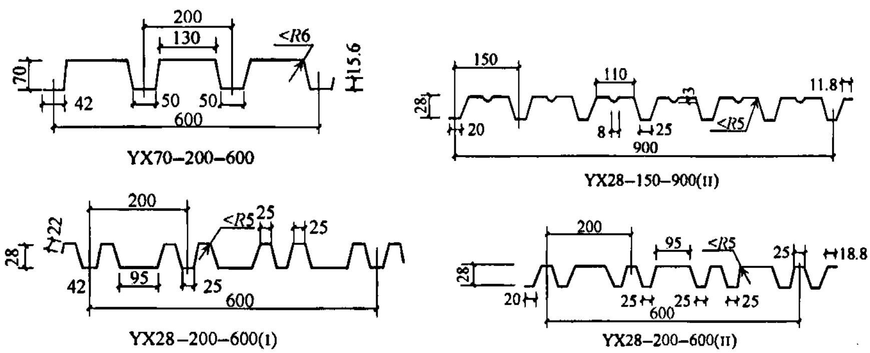



Figure 9.2 Models of Profiled Steel Sheet for Building and Decoration



Profiled steel sheet has such features as light weight (0.5-1.2mm thick), flat and solid wave-form, beautiful and fresh color, elegant and attractive modeling, durable and strong corrosion-resistant coating, high shock-resistance, simple processing and easy application etc. Therefore, it is widely applied to the decoration of interior and exterior walls, roofs and suspended ceilings in industrial and residential buildings as well as public buildings, also serves as face panels for lightweight sandwich plates etc.

## 4. Galvanized Steel Stud

It is a framework material made by rolling and stamping galvanized steel sheet and thin cold-rolled annealed steel coiled strip with a cold-bending machine. It has features such as light self-weight, high stiffness, high fire-resistance and impact-resistance, shock-resistance, easy and convenient processing and installation etc. Finishing material made up of galvanized steel stud and thistle board not only meets the requirement of fire resistance, but also is convenient for construction and suitable for massive assembling and construction. Moreover, it allows other facing decorations on its surface layer, such as coating or papering etc. Metal frame has gradually replaced traditional wooden framework material in interior suspended ceilings and partitions, and is widely used in decoration projects.

According to material, metal framework is classified to galvanized steel stud and aluminum alloy stud; according to different application areas, galvanized steel stud is classified to partition wall used and suspended ceiling used etc.

(1) Partition Galvanized Steel Stud (See Figure 9.3)

According to application, partition galvanized steel stud is classified to: along-top stud, along-floor stud, vertical stud, reinforced stud, thorough cross-stay stud and accessories etc; according to shape, classified to U- stud and C- stud etc.



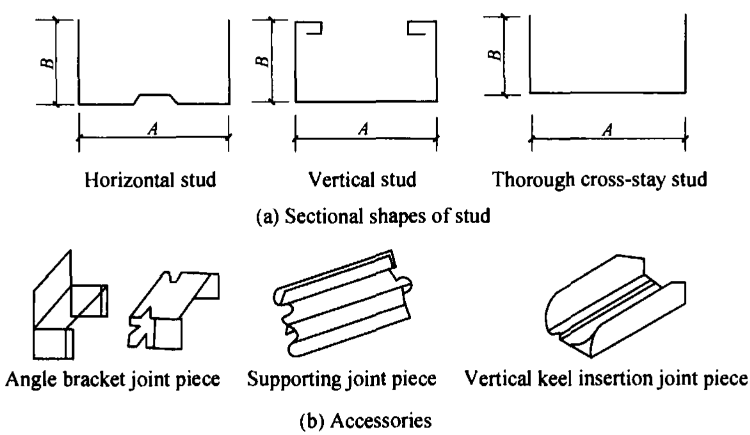



Figure 9.3 Partition Galvanized Steel Stud

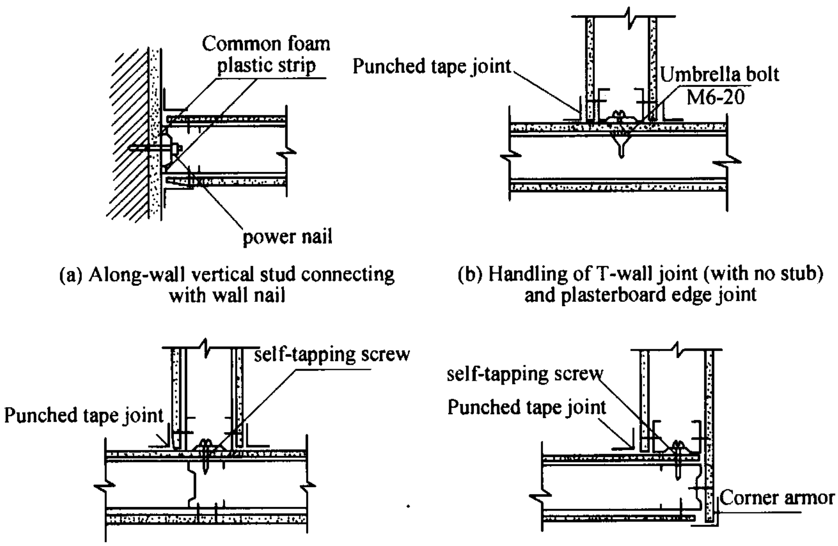
According to national standard "*Building Galvanized Steel Stud*" (GB/T 11981-2001), partition galvanized steel stud mainly has these series: Q50, Q75, Q100 and Q150. Q50 series is applied to partitions with storey height less than 3.5m; Q75 series is for partitions with storey height ranging 3.5-6.0m; Q100 and above series is for partitions with storey height more than 6.0m. The names, product codes, specifications, applications and producers of galvanized steel studs are given in Table 9.2.

**Table 9.2 Names, Product Codes, Specifications, Application Scopes and Producers of Partition Studs**

| Name | Product code | Mark | Specification (mm) | | | Steel consumption (kg/m) | Application scope | Producer |
|---|---|---|---|---|---|---|---|---|
| | | | Width | Height | Thickness | | | |
| Along-top and along-floor stud | Q50 | QU50×40×0.8 | 50 | 40 | 0.8 | 0.82 | Storey height less than 3.5m | Beijing Building Light Steel Structure Factory |
| Vertical keel | | QC50×45×0.8 | 50 | 45 | 0.8 | 1.12 | | |
| Thorough cross-stay stud | | QU50×12×1.2 | 50 | 12 | 1.2 | 0.41 | | |
| Reinforced stud | | QU50×40×1.5 | 50 | 40 | 1.5 | 1.5 | | |
| Along-top and along-floor stud | Q75 | QU77×40×0.8 | 77 | 40 | 0.8 | 1.0 | Storey height 3.5-6.0m | |
| Vertical stud | | QC75×45×0.8 | 75 | 45 | 0.8 | 1.26 | Storey height 3.5-6.0m | |
| | | QC75×50×0.5 | 75 | 50 | 0.5 | 0.79 | Storey height less than 3.5m | |
| Thorough cross-stay stud | | QU38×12×1.2 | 38 | 12 | 1.2 | 0.58 | Storey height 3.5-6.0m | |
| Reinforced stud | | QU75×40×1.5 | 75 | 40 | 1.5 | 1.77 | | |
| Along-top and along-floor stud | Q100 | QU102×40×0.5 | 102 | 40 | 0.5 | 1.13 | Storey height less than 6.0m | |
| Vertical keel | | QC100×45×0.8 | 100 | 45 | 0.8 | 1.43 | | |
| Thorough cross-stay stud | | QU38×12×1.2 | 38 | 12 | 1.2 | 0.58 | | |
| Reinforced stud | | QU100×40×1.5 | 100 | 40 | 1.5 | 2.06 | | |

Partition galvanized steel stud is mainly applicable for the partition walls and corridor walls in office buildings, restaurants, hospitals, entertainment places and theaters, especially is suitable for the partitions of multi-storey buildings and additional stories as well as for the light-weight partitions of multi-storey factory buildings and clean workshops etc. After combined to each other with relevant joint pieces, partition galvanized steel studs form a wall framework. With both sides covered with different faceplates (such as plaster board, asbestos cement panel or colored profile steel sheet etc.) and facing layers (such as wallpaper, wood faceplate or paint coating etc.), partitions with different properties are created.

The joining forms of galvanized steel stud and faceplate are shown in Figure 9.4.




(a) Along-wall vertical stud connecting with wall nail

(b) Handling of T-wall joint (with no stub) and plasterboard edge joint

(c) Handling of T-wall joint (with stub) and plasterboard edge joint

(d) The joint of right-angle corner of partition wall

Figure 9.4 Joining forms of Partition Galvanized Steel Stud and Faceplate



(2) Suspended Ceiling Galvanized Steel Stud

According to load supporting capacity, suspended ceiling galvanized steel stud is classified to accessible and inaccessible studs; according to the sectional shape of section material, classified to U-stud, C- stud and L- stud; according to applications, to main stud (also named bearing stud), sub- stud (medium, small stud also called cladding stud) and joint accessories, refer to Figure 9.5.

Suspended ceiling galvanized steel stud mainly includes four series, D38, D45, D50 and D60; as to the product codes, specifications and producers, refer to Table 9.3.

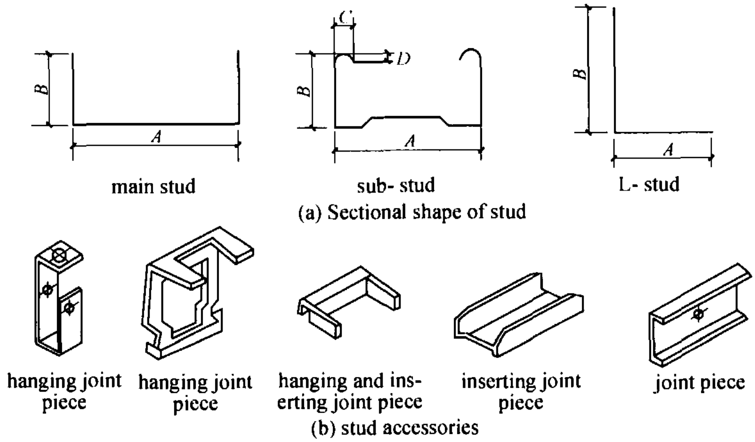



Figure 9.5 Suspended Ceiling Galvanized Steel Stud

**Table 9.3 Product Codes, Specifications and Producers of Suspended Ceiling Galvanized Steel Studs**

| Name | Product code | Specification (mm) | | | Steel consumption (kg/m) | Spacing of suspension centers (mm) | Type of suspension ceiling | Producer |
|---|---|---|---|---|---|---|---|---|
| | | Width | Height | Thickness | | | | |
| Main stud | D38 | 38 | 12 | 1.2 | 0.56 | 900-1200 | Inaccessible | Beijing Building Light Steel Structure Fatory |
| | D50 | 50 | 15 | 1.2 | 0.92 | 1200 | Accessible | |
| | D60 | 60 | 30 | 1.5 | 1.53 | 1500 | Accessible | |
| Sub- stud | D25 | 25 | 19 | 0.5 | 0.13 | | | |
| | D50 | 50 | 19 | 0.5 | 0.41 | | | |
| L- stud | D35 | 35 | 35 | 1.2 | 0.46 | | | |
| T16-40 unexposed suspended galvanized steel stud | D-1 suspended ceiling | 16 | 40 | | $0.9kg/m^2$ | 1250 | Inaccessible | |
| | D-2 suspended ceiling | 16 | 40 | | $1.5kg/m^2$ | 750 | Inaccessible, fireproof | |
| | D-3 suspended ceiling | DC+T16-40 | | | $2.0kg/m^2$ | 900-1200 | Accessible | |
| | D-4 suspended ceiling | T16-40 | | | $1.1kg/m^2$ | 1250 | Inaccessible | |
| | D-5 suspended ceiling | DC+T16-40 | | | $2.0kg/m^2$ | 900-1200 | Accessible | |
| Main stud (galvanized steel) | D60 (CS60) | 60 | 27 | 1.5 | 1.37 | 1200 | Accessible | Beijing New Type |

Continued

| Name | Product code | Specification (mm) | | | Steel consumption (kg/m) | Spacing of suspension centers (mm) | Type of suspended ceiling | Producer |
|---|---|---|---|---|---|---|---|---|
| | | Width | Height | Thickness | | | | |
| Main stud (galvanized steel) | D60 (C60) | 60 | 27 | 0.63 | 0.61 | 850 | Inaccessible | Beijing New Type Building Material Main Factory |
| Aluminum alloy T-shape main stud | D32 | 25 | 32 | | | | | |
| Aluminum alloy T-shape sub-stud | D25 | 25 | 25 | | | 900-1200 | Inaccessible | |
| Aluminum alloy T-shape side-stud | D25 | 25 | 25 | | | | | |

The structure of U-stud suspended ceiling is shown in Figure 9.6.

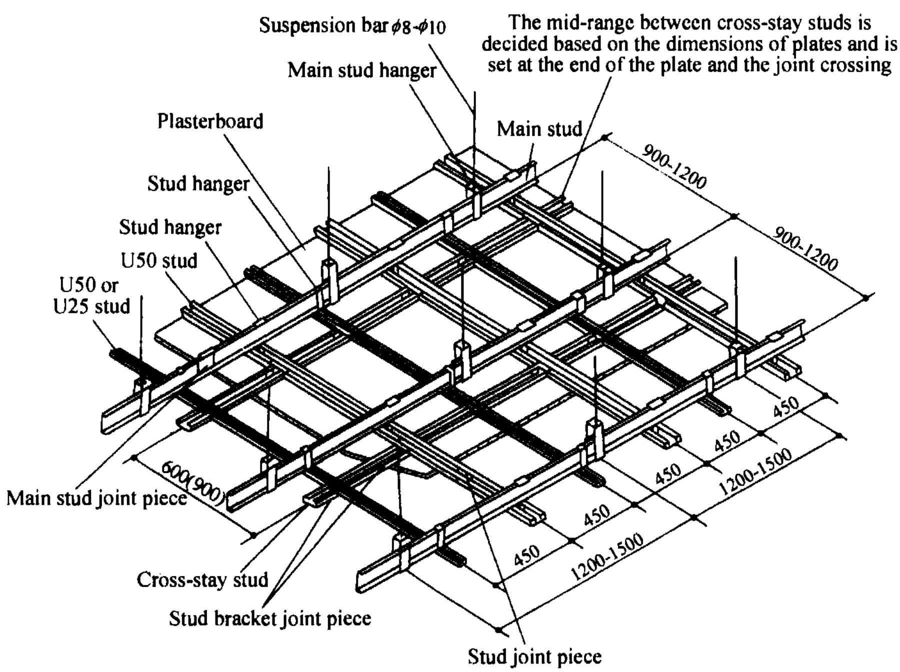



Figure 9.6 Structure Drawing of U-shape Galvanized Steel Stud and Thistle Board Suspended Ceiling

Suspended ceiling galvanized steel stud is mainly applied to the construction or reconstruction of restaurants, office buildings, entertainment places and hospitals etc. Inaccessible suspended ceiling is only capable of bearing its self-weight, and its stud has small sectional surface area. Accessible suspended ceiling not only bears its self-weight, but also bears the weight of moving people, generally is able to bear a concentrated load of 80-100kg/$m^2$, therefore, it is often applied to the construction of suspended ceilings in large space theaters, concert halls, conference centers or ceilings equipped with center conditioning system.

## 9.2 Building Decorative Aluminum and Aluminum Alloy Products

### 9.2.1 Aluminum and Aluminum Alloy



Presently, aluminum and aluminum alloy products are widely applied to produce aluminum alloy doors and windows, store shelves, counters, decorative boards, suspended ceiling panels and curtain wall frameworks in building decoration projects. They play a more and more important role in modern decoration projects.

**1. Performances and Features of Aluminum and Aluminum Alloy**

(1) Performances and Features of Aluminum

Aluminum exists in nature in the form of chemical compound, which takes up 8.13% of the total compositions of earth crust, only less than oxygen and silicon. Aluminum is a light metal among non-ferrous metals. It is in silver white and its specific gravity is 2.7, melting point is 660℃, density 2.7g/$cm^3$. It has good electric conductivity and thermal conductivity. Due to its active chemical properties, it is easy to oxidize in air and create a layer of aluminum oxide on the surface, which prevents the underneath metal from oxidation, therefore, aluminum is highly corrosion-resistant in the air. In nature, aluminum tends to get damaged by corrosion if it contacts with strong acid or alkali. In addition, aluminum has low electrode potential, if contacting with metal with high electrode potential with the existence of dielectric medium (water and steam etc.), it is likely to create local element and gets eroded very soon.

With good plasticity and ductility, aluminum is available to make tubes and pipes, wires, plates and different profiled materials etc. It can even be rolled to paper-thin aluminum foil with high reflectance to light and heat. Due to its low strength and hardness, aluminum is not allowed to serve as structural material, therefore, it is often strengthened through cold-pressing or by adding alloy elements and then applied in production practice.

(2) Performances and Features of Aluminum Alloy

Aluminum alloy is produced by adding to aluminum with elements such as magnesium, manganese, copper, zinc and silicon to improve the practical utility of aluminum. Aluminum alloy not only retains the prime features of aluminum, but also has notably improved mechanical performances, so it is widely applied to building decoration projects. The main disadvantages of aluminum alloy are small elastic modulus, high heat-expansion coefficient, low heat-resistance, new welding technique such as inert gas shielded needed for welding. Commonly-used aluminum alloy are aluminum-manganese, aluminum-magnesium and aluminum-magnesium-silicon alloys etc., among which aluminum-magnesium-silicon alloy is the main material used to produce aluminum alloy doors and windows and aluminum alloy curtain-wall frameworks etc.



Aluminum alloy inherits the lightweight feature of aluminum and has remarkably increased mechanical performances (compressive strength up to 210-500MPa, tensile strength up to 380-550MPa), due to which it is widely applied to building decoration projects and structures. For instance, it was adopted to build a hangar with a span of 66m in America, and the structural self-weight was largely reduced. An extremely huge irregular roof, impressively light and novel, was built with aluminum alloy in Japan. Aluminum alloy was used to build the 34m roof and suspended ceiling of cantilever steel structure with heat-insulation layers in Taiyuan, Shanxi. All of these cases fully reveal the unique performances of aluminum alloy.

## 2. Classification Code and Properties of Aluminum

Aluminum alloy material is applied in three aspects:

1) Application in I-type structures: serve as load-bearing structural member (such as curtain wall framework);

2) Application in II-type structures: serve as doors, windows and sections etc. (such as aluminum alloy doors and windows, aluminum sections etc.);

3) Application in III-type structures: mainly serve as decoration and thermal insulation material.

Commonly-used aluminum sections in decoration projects are window sections (sliding-sash window sections: 46 series, 50 series, 65 series, 70 series and 90 series; side-hand window sections: 38 series, 50 series; other series of window sections), door sections (floor-spring door, sliding door and frameless door sections), counter and curtain wall sections etc.

In modern building and decoration projects, doors and windows made of aluminum alloy not only have light self-weight and high specific strength, but also has good resistance to wear, corrosion, light and weathering after surface processing, and moreover, creates different elegant and beautiful color and luster.

### 3. Processing and Superficial Treatment of Aluminum and Aluminum Alloy Sections

(1) Processing of Aluminum and Aluminum Alloy Sections

Building aluminum alloy sections are manufactured in two ways: extruding and rolling.



There are various types and specifications of building aluminum alloy sections with complicated sectional shapes, strict dimensions and surface requirements. Different from steel materials, they are produced with extruding method at home and abroad. Rolling method is adopted in the production of medium and small size bars and sections with simple sectional shapes in less quantity and with low dimension and surface requirements.

(2) Superficial Treatment of Aluminum and Aluminum Alloy Sections

The surface of aluminum alloy product tends to get eroded. Therefore, it is a must to have its surface treated with anodic oxidation and surface coloring methods in construction practice, which enhances its resistance to corrosion, wear, light and weathering, and provides its surface with different colors of coating layer with excellent decorative effects.

1) Anodic Oxidation Treatment

Building aluminum section must be treated with anodic oxidation, commonly adopting sulfur acid method. After treatment, the surface looks silver white. It is the principal part of building aluminum section.

① Purposes of anodic oxidation treatment. By controlling oxidation conditions and technical parameters, a layer of oxidation film (5-20 μm ) which is much thicker than natural oxidation film (thickness less than 0.1 μm ) is created on the surface of aluminum section, then "hole sealing" procedure is taken to enhance its surface hardness, wear resistance and corrosion resistance. Smooth and dense film layer is the prerequisite for the following coloration.

② Classifications of anodic oxidation. At presently, anodic oxidation methods with commercial value are chromic acid method, sulfuric acid method and oxalic acid method. Chromic acid method creates thin film layer which has lower wear resistance, while oxalic acid method is costly. Therefore, sulfuric acid method is the most widely used.

③ Anodic oxidation procedure. The procedure of anodic oxidation of aluminum is essentially the procedure of electrolysis of water. During water electrolysis, cathode releases hydrogen and anode releases oxygen. The generated oxygen and the trivalent-aluminum ionic formed by aluminum anode combine together and create thin aluminum oxide layer.

2) Surface Coloration.

Surface coloration is carried out to aluminum section after water neutralization or anodic oxidation. It is realized by controlling the type and content of different alloy elements and by heat treatment. Commonly-used coloring methods are natural coloring and electrolyte coloring.



## 9.2.2 Aluminum Alloy Stud

### 1. Performances and Features of Aluminum Alloy Stud

According to sectional shape, aluminum alloy stud is classified to L-shape, T-shape, U- shape and square shape etc.; according to application, classified to partition and suspended ceiling studs. Aluminum alloy partition stud is solid and firm with features as easy production and easy installation. Aluminum alloy suspended ceiling stud is light, beautiful, rust-proof, fireproof, shock resistant and convenient for installation. It is suitable for interior suspended ceiling decoration.

Aluminum alloy suspended stud includes main stud (master stud), sub- stud, side- stud and hanger joint pieces etc. Main studs, sub-studs and plates combine into grids in dimensions 300mm×300mm, 300mm×600mm or 600mm×600mm, and form assembling-type suspended ceiling structure together with the faceplates; main studs are connected to the floor with hanger joint pieces and suspension bars.

### 2. Technical Requirements for Aluminum Alloy Stud

Aluminum alloy stud includes two types: partition stud and suspended ceiling stud. Aluminum alloy stud is assembling-type and is often combined with surface-covering materials to create partition and suspended ceiling surface layer in construction practice.

Aluminum alloy stud has advantages such as easy installation, fast construction, light weight and fire resistance. The suspended ceiling stud includes "T, L" series, "U, Π, L" series, "Ω, L" series etc. Faceplate includes glass plate, mineral wool board, calcium-plastic board, metal plate etc.

Technical requirements for the four types of sections applied to aluminum alloy partition stud are given in Table 9.4.

**Table 9.4 Four Types of Sections Applied to Aluminum Alloy Partition Stud**

| Name | Sectional shape | Specification (mm) | Unit mass (kg/m) |
|---|---|---|---|
| Large square pipe |  | 76.2×44.45 | 0.894 |
| Flat pipe |  | 76.2×25.4 | 0.661 |
| Equal-side channel |  | 12.7×12.7 | 0.100 |
| Equal-side angle |  | 31.8×31.8 | 0.503 |

As to specifications and technical requirements for aluminum alloy suspended ceiling stud, refer to Table 9.5.

**Table 9.5 Specifications and Technical Requirements for Aluminum Alloy Suspended Ceiling Stud**

| Name | Sectional shape | Specification (mm) | Sectional area ($cm^2$) | Unit quality (kg/m) | Length (m) | Mechanical property |
|---|---|---|---|---|---|---|
| Medium aluminum alloy stud |  | Thickness 1.3 | 0.775 | 0.21 | Multiples of 3 or 0.6 | Tensile strength 210MPa, Elongation percentage 8% |
| Small aluminum alloy stud |  | Thickness 1.3 | 0.555 | 0.15 | | |
| Aluminum alloy side- stud |  | Thickness 1.3 | 0.555 | 0.15 | Multiples of 3 or 0.6 | |
| Main stud (light stud) |  | Thickness 1.3 | 0.87 | 0.77 | 2 | |

### 3. Applications of Aluminum Alloy Stud

Aluminum alloy partition stud is usually adopted together with different kinds of glass, artistic glass, organic board and building-artificial board etc., which creates space with certain perspective effects. It is also suitable for the partitions in office buildings, factory buildings and other spaces.

To aluminum alloy suspended ceiling, whether accessible or inaccessible, the space between main studs should be less than 1200m and the space between suspending centers should range 900-1200mm; the space between medium and small studs (middle-pitch) should be less than 600m. Medium stud is fixed vertically underneath main stud, whereas small stud is vertically fixed on the flange of medium stud. Suspenders respectively adopt $\phi 6$, $\phi 8$ or $\phi 10$ steel bars. Aluminum alloy stud is classified to exposed and unexposed types. Material in small dimensions is allowed to serve as suspended ceiling material, such as decorative plasterboard suspended ceiling, acoustic plasterboard suspended ceiling, metal micro-porous acoustic panel suspended ceiling and aluminum alloy decorative panel suspended ceiling etc. Figure 9.7 is the installation diagram for horizontal mineral wool board conjunction (exposed stud).



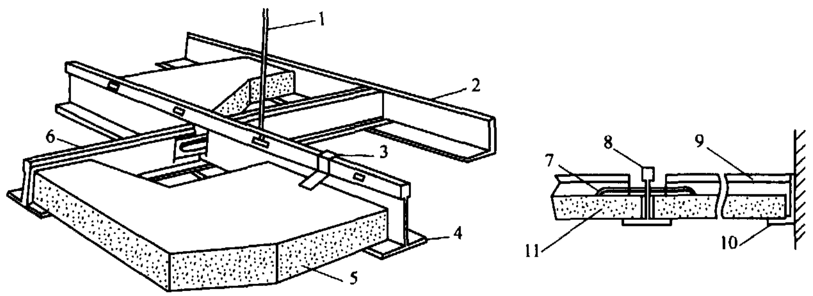



Figure 9.7 Installation Diagram of the Horizontal Conjunction of Mineral Wool Board (exposed stud)

1. Suspender; 2, 10. L-form side-keel; 3, 7. Clip-plate; 4, 8. T-shape main keel; 6, 9. T-shape sub-keel; 5, 11. Mineral wool decorative acoustic board

## 9.2.3 Aluminum Alloy Panel

Aluminum alloy panel, an advanced decorative material with unique decorative effects, is presently widely adopted in designs.

**1. Features of Aluminum Alloy Panel**

Aluminum alloy panel is the most commonly-used metal plate. It has features such as lightweight (only 1/3 of steel weight), easy processing (cutting, boring), high strength, high stiffness, durability in use (20 years in open air), convenient transportation and construction, and resistance to fire, moisture and corrosion. Moreover, it has a particular advantage that it can be made into products in different needed colors with chemical method or paint-spraying method.

**2. Types and Performances of Aluminum Alloy Panel**

The surface treatment methods of aluminum alloy panel in construction projects include anode oxide film, fluorocarbon resin spraying and baking finish; according to structure features, it is classified to monolayer, composite and honeycomb aluminum panels etc.; according to geometric shape, classified to rectangle, square and irregular panels etc.; according to color, classified to silver white, antique bronze, warm grey and gold etc. Commonly-used aluminum alloy panels are following types.

(1) Monolayer Aluminum Panel

In foreign countries it is mostly made of pure aluminum panel, generally 3-4mm thick; in China mostly made of $LF_{21}$(3003) aluminum alloy panel, generally 2.5mm thick. It is thinner than pure aluminum panel but has higher strength, and its self weight is reduced. Due to its inadequate stiffness, large area aluminum panel is often ribbed on its back for reinforcement, commonly the stiffening rib is made of the strip of the same aluminum alloy or aluminum angle, generally 10-25mm wide and 2-2.5mm thick. Aluminum panel is combined with the rib in three ways: ① weld the bolt on the backside of the panel with a percussive welding, then fasten and fix the rib to the bolt; ②stick the rib on the backside of the panel with ZE2000 glue; ③ stick it with 3M high-power double-sticky tape. Among the three ways, ② has the best effect. Whatever wall panel it is, structural calculation must be taken to make sure its strength and stiffness meet the burden requirements.

The surface treatment of aluminum panel should not adopt anodic oxidation, because the compositions and oxidation-tank liquid of each batch of aluminum panels are different and the surface colors are different after oxidation. Electrostatic spraying is adopted, which includes powder spraying and fluorocarbon spraying. The former takes polyurethane and epoxy-resin mixed with high-power coloring material, which creates many different colors. The thickness of powder spraying layer is 20-30 μm . Aluminum panel surface coated with the spraying powder is impact resistant and wear resistant, and if impacted with 50kg object, it keeps its shape with no cracking on its coating layer; the only disadvantage is that its color fades gradually when exposed in UV from sunlight for a long time. The latter takes fluorocarbon polymer resin as metal surface coating, usually 3 or 4 coatings up to 40-60 μm thick on the panel surface. Thus the panel is resistant to corrosion, acid-rain and different air contaminants, resistant to ultraviolet radiation and to extreme heat or cold. It keeps even color for a long period and has long service life. The disadvantage is that the painting layer is weaker than that of powder spraying in hardness, impact resistance and wear resistance.

(2) Aluminum Alloy Composite Panel (Aluminum-plastic Panel)

Aluminum alloy composite panel is also called aluminum-plastic board, which takes aluminum alloy panel (or pure aluminum panel) as surface layer, polyethylene (PE), polyvinyl chloride (PVC) or other thermoplastic materials as sandwich layer. It is one of the commonly-used metal panels for wall decoration and renovation, including single-clad and double-clad boards. It has good corrosion and stain resistance as well as weathering resistance. The panel surface is in different colors such as red, yellow, blue and white, which shows excellent decorative effects. It is available for bending, sawing, planing, punching and cutting in construction. Compared with aluminum alloy panel, it has features such as lightweight, convenient construction and low cost. Aluminum-plastic composite board is applicable for the decoration of curtain walls, storefronts and signboards etc.



Its main features are as follows:

1) Good durability, beautiful and brilliant surface coating layer. The composite panel is painted with fluorocarbon coating on the surface, and has features such as good brightness, strong adhesive power, thermal resistance, corrosion resistance, decay resistance, UV resistance and unfading.

2) Different colors. Panels in needed colors are supplied according to customer requirements.

3) High strength and lightweight. Because it is made by compositing thin aluminum sheet and thermoplastic material, it is of lightweight and with good performances of anti-bending and anti-deflection, which enables it to retain its flatness for a long time and to remove dents and wrinkles effectively.

4) Easy processing and molding. It can be precisely processed to different shapes such as arch, ogee(anti-arch), arc corner and small radius fillet based on the design requirements of buildings, and helps to make buildings more beautiful.

5) Easy Installation. It can be installed in traditional ways, for instance, fastened by slotting, bending, riveting and screwing etc., or fixed with structural adhesives.

6) Good fire resistance. The surface panel and the sandwich layer are of fire-resistant material and with good fire-resistance. In addition, during manufacturing, thin aluminum sheet is stuck to the fire resistant sandwich material to create the unique fire-resistant panel.

(3) Aluminum Alloy Suspended Ceiling Panel

According to appearance shape, aluminum alloy suspended ceiling panel is classified to square panel, strip panel, grating panel and insertion panel etc. Square is further classified to square and rectangle; according to surface status, classified to flat panel, buckled panel, perforated panel and arc panel etc. Its stud includes unexposed and exposed types. Square panel not only creates the integral plane-figure pattern and line style effects of unexposed stud, but also has the structural features of exposed stud, i.e. easy to install and disassemble. Moreover, it allows customized processing according to the requirements of designers. Strip panel is light, fire proof, moisture proof and easy to install. The panel surface is in strong integrity and continuity. Strip panels in different dimensions and models can be combined to achieve different visual effects.



As to grating aluminum alloy suspended ceiling, its main studs and sub-studs are distributed crisscross, which divides the suspended ceiling into some small grids, creates 3d sensation and stereovision, and endows the ceiling with more vivid and beautiful appearance and bright and spacious feelings. Insertion aluminum alloy ceiling adequately utilizes the ceiling space. It has features such as easy installation and repair, elegant and beautiful appearance. Moreover, different visual effects are invented by combining insertion panels in different ways. Lighting, spraying and air-conditioning systems inside the ceiling are installed without any additional special handling to the ceiling.

Aluminum alloy suspended ceiling panel is suitable for the interior decoration and renovation of suspended ceiling in marketplaces, hotels, office rooms, airports, bus terminals, metro stations, parking places, banks, bathrooms and washrooms. Perforated aluminum suspended ceiling is also applied to the ceiling decoration of places with higher acoustic requirements, such as language laboratories and studios etc.

(4) Aluminum Alloy Perforated Panel

Aluminum alloy perforated (sound-absorbing) panel is made of aluminum alloy panel through machinery punching. Its pore diameter and pitch are designed and produced in different needed arraying modes, such as repetition and gradual-change etc; the pores are punched to different needed shapes, such as round, square, rectangle, triangle, star and rhomb. After punching, it is not only light and resistant to high-temperature, corrosion, fire, shock and moisture, but also creates certain patterns with good decoration effects. Moreover, with sound absorbent inside, it solves the acoustic problems of structures. So it is an ideal material with functions of both noise reduction and decoration.

Aluminum alloy perforated panel is mainly applied to public buildings like theatres etc., also to ceilings or walls of places such as workshops with heavy noise in cotton mills, different control rooms and electronic computer rooms to improve acoustic effects.



(5) Aluminum Alloy Honeycomb Panel

Aluminum alloy honeycomb panel is also called honeycomb structure aluminum alloy wall panel or honeycomb aluminum composite panel. Between two aluminum panels there is a honeycombed sandwich layer made of different materials. Generally the external layer of aluminum panel is 1.0-1.5mm thick and the internal panel is 0.8-1.0mm thick. The sandwich layer is honeycomb-like aluminum foil, fiber glass or paper stuff in hexagon, rectangle, square or cross-folded hexagon, among which hexagon honeycomb core with side-length of 3-7mm is mostly used. The honeycomb core is stuck to the aluminum alloy surface panel with structural adhesives, and the whole panel- block surface is coated with resin-type metal polymer decorative film. Due to the special structure of the panel-block, such kind of panel has the best service performances.

(6) Aluminum Alloy Diamond Plate and Corrugated Plate

Aluminum alloy diamond plate is made of rustproof aluminum alloy processed by rolling with the roller that has certain figures. It has features such as good decorative performance, wear resistance, skid-proof, corrosion resistance, and easy cleaning. "*Aluminum and Aluminum Alloy Diamond Plate*" (GB/T 3618-1989) has made relevant specifications on: code of diamond plate, code of alloy, status, dimensions and room-temperature mechanical properties. Flat and in precise dimensions, it is easy to install. It is suitable for the decoration of places such as interior and exterior walls and stair steps.

Aluminum alloy corrugated panel is made by rolling the panel to create wave patterns on it with machine. Its alloy code, status and dimensions should meet relevant specifications in "*Aluminum and Aluminum Alloy Corrugated Plate*" (GB/T 4438-1984). It has such features as light self-weight, beautiful appearance, many different colors, fireproof, durability, corrosion resistance and high light-reflectance. So it is suitable for the decoration of walls, roofs, storefronts and billboards etc.

It is concluded that there are common features of aluminum alloy decorative panels such as lightweight, easy processing, high strength, good stiffness and durability in use. The surfaces are in different forms (polished, checkered, corrugated and profiled etc,) and in different colors. They are fireproofing, moisture-proofing and corrosion resistant. Their application features are: in wall decoration, when aluminum panel is coordinated with large windows like glass curtain-wall, it is adopted to decorate easily-chipped and complicated areas to achieve highlighted effect of smooth and fluent stream line style of structures; in commercial buildings, aluminum decorative panel is applied to the decoration of the entrance facades, columns and signboards, which enhances the structural style of the whole building and attract the attention of more customers.



## 9.3 Other Metal Decorative Materials

### 9.3.1 Copper and Copper Alloy

#### 1. Features and Applications of Copper

Copper and its alloy has been a building material for a long time, which has served as building decorative material and different accessories since long ago. Pure copper is claret metal, commonly known as red copper or copper. With a density of 8.92g/cm$^3$, it belongs to heavy non-ferrous metals. With good electric conductivity and thermal conductivity, it is widely applied to electric industry, for instance, as coil, wire or cable of power generators and transformers. Pure copper has rather good corrosion resistance. In humid air, its surface is covered with a layer of green alkali copper carbonate, known as copper green, which protects the copper itself. With low hardness and low strength but good plasticity, it is available for different cold and heat processing and can be produced to different plates, strips, wires and pipes.

The code of pure copper is represented with chemical symbol "Cu" plus number. Smaller number means purer copper. For instance, No. 1 (Cu-1) stands for copper with purity 99.95%; No.2 (Cu-2) means purity 99.90% etc.

**2. Features and Applications of Copper Alloy**

Due to its low strength and high cost, pure copper is not suitable to serve as structural material. The widely-used in construction projects is copper alloy, which is made by adding elements such as zinc and tin to copper. Copper alloy retains the good plasticity and high corrosion resistance of copper, and has better mechanical properties than pure copper such as strength and hardness. Commonly-used copper alloys are brass, bronze and cupronickel etc.

1) Brass is a copper alloy made by adding zinc to copper, whose properties depends on the content of zinc.

2) Bronze is a copper-tin alloy. With features as easy welding, high corrosion and wear resistance and high strength, it is primarily used to produce heating accessories, building metal wares and different kinds of decorative parts.

3) Copper powder (commonly called gold bronze powder) is a golden material made of copper alloy. It contains copper and a little amount of other metals such as zinc, aluminum and tin and is primarily used to mix into decorative coatings to take the place of gold foil.



**3. Applications of Copper and Copper Alloy**

In modern building decoration, copper is an advanced decorative material with both antique simplicity and luxurious quality. It is applied to stair armrests, handrails, anti-slip strips and columns and so on in hotels, restaurants and office buildings etc. It creates colorful and glorious, appealing and elegant effects, and exhibits brilliant and exquisite atmosphere. Moreover, it serves as exterior wall panels, luxurious copper doors, handles and locks etc and is also widely adopted in sanitary and metal ware aspects.

Copper alloy is widely used. It can be extruded or pressed into sections with different sectional shapes, including hollow section and solid section, which are further processed to pipes, plates, wires, fastening pieces and different machinery parts etc. Commonly used copper alloy in decoration projects are plates, wares, tablets and doors, handrails, panel-strips, anti-slip strips, embossed columns and embossed wall-paintings etc. Copper alloy contour plate made of copper alloy plate is applied to the exterior wall decoration of buildings to create gold-splendid, glittering and durable appearance. Copper products are mainly used in advanced places such as hotels, restaurants, high quality office buildings and banks etc.

Because the surface of copper product is easy to get eroded (such as $SO_2$) from hazardous substances in the air, it is treated with methods such as titanium alloy plating to enhance its corrosion resistance and durability. Thus the glossiness and the service life of copper products are greatly improved.

### 9.3.2 Metal Decorative Strip

Metal decorative strip is made with an advanced non-ferrous metal extruding machine. There are all specifications of products in different patterns and styles, which are fresh and elegant, flat and straight and bright. The products are in high hardness and reliable quality. It is widely applied to advanced decorative projects such as department-stores, hotels, restaurants, hospitals, schools and railway stations for floor dividing, stair skid-proofing, edge-covering and the decoration of store shelves, counters and mirror frames etc. Materials used to produce metal decorative strips are brass, aluminum alloy and stainless steel etc.



#### 1. Copper Decorative Strip

Copper decorative strip, including bars, anti-slip strips, dividing strips, decorative strips and flowery-ornaments etc., takes brass as main raw material. In addition, high-end antique style copper door are produced as follows: pressing copper sheet into edge-covering material for different doorframes and planks, combining them with copper decorative strips and copper flowery-ornaments, and then processing the surface through technique procedures such as archaizing, oxidation and spraying transparent protective paint. Commonly-used copper decorative strips and flowery-ornaments have following types.

1) Copper bar. Main specifications are $\phi 5$ - $\phi 150$. It mainly serves as raw material or is used to produce copper decorative components.

2) Anti-slip strip. It is mostly made by smelting special type of brass and has features such as good hardness, wear resistance, flexibility and no breaking when stamped. With copper screws and pin pieces, it is fixed firmly and never breaks off. The shapes are mainly: strip (3 lines, 4 lines and 5 lines), tetragon (square, rectangle), flat, mono-rhomb, dual-rhomb, buckhorn, small wrapped-angle and big wrapped-angle etc. It is also available for customized shapes based on the designs of the constructors.

3) Dividing strip. This product, made of H62 brass plate, includes I-form and flat types and is specially used for terrazzo-concrete and granite floor dividing. To facilitate the construction, it usually has already made bored holes.

4) Other copper products. Commonly-used copper products also include carpet-rollers, litter bins, stair handrails, doors, door pulls, guardrails, factory badges, arts and crafts, Buddha and censers, candle sticks and bars etc.

**2. Other Metal Decorative Strip**

In addition, metal decorative strip also includes different aluminum alloy and stainless steel sections and pipes, such as different mirror-frame strips, edge-sealing strips (U-shape, 7-shape and L-shape etc.), hold-down strips, carpet closure-strips, store shelves and counters made of aluminum alloy or stainless steel.



## 9.3.3 Iron Craft

**1. Applications of Iron Craft**

There are many types of iron craft with very wide application scopes, e.g. different kinds of metal casting and forging decorative ornamental works, different patterns of metal partitions, stair handrails, guardrails, courtyard iron-craft lightings, interior iron-craft furniture, flowery-ornaments for balconies, doors and windows, casting iron fences, ornamental decorative gates, courtyard gates, decorated archways, verandas and metal grilles etc.

**2. Types and Specifications of Iron Craft**

Metal grille used in iron-craft projects is mainly produced in two ways: one is casting molding, i.e. casting into grilles of iron, copper or aluminum with molds; the other is bending molding, i.e. first bending thin metal material such as formed steel, flat steel, galvanized steel strip, aluminum strip, steel pipe or steel bar to small grilles or different patterns, then combining them into large grilles. Types of commonly-used iron flowery-ornaments are given in Table 9.6.

**Table 9.6 Types of Commonly-used Iron Flowery-ornaments**

| Type | Material | Item name | Application |
|---|---|---|---|
| Casting decorative iron craft | Casting iron | Gun head, column foot, iron vane | Decoration of the top and footing frame of guard rail and fence |
| | | Decorative ornamental works | Serve as iron craft decorative accessories |
| | | Decorative motif piece | Partition, fence etc. |
| | | Stair motif piece | Interior and exterior stair, circular stair etc. |
| | | Door center, door side, top flower | Ornamental decorative gate etc. |
| Bending processing iron craft | Section | Frame, stand column, handrail etc. | Iron craft decorated frame, hand rail, column, framework etc. |
| | | Bending, twisting, profile accessories etc. | Iron craft decorative accessories, joint pieces etc. |



### 3. Processing of Iron Craft

Iron craft partition can be inlaid with ornaments such as colored glass, organic glass or hardwood etc.; metal grille itself can be processed in ways such as paint coating, baking varnish, chromium plating, gold plating, spraying plastics and copper foiling etc.

Welding, riveting, sleeve jointing and screwing etc. are adopted for the joining between iron crafts or between iron craft and decorative accessories. Floral ornament between accessories such as organic glass can also be stuck with bonding agent. So it is with accessories and frameworks.

### 4. Other Metal Products

With the development of material and technology, traditional iron-craft has been greatly improved in material and technique. New material is largely adopted such as glass, organic glass, stainless steel, aluminum alloy, resin material and high-grade wood component. In technology, there are joining methods such as welding, bonding, sleeve jointing and screwing; methods such as baking finish, spraying plastics, plating are used in surface treatment; methods such as archaizing, polishing, frosting and wiredrawing are adopted to create different surface effects, e.g. stainless steel fences and guardrails, stair handrails and stair posts made by combining stainless steel, aluminum alloy and solid-wood together, and metal iron-craft furniture and interior decorative components etc.

## Summary

This chapter mainly introduces the compositions, classifications, performances and applications of metal decorative material. In theory-teaching section, students are required to master different compositions and features, performance features and application requirements of such metal decorative materials as steel products, stainless steel products, aluminum alloy products, aluminum alloy doors and windows, different metal decorative plates and products etc. In the practice-teaching section, it is necessary to master the names, performances, applications and application requirements of commonly-used metal decorative materials. The names, specifications, performances, prices and applications of each type of metal decorative material and product should be learned based on the actual application status in construction projects.



## Questions for Reviewing and Thinking

9.1 What are the types and features of building decorative steel?

9.2 What should be noticed for the standard and selection of building decorative steel?

9.3 What are the types of commonly-used formed steel in construction projects? What features does each of them have?

9.4 What are the steel products applied in building decoration? What features does each of them have?

9.5 What are the performances and features of aluminum and aluminum alloy?

9.6 What are the features and performance indexes of aluminum alloy doors and windows?

9.7 What are the types and performances of aluminum alloy panel?

9.8 What are the types and applications of copper alloy?

9.9 What are the types and processing methods of iron crafts?

# 10

# Decorative Wood

## 10.1 Introduction

Wood is a traditional building material, but due to the poor resource of forest, we should scientifically consume and save wood. There are a series of advantages of wood.

**1. Natural**

Wood is a natural material and is the only one directly taken from nature among the four main materials used by human being: steel, wood, cement and plastics. So it has features such as low production cost, less energy consumption and no hazards or pollution.



**2. Good Texture**

Wood feels warm and comfortable to touch, which is far better than any other material such as metal or glass.

**3. High Specific Strength (The Ratio of Strength to Volume Density)**

It is a material with lightweight but high strength.

**4. Good Thermal Preservation (Low Thermal Conductivity)**

The thermal conductivity of wood is very small. Compared with wood, the thermal conductivity of aluminum is 2000 times higher and plastic is 30 times higher. Wood has good performance of thermal preservation.

**5. Electric Insulation**

Wood has weak electric conductivity, so it is a material with good electric insulation.

### 6. Easy to Process

Wood is neither too hard nor too soft, which makes it easy to process.

### 7. Decorative

Wood itself has natural beautiful patterns. It is a highly decorative serving as furniture or decorative material.

The disadvantages of wood: it has uneven structure, natural defect, and high water-absorption, which decreases its dimensional stability; it tends to warp and crack or to get eroded; it is combustible etc. Scientifically used, these disadvantages are avoidable.

Due to some of the above special features, in spite of its innate disadvantages, wood is still the preference to people, especially serving as advanced interior decorative material at places where people may directly touch, such as doors, door and window frames, wood floors, heating mantles and furniture etc.

There are various types of wood. Table 10.1 lists some types of commonly-used wood and the comparison of their features.



**Table 10.1 Feature Comparison of Some Types of Commonly-used Wood**

| Code | Name | High density | High hardness | High brittleness | Coarse fiber | Textural beauty | Sense of beauty |
|---|---|---|---|---|---|---|---|
| A | Sen | | | | | Stream-like style | Continuous, springy |
| B | Beech | | | | | Granite style | Popular spotty, fine hairy rain grain, full of romantic |
| C | Cherry | | | | | Shell style | White with light pink, natural prime style, noble and elegant |
| D | Padauk | √ | √ | | | | |
| E | Chempaka | | | | √ | | |
| F | Meranti | | | √ | √ | | |
| G | Delonix regia | | | | √ | | |
| H | Birch | | | | | | |
| I | Kempas | √ | √ | | | | |
| J | Kapur | | | √ | | | Solid and massive sensation |
| K | Light beech | | | | | Drizzle-like style | Silence is golden |

Continued

| Code | Name | High density | High hardness | High brittleness | Coarse fiber | Textural beauty | Sense of beauty |
|---|---|---|---|---|---|---|---|
| L | Maple | | | √ | | Terrace style | Farming, harvesting and sea-waving dynamic sensation |
| M | Mahogany | | | | √ | Loess plateau style | Coarse, bold, red color with vigorous vitality |
| N | Oak | √ | √ | √ | | Swampland style | Spacious and calm sensation |
| O | Pine | | | | | Like a clear pool | Clear and clean |
| P | Manchurian ash | | | | | Beach-like | |
| Q | White wood | | | | √ | Like snowflake | Romantic and misty |
| R | Sapele | | | | √ | Like sunglow | Hopeful and triumphant sensation |
| S | Teak | | | | √ | Like coastline | Golden, fresh |
| T | Walnut | | | | | Like black beauty | Noble, elegant, firm, mature sensation, un-deformed |
| U | White beech | | | | | Like silver sand | Veiling dimness, implicit style |



## 10.2 Classification and Structure of Natural Wood

### 10.2.1 Classification of Wood

Wood is commonly classified to two main types: wood of needle leaf trees and wood of broad leaf trees.

**1. Needle leaf Tree**

With straight and strong trunk, easy to get large-size wood, flat and smooth texture, uniform material quality, soft wood quality and easy for processing, so, also called softwood. It has small apparent density and small expansion-contraction deformation but strong corrosion-resistance. In interior construction it is mainly applied to doors and windows, ornaments or load-bearing components. Common tree species are cedar, fir, spruce, red pine, Korean pine, Mongolian scotch pine and Chinese red pine etc.

**2. Broad leaf Tree**

With shorter straight trunk, hard and heavy wood quality, higher strength, natural and appealing texture, it is the main facing decorative material for interior decoration and renovation projects and furniture manufacturing. Common tree species are elm, Manchurian ash, Chinese oak and walnut.

## 10.2.2 Structure of Wood

It is observed from the following three sections to know the macrostructure of wood.

Cross section: sectional surface perpendicular to the trunk axis.

Radial section: longitudinal sectional surface passing the pith center and parallel with the trunk.

Tangential section: longitudinal sectional surface certain distant from the pith center and parallel with the trunk. Refer to Figure 10.1.



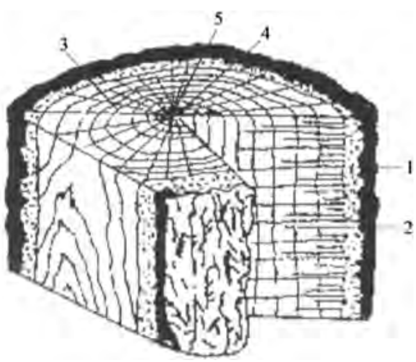



Figure 10.1 Macrostructure of Wood

1. bark; 2. xylem; 3. annual ring; 4. pith ray; 5. pith center

Xylem, pith center and bark are seen on the cross-sectional surface. Xylem is the main body of wood. In some types of trees, xylem can be seen clearly. The part close to the pith center is darker in color is lifeless, called heart wood, which is less likely to warp and has strong corrosion resistance; the part of wood close to the bark is in lighter color, called sapwood, which is high moisture-content and easy to warp with weak corrosion-resistance. There are many concentric rings on the xylem. The wood grows one ring each year, so it is called annual ring. In each annual ring, the part growing in spring is in lighter color and of softer quality, called springwood; the part growing in summer and autumn is darker and of harder quality, called summerwood. More summerwood in an annual ring means harder wood quality. The percentage of summer wood contained within a certain length along the radius direction on the cross section is called summerwood ratio, which is a very important factor affecting the strength of wood. Pith center is also called tree center, which is soft and easy to catch corrosion. The outward ray from the pith center is called pith ray, which is not well combined with the wood around it, so it is where cleavage starts from in dry period.

## 10.3 Physical Mechanic Properties of Wood

### 10.3.1 Moisture Absorption and Moisture Content of Wood

The percentage of the mass of water contained in wood to the mass of dried wood is called moisture content (M.C. or water ratio). It changes in accordance with the air humidity of the environment until it reaches equal to the latter. At this moment the moisture content of wood is called equilibrium moisture content (E.M.C.)



The moisture content of newly chopped wood is averagely 70%-140%; wet-wood is 100%, oven-dried wood 4%-12%, air-dried wood 15%, absolute-dried wood 0. Air-dried wood and oven-dried wood are applied in interior decoration, so their moisture content should meet the standard adopted in interior designs.

The moisture in wood exists in three states: free, physical-bounded and chemical-bounded. Free water and capillary water exist in the gaps between cell cavities (cavity containing cell) and between cells. Physical-bounded water or bound-water is in cell walls and covers the surface of fibrils constituting the cell wall in the form of water-film. Chemical-bounded water is one of the components of which wood structure is composed, so it is out of consideration.

When wood is drying, first free water vaporizes, and then so does bound water. When wood is damping, at first cell wall absorbs water to saturated state, then free water starts to enter. When bound water in the cell wall of wood reaches saturated state and there is no free water in the cell cavity, the moisture content of wood at this critical status is called fiber saturation point (or F.S.P.). The average fiber saturation point is 30%, which is the transitional point that determines if the strength and volume of wood change with its moisture content.

### 10.3.2 Dry Contractility, Soaking Expansion and Warpage of Wood

When the moisture content of wood ranges from 0% to fiber saturation point, its size and volume will change relevantly, namely, dry contraction or soaking expansion may appear, whose degree depends on the amount of vaporized and absorbed water as well as the fiber direction. The linear contraction along the fiber direction is smaller, generally no more than 0.1%, whereas the radial contraction ranges 3%-6%, tangential contraction ranges 5%-10%. When wood is drying, the difference between tangential and redial contraction plus the unevenness of drying contraction may create internal stress inside the wood and cause it warp and crack.

Dry contraction greatly affects the application of wood. It makes the wood crack or warp, which results in the loosened combining of wood structure and the damage of decorative components etc. Therefore, wood should be dried before application to reduce its moisture content to or close to the ambient equilibrium moisture content.



### 10.3.3 Mechanical Properties of Wood

The mechanical property of wood is defined as the performance that wood resists the action of external forces, which is considered in the following aspects.

1) Strength: the ability to resist external mechanical force.

2) Hardness: the ability to resist the press-in of other object.

3) Elasticity: the ability to recover to its primary shape and size when external force stops.

4) Stiffness: the ability to resist deformation.

5) Plasticity: the ability to change its own shape.

6) Toughness: the ability to retain unbroken after receiving maximum deformation.

The above items should be measure to quality solid wood flooring before application.

The strength of wood includes: compressive strength, tensile strength, bending strength and folding strength. Wood is anisotropic fiber, and its strength is related to the angle formed by the stress direction and the fiber direction. The tensile strength parallel to its grain is 20-30 times of that perpendicular to the grain. The compression strength parallel to the grain is 5-10 times of the later.

Factors affecting wood strength are: wood type, volume density, natural defect, temperature, time and moisture content etc. When moisture content changes below F.S.P., its strength decreases with the increase of moisture content, and vice versa.

## 10.4 Types and Selection of Commonly-used Wood Decorative Materials

### 10.4.1 Types of Commonly-used Wood Decorative Materials

Commonly-used wood decorative material mainly includes different wood-based panels, surface decorated wood-based panels, wood strips and assembled wooden floor.



**1. Wood-based Panel**

Wood-based panel is made of wood, wood fiber, wood scraps or the fiber of other plants as raw material added in bonding agent and other additives. It is to avoid waste and to increase the utilization rate of wood, and is the main approach to make integrated use of wood. The main types of wood-based panel are veneer, plywood, laminated wood board, fiberboard and particleboard etc.

(1) Plywood

Plywood is made up of three or more layers of veneer. It is classified to broad-leaf plywood and needle-leaf plywood. Plywood may also be classified according to its structures, bonding performances, surface processing, processing methods, shapes or applications. Commonly-used plywood is ordinary plywood (plywood for general use).

Plywood is known as triply, 5-layer plywood, 9cm board and 12cm board etc. with thicknesses as 2.7mm, 3 mm, 3.5 mm, 4 mm, 5 mm, 5.5 mm, 6 mm, 7 mm and 8 mm, among which 3 mm, 3.5 mm and 4 mm are most used. Single piece can be a whole block and is allowed to be pieced together. The two symmetric veneers backing up the center layer should be of the same thickness and the same tree species or tree species with similar performances, be processed with the same method (rotary cutting or sliced cutting) and with the same grain orientation. Each two adjacent veneers should be with the same grain orientation. The face veneer of each block of plywood should be made of the same tree species.

Ordinary plywood is classified to four types: I-type: weather-resistant plywood; II-type: water-resistant plywood; III-type: moisture-resistant plywood; IV-type: non-moisture-resistant plywood.

(2) Fiberboard

Fiberboard is made in this way: crushing, steeping and grinding waste materials such as slab edgings, sawmill scraps and barks into wood pulp, then processing it through procedures as hot press molding and drying process. According to different performances, it is classified to three types: hard board, semi-hardboard and soft board.

1) Hard board: hard board is of dense board with the density more than $0.80g/cm^3$, including double surface hardboard and single surface hardboard with one side polished and the other side having reticulated patterns. Four quality grades: super, grade one, grade two and grade three, with indexes similar to those of semi-hardboard, but the strength is higher. There are less types of thickness: 2.2mm, 3mm, 3.2mm, 4mm and 5mm etc.



2) Medium density fiber board (MDF): It is made of wood fiber or fiber of other plants added with bonding agent and pressed into panels with the density ranging $0.50$-$0.88g/cm^3$. According to different densities, it is classified to 80-type, 70-type and 60-type. The quality grade includes super, grade one and grade two. The thicknesses are 6mm, 9mm, 12mm, 15mm and 18mm etc. Its main performance indexes are: moisture content 4%-13%, thickness swelling$\leqslant$12%, and tensile strength, static bending strength and nail-holding power etc.

(3) Particleboard

Particleboard is made by gluing and pressing the fiber of wood or other plants (such as sugarcane residue) together.

Its thickness ranges 4-30 mm and the commonly-used is 16mm. Residential use particleboard is mainly of A-type, which is classified to super, grade one and grade two.

The quality indexes include: appearance, with or without metal debris or stains, strength, thickness soaking expansion rate, moisture content and nail-holding power etc.

(4) Laminated wood board

It is a solid panel made of wood lathes pieced together with wood veneers glued on both sides. The veneer is also called face veneer, the layer underneath the face veneer and close to the core-board is called intermediate-lamella. The quality of two face veneers is allowed to have difference, the one of better quality is called face-veneer and the other is back-veneer. Laminated wood board includes one-side sanded, both-side sanded or non-sanded.

The thickness is 16mm, 19mm, 22mm and 25mm, quality grade includes grade one, grade two and grade three. Its core-board should be made of the same tree species or tree species of similar performances, moisture content ranges 6%-12%. The width of core-strip should be no more than the triple of its thickness and is not allowed the existence of big cracks or holes etc. Its intermediate-lamella should have the same wood grain orientation and keep perpendicular to the wood grain orientation of the core-board. The total thickness of the veneers should be no more than 3mm. The face-veneer allows certain mending.

(5) Excelsior Board

It is also called wood-wool or wood-cement board, which is made in this way: shaving wood scraps into wood wool with machine, steeping wood wool in chemical solution and mixing it with cement, then carrying out processes as molding, pressurizing, steaming, setting and drying.



**2. Finishing Wood-based Board**

Finishing wood-based board is made of the above boards as base material with one side or both sides finished.

(1) Finishing Wood-based Board with Paper Impregnated Thermosetting Resins

Impregnate special paper in amino resins (containing melamine), lay and glue it on the surface of wood-based board such as particleboard, medium density fiber board and hardboard, then create the end product after hot pressing.

The surface of this board has performances such as strong hardness, wear-resistance, stain-resistance and resistance to high-low temperature cycles, dry and hot weathers, cigarette burning, water-vapor and corrosion etc.

(2) Decorative Veneered Wood-based Board

It is made of plywood, particleboard, medium density fiber board or hardboard finished with natural decorative wood veneer.

(3) Unsaturated Polyester Resin Decorative Plywood

Known as polychrome plate, it is made in this way: glue a layer of decorative paper on the surface of II-type plywood, coat the paper surface with unsaturated polyester resin, then get the end product after setting. It has performances such as stain resistance, water resistance, high-low temperature cycle resistance and wear resistance.

(4) Wood Pattern Imprinted Wood-based Board

Also named surface decorated wood-based board, it is a new surface decorative board made by imprinting the surface of wood-based board with different patterns (such as wood pattern) with the panel-pattern rubber-roller rotary-imprinting multicolor imprinter. The types are wood pattern imprinted plywood, wood pattern imprinted fiberboard and wood pattern imprinted particleboard etc.

### 3. Thermosetting Resin Decorative Laminated Board (known as decorative board)



It is made by impregnating special paper in melamine resin and phenol-formaldehyde resin and then carrying out hot pressing. Commonly-used thickness is only 0.6-2mm, its surface physical mechanical performances are close to those of finishing wood-based board with paper impregnated thermosetting resins or unsaturated polyester decorative plywood (polyester board).

### 4. Parquet

It is made of quality wood such as ash, Chinese oak, walnut and teak, which is dried and processed into strips. In application the strips are combined to create gorgeous and elegant designs and patterns.

### 5. Timer Line

Timer line is made of wood with hard quality, fine texture, wear resistance, non-cleavage, smooth sectional surface, good processing quality, good paint-coating quality, strong cohesion and nail-holding power, which is dried and processed by hand or with machine. Timer line includes following types.

1) Timer line for ceiling borders: used for the edge sealing of different layers and surfaces and the sealing for different material surfaces; the sealing for the molding lines on ceiling surface; the edge sealing for the equipments on the ceiling.

2) Timer line for ceiling angles: used for the sealing at the junctions between ceilings and walls and the junctions between ceilings and column surfaces.

3) Timer line for walls: used for the edge sealing of different layers and surfaces on the wall and the sealing at junctions between different material surfaces, pressed-edge of dados, pressed-edge of baseboards, decorative edging and sealing of equipments, pressed lines of wall decorative materials and molding lines on wall surfaces.

4) Other timer lines: sealing lines and decorative lines on molding structures, decorative partitions, screens, and different furniture.

Refer to Figure 10.2 and Figure 10.3.

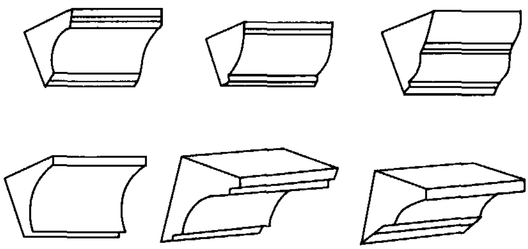


Figure 10.2 Angle Lines

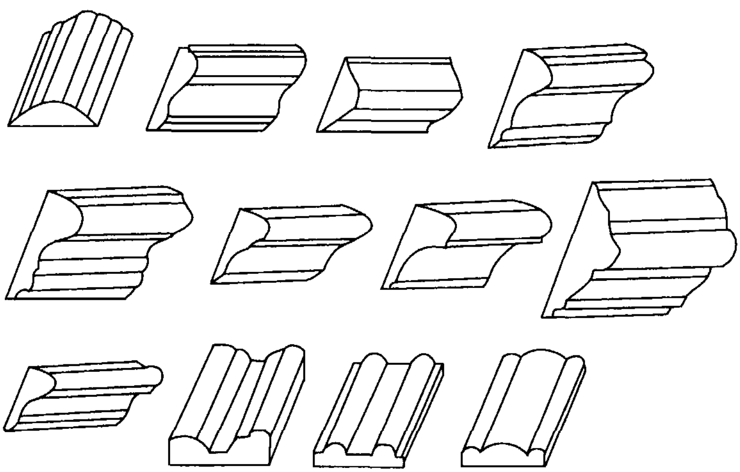


Figure 10.3 Edge Lines

## 10.4.2 How to Select Wood Decorative Materials

There are many different types of wood decoration material with different features and different application scopes.

**1. Plywood**

Plywood is the most largely used material in building decoration, which not only serves as the base material for other surface decorative material, but also is directly applied in surface decoration to create the decorative effect of natural wood. With large surface area, it is thin and light and bendable, with the advantages as small expansion-contraction deformation, appealing surface and high strength. Therefore, it is the unique material in building decoration and furniture manufacturing.

**2. Fiberboard**

Hardboard has high density and high strength, which is a quality substitute for wood and is the commonly-used panel in building decoration and for furniture manufacturing. It is applied to many places such as dados, doors, roofs, partitions and furniture etc. Semi-hardboard is available for packing and partial decoration. The new type flooring decorative material (composite floor board), which takes semi-hardboard as base material and special wear-resistant plastic as face-veneer, has the features such as cigarette-burn resistance, chemical stain resistance, easy cleaning, resistance to heavy pressure and wear resistance (triple of that of ordinary face veneer).Such kind of floor is the most suitable for the decoration and renovation of conference rooms, office rooms, medium and high-end tourism restaurants and residential buildings.



**3. Particleboard**

There are many types of particleboard. According to different bonding agents, it is classified to particleboard (taking organic glue as bonding agent) and cement particleboard (taking cement as bonding agent). The surface of particleboard is classified to covering and non-covering types. It has such advantages as lightweight, sound insulation, thermal preservation, fire resistance, insect resistance and it is economical etc. It is available for the decoration of exterior and interior walls, floors and roofs.

**4. Laminated wood board**

According to surface processing status, laminated wood board is classified to three types: one-side sanded, both-side sanded and non-sanded; according to different bonding agents, classified to I-type and II-type; according to material quality and processing technique quality of the face-veneers, classified to three grades: grade one, grade two and grade three. It has features such as lightweight, sound absorption and thermal insulation and is suitable for furniture manufacturing and the interior decoration and renovation of buildings.

**5. Thin Decorative Wood Veneer**

As an advanced decorative material, it has beautiful patterns and creates realistic feelings and strong 3d impressions.

**6. Chinese Lacquered Building Decorative Board**

Chinese lacquered building decorative board has bright lacquer film and many styles and patterns. It is beautiful and elegant, resistant to hot water and to fire burning etc. Such high-quality decorative board is suitable for the interior decoration and renovation of advanced buildings, at areas such as columns and walls.

**7. Pattern-imprinted Wood-based Panel**

Pattern-imprinted wood-based panel has beautiful and vivid patterns, fresh and coordinated glosses and creates 3d impressions. Its surface is glossy with certain resistance to wear, heat, water and stain etc. It is directly applied to interior decoration, residential wood doors and furniture surface decoration etc.

**8. Parquet**

With hard and solid surface, it is wear resistant, not easy to deform or crack, moreover, its surface has soft and mild glosses and beautiful patterns, which presents beautiful and elegant designs after jointing together. It is an advanced floor decorative material.

**9. Timer line**

Timer line has smooth surface. Its edges and corners and arch-surfaces as well as arch lines are solid and firm and in clear contour. It is painted to different colors and the prime color of wood grains and is available for joining together. It is widely adopted in interior decoration projects, serving as ceiling edges and angles, wall angles and edges etc.

**10. Melamine Board**

"Melamine" is one of the resin bonding agents for making boards. First steep paper in different colors and with different textures in the resin, after drying and solidifying it to certain extent, put it on the surface of particleboard, semi-hardboard or hardboard, and melamine board is produced after hot pressing. Its canonical name is surface decorated wood-based panels with paper impregnated melamine resin; the name "melamine board" only shows one part of its surface decorative components.

There are different base materials for melamine board. Presently, the melamine board furniture sold to families mostly adopts semi-hardboard and particleboard as base material. Semi-hardboard is better than the later in performances, with even internal structure, bigger bonding power, less deformation, good flatness of surface and strong nail-holding power. Therefore, melamine board taking semi-hardboard as base material is more solid and durable, and is more excellent for furniture. Particleboard has relatively looser texture, weaker nail-holding power, and of course costs less than the former.



Melamine board is able to solidify the appearance of furniture. The paper printed with colors and imitated wood grains is flimsy itself, whereas after steeping in the translucent melamine resin, the resin filmed paper is solider and harder. After hot pressed together with the base material, it has excellent performances. Furniture made of such kind of board does not need to be covered with additional coating, because a protective film has already been created on the surface, which is resistant to wearing, scratching, acid and alkali, burning and stain.

In selection, besides color and texture, there are some other factors related to its appearance quality: stains, scratches, press traces or holes on the surface; even color and gloss; bubbles and breakage or defects on the paper.

## 10.5 Selection of Decorative Wood

### 10.5.1 "Three Checks" When Purchasing Decorative Wood

First, check if it is genuine (or original). Manufactures sometimes sell product made of domestic board as that of imported board, low grade board as advanced board, especially sell fakes as those of global fame brands. Users should first check the trademark, factory address, grade and anti-fake label on the whole package. After conforming it is genuine, check the quality. Low quality board often has burrs around the surface, whereas quality board is trim and smooth with uniform and dense laminated layers and the board surface is flat and with uniform color and gloss, rarely with knots or patches. Particle board, semi-hardboard and sapele board are in many different thicknesses and grades at considerably varied prices. High quality board is not only thick but also compacted and dense, not likely to swell or deform in water.

Second, check if the quality of log material is reliable. There are overflowing fakes in many ways. Consumers should keep aware of fakes, learn about the tricks of faking and make sure purchase after conforming that the product is genuine and the price is in accordance with the quality. Timer is excellent seasoned material with no bending or deformation, with no fracture or decay, with less rake of wood grain, no resin trace, no white spot or honeycomb and with small and less knots.



Third, check if semi-manufactured products are of the same material. Because some clients prefer to buy un-coated semi-finished products, some manufacturers may mix the fake in the genuine, e.g. use quality material on the surface but less quality material on the back and in interlayer; even worse, show consumers high quality samples but provide less quality goods after payment. There are more fakes for products such as wood floors, wood doors and windows, wood dados, wood strips and grilles etc. When buying these kinds of goods, users should check carefully, not only to confirm the exterior quality, but also to confirm that both the surface and the core layers match the requirements. Especially to whole bundles of wood strips and floor boards, check if there are short or low quality pieces inside. To make sure windows and doors are well processed and firmly jointed, tenons and mortises instead of nails should be used for joining; the sectional surface of wood and the edge-covering wood are not allowed to expose.

## 10.5.2 How to Select Plywood

Pay attention to the following aspects when selecting plywood.

1) The back and the front of plywood are different. Plywood has clear wood textures (or grains); its front is bright, clean and smooth, flat and with no sluggish feeling to touch.

2) Plywood is required to have no defect such as breakages, bumps, dog marks, scars or knots etc.

3) Plywood should have no adhesive failure.

4) Some plywood is made by sticking together two veneers with different grains, therefore, when selecting, consumers should notice if the joint is solid and tight, even and flat.

5) Plywood with no bonding dispersion is preferred. Knocking at different areas of the plywood, clear and crisp sound marks fine quality, low and rumble sound shows the existence of bonding dispersion in plywood.

6) When selecting finishing plywood, the uniform of colors and textures should also be taken into consideration. Moreover, the luster of wood should be coordinated and harmonized with the furniture coating.

## 10.5.3 How to Select Massive Plate

It is also called laminated wood board and is applied to almost all home decorative projects. The quality of the board directly affects the decorative effect. There are several problems to be noticed in selection.



**1. Machine jointed board is the preference**

Its middle sandwich layer is solid wood (or wood block). It is produced with two jointing methods: hand jointing and machine jointing. The joints on panels made by machine are more uniform.

**2. The joint no more than 3mm**

It is better to have smaller gaps between the middle sandwich wood blocks, and the maximum should be no more than 3mm. Saw open a section for checking.

**3. It is better to take poplar or pine wood as the middle sandwich layer material. Mixed hard wood is not allowed, because it is not able to "hold nail"**

**4. Surface Sanded Status**

Quality laminated wood board is both-side sanded, feeling very smooth.

**5. Moisture Content**

In Beijing, the moisture content of wood should range 8%-12%; high quality board is vapor-dried, so its moisture content meets the requirement; low quality board is often not qualified in moisture content.

**6. Environmental Index**

Laminated wood board is composited with bonding agent that is mainly composed of formaldehyde, whose content should be less than 50mg/kg. Some brands don't take formaldehyde as bonding agent, so their formaldehyde content is qualified. Check the inspection report and confirm by calling the manufacturer at the telephone number marked on the surface of the board.

**7. It is not enough to check the appearance only. Product of reputable brand is more reliable in quality**

Shop around and believe in the law of "cost is in proportion to quality". Product should be selected based on how much money you have. Do not believe the myth of low price for famous brand which is often advertised by some suppliers.



## 10.5.4 How to Select and Purchase Suitable Veneers

The quality of veneers can be judged in the following four aspects, which are also main standards for measuring the quality of veneers.

(1) Skin (Veneer) Thickness

Thicker skin provides better durability. After paint-coating, solid wood impression is enhanced, the grain is more distinct, the luster becomes fresher and more saturated. The method to differentiate skin thickness: observe the veneer edge, see if there is sand or bonding agent leakage; if there is color deterioration or ground exposure after water test. If any of the above problems appears, the veneer is not thick enough.

(2) Material of the Base Plate

It is better to take Meranti as base plate but poplar wood core is common in the market. It is judged as follows: firstly, check the weight of the plate, the heavier is mostly Meranti or other hard wood, the lighter is poplar wood; secondly, observe the color of the middle plate, even white wood or middle plate covered with color disguising process is mostly poplar. Thirdly, check if it warps and if it stands upright. The boards that become warped when naturally laid horizontally or that are too soft or loose to stand straight are made of ungraded base plates.

(3) Processing Technique

It is measured from the following aspects: lamella shaving, laying and jointing process, mending of defects, sanded defects, base plate defects, other appearance defects and stains etc. When people with normal eyesight observe it in a distance around 1-1.5m, those without defects affecting the decorative beauty, such as process defects, base plate defects, manual defects or stains are deemed super. Those with visible defects or severe defects should be degraded to grade one or grade two.

(4) Beauty and Decorativeness of Board Surface

Board surface with clear grains, regular arrays, beautiful appearance and coordinated luster are regarded super; board surface with discord luster, irregular color differences or even color deterioration or darkened color is degraded to grade one or grade two. As to natural defects such as black spots, knots and scars etc., when people with normal eyesight observe it at a distance around 1.5-2m in normal light, those with no visible natural defects affecting its beauty and decorativeness are deemed super; those with apparent visible defects are degraded to grade one; with serious defects, degraded to grade two. Moreover, it is the precondition of the above four aspects to select veneers of reputable brands produced by qualified manufacturers, with quality certificate and standard package, and meeting the national standards.



### 10.5.5 How to Select and Purchase Timber Floor

1) Find out the material and the color (dark or light) of the floor. The price of timber floor varies greatly due to its different raw materials. Different species of wood provide different colors and textures to the floor. Consumers should make decisions based on their economic power and their preference to colors and patterns. As to the color of the floor, the coordination of the entire room should be taken into consideration. Generally unbalance color tone should be avoided.

2) Dimensions of wood floor. The size of wood floor pieces is related to its ability to resist deformation. In the same condition, smaller pieces are less likely to deform. So usually pieces with smaller length and width are preferable. Besides, the size of floor pieces is related to the price and the space of the room: larger pieces cost more; smaller room is not suitable to apply larger pieces.

3) Appearance quality of the floor. The existence of decay and broken edge is not allowed on the floor surface of premium, first and acceptable grades; cracks are not allowed on the floor surface of premium and first grades, whereas acceptable grades allow only two pieces; 2-4live-knots with dimensional limit are allowed on the surface of premium and first grades pieces, no quantity limit to acceptable grades. Premium grades are not allowed to have death-knots or wormholes, while first grades are allowed to have but with quantity limitation.

4) Processing precision. Consumers can check the processing precision with simple methods. For instance, take 10 pieces from the packing case and lay them horizontally on flat ground for model jointing. There should be no apparent height difference or gap.

5) Paint-coating quality. The commonly-used UV coating wood floor is classified to glossy coating and matt coating etc. Observe the coating and see if it is uniform, saturated, clear and clean, no lack-coating, no bubbles and no holes.

6) Choose wood floor with qualified moisture content. Moisture content is the important factor that determines whether there is deformation after installation. It can be measured quickly with the seller's watercutmeter, simultaneously the uniformity of moisture content should be noticed. It is notable that the moisture content of wood floor is required to be lower than the equilibrium moisture content of the selling place, and the ideal is to be close to the later.



## 10.6 Wood Floor

The types of wood floor are timber floor (paint-coating floor or plain floor), solid wood laminated floor and reinforced laminated floor, in addition, there are bamboo floor and cork floor.

### 10.6.1 Timber Floor

It is made by directly processing wood material and is the most commonly-used material for interior floor decoration and renovation. It is natural, rustic and noble, creating affinity and elegant interior ambient; it has good elasticity and feels comfortable; it feels warm in winter and cool in summer, balancing the interior humidity and temperature; it doesn't send out any hazardous gas, and is a real green environmental protective material. Due to its advantages, solid wood floor board is popular to consumers.

Adopting different species of wood, it varies noticeably in hardness, natural gloss and texture. According to laying and joining method, timber floor is classified to mortise-joint, flat-joint and embedded floor, among which the most commonly-used is mortise-joint board; according to surface coating status, classified to paint-coated and un-coated (known as plain wood floor), nowadays the most commonly-used is UV board; according to the adopted species of wood, to domestic and imported. Domestic wood floor is usually made of birch, Manchurian ash, Chinese oak, European beech, beech, elm, hard maple, walnut, maple or mono maple as raw material; the most commonly-used species are birch, Manchurian ash and Chinese oak. Imported board is mostly made of Kempas, Mengaris, Balsamo, Ipe, teak, Bubinga, Jatoba, Cumaru, Kulim, Punah or Macaranduba.

The national standard of timber floor in our country has specified as superior quality, first quality and quality three grades.



## 10.6.2 Composite Floor Board

Composite floor board is a new floor type in the market of China, which has been used in recent years. Presently, there two main types in the market: solid wood and reinforced. They have different features and therefore different requirements in usage and maintenance aspects.

It directly takes wood as raw material, so retains the advantages of natural solid wood floor board such as natural textures and comfortable feelings, but its surface is weaker than that of reinforced board in wear resistance.

Reinforced composite floor board is made of sub-marginal logs and branches added with bonding agent and processed with certain production technique. It has flat surface, trim patterns, strong wear resistance, hard feelings and easy maintenance. Consumers should learn in detail the features of these two types of composite floor board and make choices based on self preferences.

### 1. Solid wood composite floor board

Solid wood composite floor board is classified to tri-layer and multilayer. Tri-layer is produced by gluing and hot pressing the surface veneer made of quality and precious wood and the middle and bottom layers made of fast growing wood. The surface thickness is around 4mm, core layer ranges 8-9mm, bottom layer is around 2mm, the total thickness ranges 14-15mm.

Multilayer solid wood composite floor board takes multiple layers of plywood as base material, the surface layer is hardwood lamina jointed panel or sliced veneer. It is made through gluing and hot pressing. Usually there are three or five (odd number) plywood layers; if the surface layer adopts hardwood lamina, usually it is 1.2mm thick, if adopts sliced veneer, 0.2-0.8mm thick; the total thickness is no more than 12mm.

Solid wood composite floor board inherits the merits of solid wood with natural and gorgeous wood pattern, comfortable feeling, sound insulation and thermal preservation etc., simultaneously it surpasses the disadvantage of deformation of the latter (wood fiber of each layer keeps perpendicular to one another, which disperses the amount of deformation and stress). And it is in large dimensions, which leads to easier installation. The disadvantage is that if bonding is ineligible, it tends to result in adhesive failure. And due to its thinner surface layer (especially to multilayer board), maintenance is of great importance in service, so there is relative limit to its application scope.



Solid wood composite floor strips are bonded together with glue whose emission rate of formaldehyde is a very important index, for which there is obligatory standard in China, that is, "*Limitation to Formaldehyde Emission Rate of Synthetic Panels and Relevant Products in Interior Decoration and Renovation*" (GB18580-2001). The standard has specified that solid wood composite floor must meet E1 level requirements (formaldehyde emission rate $\leqslant$ 1.5mg/L) and mark it clearly on the product label.

**2. Reinforced composite floor board (Impregnated Paper Layered Wood Floor Board)**

Structure: reinforced composite floor board is composed of four layers.

The first layer: wear resistant layer. Mainly composed of $Al_2O_3$ (alumina), with strong wear resistance and hardness. Some reinforced composite floor board composed of melamine can not meet the requirements of standard.

The second layer: decorative layer. It is a layer of paper steeped with melamine resin, and the paper is printed with wood grains imitating precious species of trees or other patterns.

The third layer: base layer. It is semi-hardwood or hardwood laminated plate. After high temperature and high pressure treatments, it has certain moisture-proof and fire retardant performance, its basic material is wood fiber.

The fourth layer: balance layer. It is a layer of craft paper with certain strength and thickness, and steeped with resin that plays the role of moisture-proof and anti-deformation.

Main quality indexes are as follows:

1) Surface wear resistant revolutions: for public application, ≥9000r/min; for home application, ≥6000 r/min. Above revolutions are initial wear resistant value, namely, the revolutions reached when the surface layer is worn out, not the final value of wear resistance when the whole floor is worn out (some reinforced composite floor in marketplace is clearly marked with high wear resistant revolutions, but it is possibly the final value of wear resistance).

2) Thickness soaking expansion rate: it is defined as the thickness expansion of the base layer after the board is steeped in 25℃ water for a certain period of time, counted in percentage. The bigger the thickness soaking expansion rate is, the greater its strength decreases when receiving moisture, and even worse the surface tends to bulge and even fall off, which severely shortens its service life. Presently there are different brands of products in the market, whose thickness expansion rate are more than 10 times different.



3) Surface impact resistance: carry out impact test to the wood floor with specified method, the diameter of the impact concave is the factor used to decide the impact resistance. Smaller diameter stands for better impact resistance and longer service life. The wear resistant layer of reinforced composite floor is more than 0.1mm, maximum thickness up to 0.7mm.

4) Formaldehyde emission amount: according to the specifications in GB18580-2001, reinforced composite floor is a product directly applied to interior use. So its formaldehyde emission amount should meet E1 level, namely, ≤0.12 mg/L.

Besides the above aspects, there are indexes such as static bending strength, internal bonding strength, density, water content and adhesive strength. The wear resistant grade and formaldehyde limitation amount should be marked clearly on the product.

Merits of reinforced composite floor board are mainly as follows:

1) Wear resistant: around 10-30 times of that of ordinary paint-coated wood floor.

2) Beautiful: with different emulated designs, wood grains, patterns and colors.

3) Stable: thoroughly dismantle the primary wood structure and destruct the anisotropy and the features of soaking expansion and dry contraction of wood. With excellent dimensional stability, it is especially available for rooms with geothermal power system.

There are other advantages such as impact resistance, antistatic, stain resistance, light proof, cigarette burning resistance, easy installation and simple maintenance. Its disadvantages are irrecoverable after damaged by water and unappealing to touch. What must be pointed out is some sellers said reinforced composite floor board is "waterproof", which is true only to the surface; as a matter of fact, what should be avoided in use is to soak it in water.

### 10.6.3 Bamboo Floor

**1. Features**



Bamboo floor is made of bamboo at proper age processed delicately. It has good appearance, fresh and elegant fashions, straight-through grains and elegant color tones; it is strong and smooth with high hardness and fine textures, which present antique rustic and natural decorative effect. It provides living rooms with more cultural atmosphere; its natural luster is very gorgeous and springy; the board is moisture and mould proof with strong hardness. Due to the low heat conductivity, it feels warm in winter and cool in summer; no matter in which season, people can comfortably walk barefooted on the floor. It is especially suitable for rooms for senior people and kids. The arch surface of bamboo creates charming external appearance, and what's more, bamboo board is suitable for rooms with geothermal power system.

**2. Classifications of Bamboo floor**

Based on color, bamboo floor in the market is mainly classified to two types. One is of natural color, whose color difference is less than that of wood floor. Because the growth radius of bamboo is far smaller than that of wood, it is less affected by sunlight, so no apparent color difference between the sun-exposed and the shadow sides. Therefore bamboo floor made of fresh raw bamboo has rich bamboo grains and even luster, and with relative uniform color tone. This type is further classified to prime color and carbonized color: the surface of the former is processed with varnish and retains the primary color of bamboo, which is bright and lively; the latter is close to walnut color which is in fact created by baking, bamboo grain is seen clearly in the solemn and firm sensation. The other type is man-made paint-coating, in many different colors but with less bamboo texture left.

Due to its high hardness and density as well as charming texture, bamboo floor is somewhat better than other wood flooring in performances such as heat conductivity, thermal stability and deformation resistance.

### 10.6.4 Cork Floor

To make it easy, cork flooring is a floor material made of cork wood particles and elastic bonding agent processed with special techniques and equipments, usually 3.2-4mm thick. Strictly, cork wood is not wood but the bark of oak. The main component of cork wood, cork wood fiber, is made up of polyhedron death cells with the inter-cell spaces full of mixture gas which is almost the same as natural air. Special structure and components develop a series of special properties of cork wood: lightweight, flexibility and resistance to compression, strong impermeability, moisture-proof and corrosion resistance, weak conductibility, thermal insulation, sound insulation, wear resistance and incombustibility. Cork wood is composed of countless air chambers and numerous suction cups are formed on its surface, when people walk on it, cork wood is able to slightly adhere the footstep to the floor surface, lessen the relative displacement between footstep and the floor and lessen the friction, which increases its wear resistance and prolongs its service life, moreover, reduces noise and absorbs sound.



In addition, cork floor also has the following features: suitable structure, good dimensional stability; under thermal shock or moisture shock, it keeps no cracking or warping, suffers no corrosion or insect attack; due to its thermal preservation and insulation, in summer it helps to keep out the hot air, in winter it avoids the leakage of interior hot air through ground, which makes it a good insulator, especially suitable for places with many electronic apparatuses and requiring antistatic performance; with natural and comfortable and springy feeling, it is able to reduce injuries caused by falling. It is also conducive to the growth of bones for kids and the protection of knee joints for adults, especially for senior people. People are less likely to feel fatigue or tired when walking or standing on cork flooring for a long time.

## 10.7 Decay and Decay Prevention of Wood

Wood is natural organic substance, so it is easy to decay and get burnt; in construction, approaches for decay and fire prevention should be taken into consideration.

### 10.7.1 Corrosion of Wood

Common wood-destroying fungi include stain fungi, mould fungi and rot fungi. The former two have less affects to the strength of wood. Rot fungi secrete ferment which resolves the cellulose in the cell wall of wood into simple substance as its own reproducing nourishment, and this leads to the decay and destruction of wood. There are three prerequisites for rot fungi to live and reproduce in wood: suitable water, air and temperature. If moisture content ranges 35%-50%, temperature ranges 25-30℃ and with sufficient air, wood is at the best chance to get rotten. Besides fungi, wood is also decayed by insects such as termites and longhorn beetles etc.



### 10.7.2 Decay Prevention Approaches

There are two approaches to prevent decay: one is to create conditions to prevent fungi from infesting or reproducing; the other is to carry out chemical treatments to destroy or deter the growth of fungi.

The first approach is to keep the wood dry, with its moisture content less than 20%. Different paint-coating on wood surface not only develops good appearance but also isolates air and moisture.

The second approach is to process the wood with chemical preservatives, which is more effective for decay prevention. There are mainly water-soluble and oil preservatives. Oil preservative has certain waterproof function.

The methods for preservative treatment include spraying method, immersion method, pressure permeability method and boiling-cooling method.

### 10.7.3 Fire Prevention of Wood

Wood is poor in fire resistance, its fire prevention methods mainly include surface coating method and fire retardant solution immersion method.

(1) Surface Coating Method

Surface coating method is to paint fireproof coating with the methods such as brushing, spraying and rolling, which plays the role of fire resistance, corrosion resistance and decoration. It is a common fireproof method.

Fireproof coating: a decorative coating layer on the surface of the combustible base material to change its reaction to fire.

Surface decorative fireproof coating has both fireproof and decorative functions. Here is how it works.

1) Isolate the combustible base material from the air;

2) Release inert gas to deter the burning;

3) Expand and form carbon foam thermal insulating layer.

(2) Fire Retardant Solution Immersion Method

Fire retarding and fire retardant: To retard is to delay, postpone or even wholly remove the occurrence of fire accident to ensure the safety of life and property. Retardant is the specialized fireproof product mixed into different materials to achieve the above stated functions.

After retardant solution immersion treatment, the conbustibility of wood is changed. When wood is on fire, the interior temperature declines remarkably due to the reasons: first, the burning carbonization speed of the wood is slowed down, the radiation and convection heat transfer to the wood from external heat source are postponed; second, the heat released by the burning wood itself is decreased, which reduces the heat effect to the adjacent position of burning carbonization area.



Commonly-used wood retardants are as follows:

1) Phosphor-nitrogen series;

2) Borium series;

3) Halogen series;

4) Metallic oxide or hydrate retardants containing aluminum, magnesium or antimony etc.;

5) Other Retardants.

# Practice

Practice one: carry out investigation in the local markets of building decorative materials, learn about the types, features, application status of wood decorative materials; collect samples and write research reports.

Practice two:

1. Task: according to local practical conditions, select proper wood decorative materials for the decoration and renovation of a certain home (or public building). For instance, wood floor, door and window frames, wood dados and timber lines etc.

2. Requirements: select proper materials based on factors such as functions of use, decorative effects, indoor environmental pollution and expenses etc.

3. Objective: Learn about the types, performances, application status and prices of wood decorative materials.

4. Method: 2-3 students in a group; carry out simple designs and decide the application areas of wood decorative materials based on the plane-view drawing of a certain home; according to selection requirements, select proper wood decorative materials in terms of types, colors and shapes etc.; make relative drawings and write out selection reasons.



## Summary

This chapter introduces the components, classifications and mechanical properties of wood, as well as the types and the selection of commonly-used wood decorative materials; features and classifications of wood floor; decay and decay prevention of wood etc. Among them, the features and the selection of commonly-used wood decorative materials are the focal points of this chapter.

## Questions for Reviewing and Thinking

10.1 What are the merits and disadvantages of wood?

10.2 How to prevent wood from dry contraction, soaking expansion or deformation?

10.3 What are commonly-used wood-based boards and wood-based decorative boards? How to make selection based on practical conditions?

10.4 What are the types and features of wood flooring?

# 11

# Decorative Plastics

With the development of petroleum industry, plastics are more and more widely used in building and decorative projects. New type building decorative materials, mainly plastics, are constantly coming to the fore. Plastic decorative material and its products have unique merits such as lightweight, electric insulation, corrosion resistance, heat insulation and sound insulation. It has resourceful raw material and needs simple manufacturing technique and is easy to process and mold, which makes it available for industrial production. But plastic has disadvantages: some of its mechanical strength is lower than that of metal; it has lower thermal-stability but higher heat-expansion coefficient; it is easy to deform, easy to get aged by atmospheric action etc. Presently, deeper scientific research is carried out on its performances to find out methods to overcome or compensate its disadvantages and to develop and perfect its modified types.



## 11.1 Introduction of Plastic

### 11.1.1 Components of Plastic

Plastic is made by taking synthetic resin as basic material, adding filler, plasticizing agent, curing agent, coloring agent and other additives etc. at certain ratio, then processing them to make the end product. Plastic material produced after processing or toughened material made by solidifying and cross-linking have bigger plasticity at certain temperature and under certain pressure, so they are easy to make into products in different shapes and dimensions. After molding, they retain their shaped form and necessary strength at normal temperature. Commonly-used plastic and its products in building and decoration projects are as follows.

**1. Synthetic Resin**

Synthetic resin is a chemical organic compound mainly composed of atoms such as carbon, hydrogen and a little oxygen, nitrogen and sulfur etc. combined together with certain chemical-bond. Synthetic resin, as a bonding agent, is the main component in plastic. It not only bonds together its own structure, but also bonds other materials together tightly and firmly.

Plastics is made by adding to resin with fillers and additives that play apparent function of modification to plastic, but resin is still the most primary factor that determines the features and main applications of plastic. The content of resin in plastic is around 30%-60%. According to different chemical reactions in production, synthetic resin is classified to polymer (poly-addition) resin (such as polyvinyl chloride and polystyrene) and condensation (poly-condensation) resin (such as phenolic aldehyde, epoxy and polyester etc.); according to the change in performances when heated, classified to thermoplastic resin and thermosetting resin.

Plastic made of thermoplastic resin is thermoplastic plastic. It becomes soft when heated, then melted at even higher temperature, whereas it is hardened again when temperature goes down. This procedure goes repeatedly without considerate affect to its performances and appearance. Polymer resin is thermoplastic resin with low heat resistance and low stiffness but with good performance of impact toughness. Plastic made of thermosetting resin is thermosetting plastic. During processing, thermosetting resin becomes soft when heated, but after setting and molding, it no long changes its form even when heated again, namely, it is available for plastic molding, setting and hardening only once. Condensation resin is hard and brittle thermosetting resin with better heat-resistance and higher stiffness.



**2. Filler**

Filler, also called filling agent, is the indispensable raw material for most plastic and takes up 40%-70% of all the components in plastic. It is to improve the plastic in aspects such as strength, toughness, heat resistance, aging resistance and impact resistance, and to reduce its cost. Commonly-used filler includes talc powder, diatomite, limestone powder, mica, graphite, rock wool, glass fiber, and also wood powder, wastepaper, waste-cotton and waste-cloth etc.

Filler plays an important role in plastic industry. With the development of the research on filler, especially with the creation of coupling agent used to improve the bonding power between the filler and resin, the function of filler as a component of plastic is further developed.

### 3. Plasticizer

The purpose of adding plasticizer is to enhance the material of its plasticity, pliability, elasticity, shock resistance, frost resistance and elongation percentage etc., however, it reduces the strength and heat resistance of plastic. Requirements for plasticizer are: good miscibility with resin, colorless and nontoxic and with less volatility. Plasticizer adopts involatile liquid chemical organic compound with high boiling point, or low melting point solid substance. Commonly-used plasticizer includes dimethyl phthalate, dibutyl phthalate, dioctyl phthalate and triphenyl phosphate etc.

### 4. Curing Agent

Curing agent, known as hardening agent, has the main function of converting linear high polymer into three dimensional high polymer by cross-linking, and providing the resin with thermosetting property. Curing agent includes: amines (ethylene diamine, diethylenetriamine and lentine) applied to epoxy resin; hexamethylene tetramine (urotropine) used in some phenolic resin, acid-anhydrides (phthalic anhydride, maleic anhydride) and macromolecules (polyamide resin).



### 5. Coloring Agent

Coloring agent, also called colorant, is to dye the material to needed colors. According to its dissolvability in coloring medium or water, it is classified to dye and pigment.

1) Dye: a chemical substance dissolved in the solution playing the function of dyeing colors through the ion or chemical reactions. As a matter of fact, dye is organic substance with fresh color gloss, good coloring performance, but with weak alkali-resistance and heat-resistance, and tends to dissolve and fade affected by ultraviolet.

2) Pigment: an insoluble fine powder creating colors by its own spectral absorption and its reflection to specific spectral light. Besides the excellent function of coloring, it improves the performances of plastic as a stabilizer and filler. To plastic products, inorganic pigment such as carbon black and cadmium yellow is more widely used.

#### 6. Other Additives

To improve or adjust some performances of plastic to meet specific requirements in application and processing, different additives are added to plastic, such as stabilizer, fire retardant, foaming agent, lubricant and anti-aging agent etc. There are many types of plastic additives with different chemical compositions and physical structures, and with different acting mechanisms and functioning effects to plastic, so plastic made of the same type of resin has different functions due to the different additives added.

### 11.1.2 Types and Features of Building Decorative Plastic and its Products

#### 1. Types of Building Decorative Plastic and its Products

(1) Classified Based on the Change of the Resin When Heated

1) Thermosetting resin. It is softened and partially molten when heated, after cooling, it becomes infusible and solid plastic; after molding, it no longer gets softened again even reheated, only molded and produced once. Commonly-used thermosetting plastic products are made from phenolic resin, urea-formaldehyde resin and unsaturated polyester resin etc.

2) Thermoplastic resin. It is softened and melted when heated, and becomes set and molded after cooling. The procedure can be repeated. Commonly-used thermoplastic plastic includes polyvinyl chloride, polystyrene and polyamide etc.

(2) Classified Based on Synthetic Method of Resin

1) Condensation plastic. Condensation compound is defined as: when two or more different molecules carry out reaction, they release water or other simple substances (such as ammonia and chlorine hydride), and create chemical compound totally different from the prime molecule, called condensation compound. Examples are phenolic plastic, silicone plastic and polyester plastic etc.

2) Polymer Plastic. Polymer is defined as: many molecules of the same type are connected to form huge size molecules with their primary chemical compositions remaining unchanged, the created chemical compound is called polymer. All polymer plastic has thermoplasticity. Examples are vinyl plastic, polystyrene plastic and poly methyl methacrylate plastic etc.

## 2. Features of Building Decorative Plastic and its Products

It is because plastic is more excellent in performances than any other building material that it is widely adopted in construction. Plastic is a material with low energy consumption and high service value.

Compared with traditional materials, plastic has merits as follows.

1) Excellent workability. Plastic can be processed into different products with simple methods, and it is available for mechanized massive production.

2) High specific strength. Namely, the ratio of its strength to its volume density is much more than that of cement and concrete, and is close to or even outdoes that of steel. It is a unique material with lightweight and high strength.

3) Lightweight. The density of plastic ranges 0.9-2.2g/cm$^3$, the average is 1.45 g/cm$^3$, which is only 1/2 that of aluminum and 1/5 that of steel and 1/3 of concrete, and is close to that of wood.

4) Low heat-conductivity coefficient. The conductivity of plastic products is less than that of metal or rock, namely, its heat conduction and electric conduction ability are smaller. Its heat conductivity is around 1/500-1/600 that of metal, 1/40 that of concrete and 1/20 of brick, which makes it an ideal thermal insulation material.



5) Good decorative performance and usability. Plastic products are in gorgeous colors, with abundant glosses and clear designs on the surface to achieve considerable genuine effects by imitating the grains of natural materials; different designs and patterns can be created by adopting techniques such as plating, hot pressing and burning gilt to provide the surface with 3d sensation and metallic texture. By adopting electric plating treatment, plastic is provided with functions such as electric conductivity, wear resistance and barrier to electromagnetic-wave etc.

6) Economical. Plastic building material is energy saving both in production and in service. The energy consumption for plastic products, which ranges 63-188kJ/m$^3$, is lower than that for traditional materials, e.g. up to 316kJ/m$^3$ for steel, 617kJ/m$^3$ for aluminum. Plastic windows, taking the place of steel windows, have good thermal insulation and help to save air-conditioning expenditure; the water conveying capacity of plastic pipe is 30% higher than that of any other pipe due to its smooth internal wall, which helps to save a great amount of energy. Therefore, great economic and social benefits are created from the wide application of plastic building materials.

Plastic has its own disadvantages:

1) Easy to get aged. When plastic is affected by heat, air, sunlight and acid, alkali and salt etc. in the environmental media, its molecular structure deteriorates, its plasticizer volatilizes, the chemical-bond ruptures and the mechanical property changes, even worse it becomes hard and brittle and destroyed.

2) Low heat-resistance. Plastic becomes deformed when heated to a certain temperature, even worse gets dissolved, so its service temperature should be limited.

3) Flammable. Plastic is not only flammable, but also releases noxious, stinky gas when burning, which is hazardous to human health, so it is required to add certain amount of fire retardant in production.

4) Low Stiffness. Plastic is a viscoelastic material with low elastic modulus, which is only 1/10-1/20 that of steel and it tends to creep under load for a long time. So it should be carefully considered to apply it to load-carrying members.



In conclusion, plastic has more merits than disadvantages, and the disadvantages are improvable or removable. With the development of petrochemical industry, plastic is more and more widely applied in building industry especially in building decoration. It is one of the development trends of building material in the future, and will replace wood, cement and steel in many aspects and become one of the main building materials in construction projects.

### 11.1.3 Types of Plastic Serving as Building Decorative Materials

#### 1. PVC (Polyvinyl Chloride)

PVC is the raw material of many types of plastic decorative material such as plastic wall paper, plastic flooring and plastic gusset plate. It is a multifunctional plastic. With different formulas, it is made into hard or soft products, and also into light foaming products.

PVC has good fire resistance and self-extinguishing performance. It is resistant to ordinary organic solvents but soluble in solvents such as cyclohexanone and tetrahydrofuran, and because of this, PVC can be bonded with the above solvents. Hard PVC product has good ageing resistance and mechanical properties, but weak impact resistance which can be improved by adding impact modifier such as chlorinated polyethylene.

**2. PE (Polyethylene)**

PE is combustible with its burning flame in light blue, and it will drop when molten, which is likely to expand the flame. As a building material, PE product is added with fire retardant to improve its fire resistance. It is a crystalline polymer, whose crystallization degree is related to its density; usually higher density leads to higher crystallization degree. With wax-like translucent appearance, PE has low light-transmittance, good solvent-resistance and flexibility (or pliability), moreover, its low-temperature resistance and impact resistance is much better than those of PVC.

**3. PP (Polypropylene)**

PP has relatively smaller density among plastics, around 0.9g/cm$^3$. Its flammability is close to that of PE, combustible with light blue flame and tends to drop when molten, which is likely to cause fire. Its heat-resistance and mechanical properties are better than those of PE. PP has good solvent-resistance, which means it is not soluble in any solvent at normal temperature. The disadvantages of PP include weak low-temperature resistance and certain brittleness. PE and PP are adopted to produce pipes and sanitary wares etc.



**4. PS (Polystyrene)**

PS is a colorless and glass-like transparent plastic with light-transmittance is up to 88%-92%. PS has good mechanical strength, weak impact-resistance and brittleness. There comes tinkle sound when it is stricken. When burning, it releases large amount of black smoke with yellow flame, and keeps burning and releasing styrene-odor after taken away from the fire source. PS is soluble to aromatic solvents such as benzene and methylbenzene.

**5. ABS Plastic**

ABS plastic is rubber modified polystyrene. It is opaque plastic in ivory color with relative density at 1.05g/cm$^3$. When burning, it releases black smoke with yellow flame. Its impact resistance and low-temperature resistance are very good, and the heat-resistance is better than that of PS.

**6. PMMA (known as organic glass)**

It is plastic with the best light-transmittance, up to 92%, so it can be used to take the place of glass, and less likely to get broken. But it is weaker than glass in surface hardness, easy to get scratched. The burning flame is light blue with white top, releasing no drop or smoke but typical monomer odor. PMMA has good ageing resistance. Its transparency and color and luster slightly change after exposed in tropical sunlight for years, so it is used to make weatherboards or billboards.

**7. UP (Unsaturated Polyester)**

UP is a thermosetting resin, before setting, it is a liquid with high viscosity. It sets at room temperature, requiring curing agent and accelerant to help setting. There are many types of raw material, from which UP with different performances is produced by adopting different material formulas or techniques to meet different requirements, e.g., UP for producing glass-steel or ductile UP for making coating etc. UP works easily, which means it is easy to process, i.e. it can be molded under low pressure or with no pressure. Its disadvantage is: when it is setting, its volume shrinkage is high, up to 7%-8%. UP is largely adopted to produce fibre reinforced plastic products.



**8. EP-(Epoxide-resin)**

EP is another thermosetting resin, before setting, it is a liquid with high viscosity or brittle solid, and is easy to solute in solvents such as acetone and xylene; after added in curing agent, it sets at room temperature or high temperature. Room temperature curing agent is ethylene polyamine such as diethylenetriamine and triethylenetetramine; high temperature curing agent includes o-dicarboxylic anhydride and acid anhydride etc. The prominent feature of EP is that it has very strong bonding power with different kinds of material, which is because after setting it contains different kinds of polar group (hydroxyl group, ether linkage and epoxy group) in its molecules. EP has very low shrinkage rate when setting, and even at maximum shrinkage, the resin is still in gel-state with certain fluidity, therefore with no internal stress created.

**9. PU (Polyurethane)**

PU is a thermosetting resin with superior performances and can be made into mono-component or bi-component coatings and adhesive foam plastic.

Different components make it soft or hard. It has excellent performances and is much better than PVC in mechanical performances, ageing resistance and heat-resistance etc. Applied to building coatings, it has very good wear resistance, stain resistance and ageing resistance.

**10. GRP (Glass-fiber Reinforced Plastic, Glass-steel)**

GRP is a thermosetting plastic made by reinforcing resins such as UP and EP with glass fiber (yarn, fabric, chopped fiber, blanket and non-woven fabric etc.). It is a composite material or reinforced plastic with its mechanical strength reinforced with glass fiber, whose strength is even higher than that of steel.

### 11.1.4 Applications of Plastic Products in Building Decorative Projects



In building decorative projects, plastic is widely adopted to produce different kinds of decorative plastic plates (such as melamine laminate plate, hard PVC plate, FRP plate, aluminum-plastic composite plate and polycarbonate PC plate etc.), plastic flooring, plastic wallpaper and plastic doors and windows etc. Moreover, it is also widely applied to the production of different kinds of sanitary wares (such as GRP sanitary wares, artificial agate sanitary wares, acrylic plastering sanitary wares), plastic furniture (such as FRP and GRP furniture, ABS resin furniture, soft or hard sponge foam furniture and acryl furniture). In addition, it is used to produce all kinds and all grades of decorative metal wares (such as plastic door-pulls, different kinds of ornamental pieces), decorative sections (such as plastic pelmet, baseboard, handrail), electrical components (such as lamps and switches), water-heating devices and different pipeline fittings etc.

## 11.2 Building Decorative Plastic Plate

Plastic decorative plate refers to regular-sectional or irregular-sectional plate with decorative function made by processing resin as steeping (or dipping) material or as basic material with certain production techniques. Plastic decorative plate is more and more applied to decorative projects due to its features such as lightweight, high decorative performance, simple production technique, convenient construction, easy maintenance, suitable combination with other materials etc.

According to different raw materials, plastic decorative plate is classified to hard PVC plate, plastic veneer (such as melamine decorative laminate), organic glass decorative plate, GRP plate, plastic-metal composite plate and polycarbonate light-picking sheet etc; according to its structure and sectional shape, classified to flat plate, wave plate, solid irregular sectional plate, hollow irregular sectional plate, grid plate and sandwich panel etc.

### 11.2.1 Melamine Decorative Laminate

Melamine decorative laminate is the most commonly-used plastic laminated sheet, also called paper decorative laminate, plastic veneer, resin plate or fireproof plate. It is a thin surface lining made by adopting thick paper as skeleton, steeping it in thermosetting resin such as phelonic resin or melamine resin, then hot pressing and setting multiple layers together.



Phelonic resin costs less than melamine formaldehyde resin, but it is brown-yellow and non-transparent, so not suitable for surface layer application. Melamine formaldehyde resin is clear and transparent and wear-resistant, often serves as surface dipping material, so the plate is named after it.

Melamine laminated sheet is in multilayer structure, including surface paper, decoration paper and bottom paper. The surface paper is to protect patterns and designs on the decorative paper, to make the surface brighter, solider and harder and to provide it with better wear-resistance and corrosion resistance.

Melamine laminated sheet is made of thermosetting plastic, so it has superior heat-resistance and does not get softened, cracked or bubbled at temperature over 100℃. It is well resistant to ironing and fire. The skeleton is made of thick fiber paper, so it has high mechanical strength and its tensile strength is up to 90MPa, and its surface is wear-resistant. The surface of melamine laminated sheet is smooth and dense with features such as strong stain-resistance, moisture resistance, scrubbing-resistance, durability and resistance to corrosion of solvents such as acid, alkali, oil and grease as well as alcohol.

Melamine laminated sheet is commonly applied to the surface decoration projects of walls, columns, table tops, furniture and suspended ceilings etc.

### 11.2.2 Hard PVC Plate

There are transparent and non-transparent hard PVC plates. Transparent plate is made of PVC as basic material, added in plasticizer and anti-aging agent and extruded to mold. Non-transparent plate takes PVC as basic material added in filler, stabilizer and pigment etc. and is molded after kneading, mixing, lamella-drawing, pelleting and extruding or rolling press. According to its sectional shape, hard PVC plate is classified to flat plate, corrugated plate and irregular-shaped plate etc.

**1. Flat Plate**

The surface of hard PVC plate is smooth, freshly colorful, not easy to deform, easy to clean, waterproof and corrosion resistant. It has good workability and can be sawed, planed, drilled and nailed. It is applied to interior surface decoration and table top surface decoration. Commonly-used dimensions include 2000mm×1000mm, 1600mm×700mm and 700mm×700mm etc., thickness includes 1mm, 2mm and 3mm.



**2. Wave Plate (or Corrugated Plate)**

Hard PVC wave plate is made of PVC as basic material processed with extrusion molding method to create plate with different kinds of wave section, which not only increases its flexural stiffness but also absorbs certain amount of expansion or shrinkage generated from the deformation of the sectional shape. The dimension of its wave is the same as that of ordinary asbestos cement wave tile and color steel wave plate etc. for coordinated application with them when necessary.

Hard PVC wave plate can be colorized freely, often into white or green. Transparent wave plate has a light-transmittance up to 75%-85%. Colored hard PVC wave plate serves as wall decoration or waterproof roof material. Luminescent flat ceiling adopts transparent PVC transverse-wave plate, which, with lamps installed on it, is laid on the wing-flange of ⊥-shape stud. There is no limit to its length, so transparent longitudinal-wave plate can be made into arch light-picking roof with no joint in the middle. Figure 11.1 is an illustration of its sectional shapes.

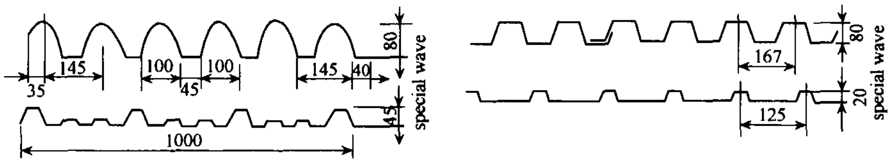



Figure 11.1 Sectional Shapes of Wave Plate

### 3. Irregular-shaped Plate

Hard PVC irregular-shaped plate, also called PVC pinch plate, has two primary structures: one is mono-layer irregular-shaped plate; the other is called hollow irregular-shaped plate. Monolayer irregular-shaped plate has various sectional shapes, among which square wave is commonly-used to create clear lines on the facade. Just like aluminum alloy pinch plate, the two edges of PVC irregular-shaped plate are respectively processed into groove and insert-piece, not only to make the joint waterproof, but also to cover the fastening screws. Each piece has one edge fixed and the other edge inserted to flexible joint, which allows certain transverse deformation to adapt to the transverse hot-expansion or cold-shrinkage. Hollow irregular-shaped plate has thin grid irregular sectional shape. Due to its sealed internal air cavity, it has excellent thermal insulation and sound insulation. Meanwhile, the thin-wall space structure greatly increases its stiffness, which enables it to be better than flat plate or monolayer plate in bending strength and surface denting-strength. Moreover, it saves material with less weight per unit area. There are two types of joining method: tongue-groove joint and hook- groove joint; the former is more popular at present. Structures of hard PVC irregular-shaped plate are shown in Figure 11.2.



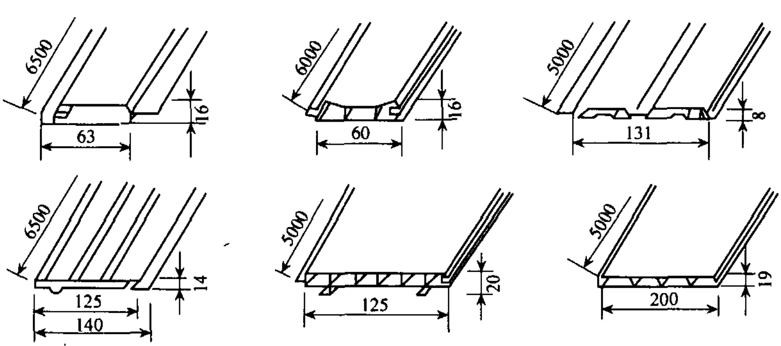



Figure 11.2 Structures of Hard PVC Irregular-shaped Plate

The surface of hard PVC irregular-shaped plate can be printed or combined with different imitated wood grains and imitated stone-like decorative geometric designs. It creates good decorative effects and has features such as moisture-proof, smooth surface, easy cleaning and simple installation. Generally it serves as wall panel or suspended ceiling plate in moisture environment (such as bathrooms and washrooms).

### 11.2.3 GRP Plate

Glass reinforced plastic (shortened as GRP) is made of synthetic resin as main basic material and glass fiber or other product as reinforced material, processed into a solid material by molding and setting.

Synthetic resin adopted to produce GRP includes unsaturated polyester resin, phenolic resin and epoxide resin. Unsaturated polyester resin has good processability, i.e. it sets at normal temperature, and can be made into translucent product. Presently it is mostly adopted to produce GRP decorative material.

Glass fiber is made by drawing molten glass into fine fiber thread, which is a smooth and soft inorganic fiber with high strength in diameter ranging 9-18 μm . It is also combined well with synthetic resin into reinforced material. Glass fiber products such as glass fiber fabric or glass fiber mat are adopted in the production of GRP.

GRP decorative product has great light transmittance and decorative performance and can be made into colorful non-light tight or light tight structural parts or ornamental pieces. Its light-transmittance is close to that of PVC, but with the performance of light-diffusion, it creates soft, mild and even light effect when acting as light-picking roof. It has high strength (superior to ordinary carbon steel), lightweight (only 1/4-1/5 that of steel and around 1/3 that of aluminum), so is a typical light material with high strength; it needs simple and adaptive molding technique and can be made into complicated components; it has good chemical resistance and electric insulation; With good resistance to wet and moisture, it is suitable for some building areas requiring moisture-proofing. The main disadvantage is: its surface is not smooth enough.

Commonly-used GRP decorative plate includes wave plate, grid plate and folded plate etc.

### 11.2.4 Aluminum-plastic Composite Plate

Aluminum-plastic composite plate is a composite panel taking PVC plastic as core sheet. According to structure, the plate with both surfaces covered with aluminum alloy sheet is called double-sided composite panel and the one with only one surface covered with aluminum alloy sheet is called single-sided composite panel; according to application, it is classified to interior wall panel and exterior wall panel. The former usually adopts single-sided composite panel and the later double-sided. Thickness is 3mm, 4mm, 6mm and 8mm, commonly-used size is 1220mm×2440mm. Its surface aluminum sheet, processed through anode oxidation and colorization, has fresh and beautiful luster. Due to its composite structure, it has advantages of both metal and plastic material. Main features are: light, solid and firm, durable in use; with much stronger impact resistance and denting resistance than aluminum alloy sheet; free for bending and no rebound after bending, so convenient for molding; when bending to meet the curve surface of the substrate, no special fixture needed, i.e. it combines with the structure body very well and is convenient for bonding and fixing; due to the surface processing such as anodic oxidation, colorization and paint finishing, it not only has good decorative performance but also strong weather-resistance; it can be cut, riveted, planed (side-edge), drilled, cold-bended and cold-folded, so it is easy for processing, assembling, installation, repairing and maintenance.

Aluminum-plastic composite plate is a new metal-plastic composite plate which is more and more widely applied to building surface decoration of exterior curtain walls and interior walls, columns and ceilings. To prevent its surface from being scratched in delivering or constructional operation, the surface of aluminum-plastic plate is pasted with protective foil, which is uncovered after the construction is completed.



### 11.2.5 Polycarbonate PC Plate

Transparent polycarbonate plate (PC), known as sunlight sheet, is a commonly-used new building material with high strength, thermal insulation and light-transmission in the world at present. It has merits superior to other materials (such as laminated glass, wired glass, tempered glass, insulated glass and organic glass), so is rapidly accepted in building designs, decoration projects, environmental protection and advertising industry. Especially special type PC sheet is applied for bulletproofing and explosion-proofing and is highly valued in security industry.

Transparent polycarbonate sheet is a grid-form irregular sectional plate with hollow structure, which takes polycarbonate plastic as basic material and is processed with extrusion molding technique. It is a quality translucent decorative plate imported in recent years. Its structure is shown in Figure 11.3. The sectional surface is double layer straight-grid structure, the backbone width (*D*) is 6mm, 7mm, 11mm, 18.5mm and 27mm, thickness (*A*) includes 6mm, 8mm, 10mm and 16mm. Both surfaces are covered with transparent protective film （or membrane）. The side printed with patterns is processed with UV protection treatment and should be installed facing outward; the side with no patterns should face inward.

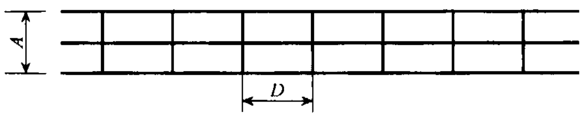



Figure 11.3 Sectional View of Polycarbonate PC Sheet

Transparent polycarbonate sheet is light and thin, and with high stiffness. Its mass per unit area is 1.70-2.94kg/m$^2$, thickness is no more than 16mm. However, due to its multilayer space grid structure, it has high stiffness and is not easy to deform, so it can resist the destructive impact caused by rainstorm, hail or heavy snow; it has gorgeous appearance and is in different colors such as transparent, blue, green ,tea brown and milky white, so it creates excellent decorative effects; it absorbs little water, so is well resistant to water and moisture; good light transmittance: the light-transmittance of 6mm thick colorless transparent sheet reaches 80%; thermal insulation and preservation: due to its hollow structure, it makes full use of the extreme low heat-conductivity coefficient of dry air; good flame retardance: it is flame retardant and gives off no noxious gas in burning, which meets the standard of environmental protection; good weather-resistance: the surface of the sheet is treated with special ageing-resistant processing, no aging, no deformation and no fading appears after long term service, the allowed service temperature ranges 40-120℃； enough deformability: when acting as arched roof, its minimum bend radius reaches 1050mm ( 6mm thick sheet)

Transparent polycarbonate sheet is available for sunshades, hall light marquees, roofs of swimming pools and stadiums, light passages of large buildings and gardens, top hoods of flower or vegetable greenhouses.

As to dimensions of commonly-used PC sheet, refer to Table 11.1.

**Table 11.1 Dimensions of Commonly-used PC Sheet**

| Product | Thickness (mm) | Width (mm) | Length (mm) | Weight ($g/m^2$) |
|---|---|---|---|---|
| Double-layer ~~PC sheet~~ | 6 | 600 1000 1250 2100 | 5800 11800 | 1300 |
| | 8 | 600 1000 1250 2100 | 5800 11800 | 1500 |
| | 10 | 600 1000 1250 2100 | 5800 11800 | 1700-2000 |
| Monolayer PC sheet | 2 | 1220, 1930 | 2440 or any length | 2400 |
| | 3 | 1220, 1930 | 2440 | 3600 |
| | 4.5 | 1220, 1930 | 2440 | 5400 |
| | 6 | 2400 | 3600 | |
| Wave plate | 0.8 | 860, covering width 760 | 2400, 3000, 4200 4800, 5400, 6000 | |
| | Wave height 18 | 1260 | | |
| Film | 0.18-0.77 | | Coil | 214-915 |



# 11.3 Plastic Flooring

## 11.3.1 Performances of Plastic Flooring

Generally speaking, plastic flooring includes all ground cover material mainly made of organic material. Plastic (PVC) flooring is one of the commonly-used building decorative materials and also a plastic product that has been developed earliest and most rapidly.

PVC plastic flooring has various performances. Table 11.2 is the performance comparison of different kinds of PVC plastic flooring.

**Table 11.2 Performances of PVC Plastic Flooring**

| Type / Item | Semi-hard flooring | Filmed-printed flooring tile | Soft mono-color coil | Non-foaming printed coil | Printed foaming coil |
|---|---|---|---|---|---|
| Surface tactile sensation | Purple drawn-pattern, embossed-printed pattern | Flat, embossed orange-peel pattern | Flat, drawn-pattern, embossed pattern | Flat, embossed pattern | Flat, Chemically-e mbossed pattern |
| Elasticity | Hard | Soft-hard | Soft | Soft-hard | Soft, elastic |
| Denting resistance | Good | Good | Medium | Medium | Weak |
| Scratch resistance | Weak | Good | Medium | Good | Good |

Continued

| Item \ Type | Semi-hard flooring | Filmed-printed flooring tile | Soft mono-color coil | Non-foaming printed coil | Printed foaming coil |
|---|---|---|---|---|---|
| Cigarette-burn resistance | Good | Weak | Medium | Weak | Worst |
| Stain resistance | Good | Medium | Medium | Medium | Medium |
| Mechanical-damage resistance | Good | Medium | Medium | Medium | Fairly good |
| Foot feeling | Hard | Medium | Medium | Medium | Good |
| Constructional operation | Paste | Paste, may warp | Allowed no pasting | Allowed no pasting, may warp | Allowed no pasting, lay flatly |
| Decorative performance | Common | Fairly good | Common | Fairly good | Good |

## 11.3.2 Features of Plastic Flooring

1) Good decorative effect. No limit to colors and designs, which meets the requirements of different applications, also can be used to imitate different kinds of natural material, looks true to life.

2) Many types. There are hard flooring for public buildings and also soft foam flooring for residential buildings to fulfill the application requirements in different buildings.

3) Easy construction.

4) Excellent wear resistance and long service life.

5) Easy maintenance and cleaning.

6) Multifunctional. Thermal insulation, sound insulation and moisture-proofing etc.

7) Feel comfortable and warm to the touch.

## 11.3.3 Applications of Plastic Flooring

Plastic flooring is classified to many types based on different material components, processing techniques and structural forms. Refer to Table 11.3.

**Table 11.3 Classifications of Plastic Flooring**

| Name | Main components | | Processing technique | Structure |
|---|---|---|---|---|
| | Resin | Filler | | |
| Linoleum | Vegetable oil, rosin resin | Calcium carbonate, wood chip, cork powder, pigment | Continuous rolling | Coil material composed with asphalt oil paper or linen wood fabric |

Continued

| Name | | Main components | | Processing technique | Structure |
|---|---|---|---|---|---|
| | | Resin | Filler | | |
| Rubber mat | | Natural rubber, reclaim rubber or styrene-butadiene rubber | Calcium carbonate, plasticizer, age inhibitor, curing agent | Laminating press or drum-type continuous vulcanization | Soft monolayer block material or coil material |
| Polyvinyl chloride plastic flooring | Coil material | Polyvinyl chloride | Calcium carbonate, plasticizer, stabilizer, pigment | Extruding or continuous rolling | Soft monolayer or multilayer-laminated block material |
| | Asbestos flooring tile | Polyvinyl chloride, vinyl chloride-acetate copolymer | Rock wool short fiber, calcium carbonate, plasticizer, stabilizer, pigment | Mainly by laminating | Semi-hard monolayer or multilayer-laminated block material |
| | Multi-filler flooring tile | Polyvinyl chloride | light and heavy calcium carbonate, plasticizer, stabilizer, pigment | Laminating | Close to hard block material |
| | Recycled flooring | Polyvinyl chloride recycling | Calcium carbonate, a little of plasticizer and stabilizer, pigment | Continuous rolling | Semi-soft monolayer coil material or block material |



Rubber mat is made of natural or synthetic rubber as main raw material, added with chemical softener, and after de-polymerization at high temperature and under high pressure, added in coloring reinforcing agent, then processed through mixing, plasticizing and rolling. Domestic natural rubber resource is in shortage and there is small output of synthetic rubber at high price. As a result, there is no specialized rubber mat product. Generally, multifunctional rubber plate or coil material is adopted at places requiring higher elasticity, thermal preservation, impact resistance or electric insulation. Rubber mat is scarcely applied to residential buildings.

Polyvinyl chloride (PVC) plastic flooring is developed based on the development of organic synthetic industry and the continual widening of the application scope of PVC resin. PVC plastic flooring is at the dominating place among all plastic floorings. It is largely produced and widely used, which is superior to any other plastic flooring material. Compared with linoleum or rubber mat, its prominent performance is that it has good wear resistance and merits such as abundant colors, good decorative effect, good moisture resistance, high resistance to load and durability etc.

Due to its better fire resistance and self-extinguishing property and its changeable performances which vary with different adding amounts of plasticizers and fillers, it becomes the ideal raw material for plastic flooring. Apart from PVC resin, PVC plastic flooring also contains reinforcing agent, stabilizer, processing-lubricant, filler and pigment etc. which greatly influence the performances of PVC plastic flooring. According to its components and structures, PVC plastic flooring is classified to several main types as follows.

## 1. Mono-color Semi-hard PVC Flooring Tile

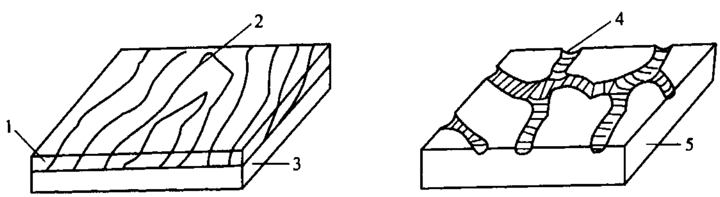
Mono-color semi-hard PVC flooring tile is of PVC block flooring, which is a kind of the earliest PVC plastic flooring products and is produced mainly with hot pressing technique in China. Its surface is fairly hard but with certain softness and flexibility. It has features such as good feeling, no warp, good denting-resistance and stain-resistance, but its scratch-resistance and mechanical strength are not well performed.

PVC mono-color flooring tile is classified to plain color and mottled drawn-pattern. Mottled drawn-pattern is made by drawing straight stripes in other colors on the mono-color background. Some of its appearance looks like the pattern of marble, so also called drawn-marble-pattern flooring. Mottled drawn-pattern not only decorates the surface with patterns, but also helps to cover scratches on the surface.



## 2. Printed PVC Flooring Tile

Printed PVC flooring tile has its surface printed with color designs. There are two types, whose structures are shown in Figure 11.4.




(a) Printed-filmed type (b) Printed-embossed type

Figure 11.4 Structures of Printed PVC Flooring

1. Transparent PVC surface layer; 2. Printing-ink layer; 3. PVC bottom layer; 4. Printing-ink embossed pattern; 5. PVC base material

1) Printed-filmed PVC Flooring: it is composed of surface layer, printed layer and bottom layer. The surface layer is transparent PVC film around 0.2mm thick; the bottom layer is PVC with fillers, recycled second hand plastic is sometimes adopted. Printed-pattern is in mono-color or multicolor. The surface is flat, some also embossed with orange-peel pattern or other patterns, playing the function of extinction.

2) Printed-embossed PVC flooring tile (groove embossed flooring tile): with no transparent PVC film on its surface; the printed-pattern is in stripe or big spot etc. and it is depressed so that the printing ink is hard to be scrubbed off in application. It has the same performances and application scope as mono-color semi-hard PVC flooring tile, except that it has embossed-printed patterns.

3) Granular patterned flooring tile: it is the combination of (2-3 types) PVC particles in many different colors, so the pattern is everywhere through the whole depth. Though the particles are in different colors, they are of the same color tone. The granularity is 3-5mm. Granular patterned flooring tile has almost the same performances as mono-color PVC flooring tile. Its main features are good decorative performance, granular patterns are not worn out, and it is resistant to cigarette burning.

4) PVC Terrazzo flooring tile: it is composed of PVC particles in different colors and the "grey seam" surrounding them. The particles look like gravels, so its appearance is like terrazzo, and the pattern is fully distributed through the whole depth.



### 3. Soft PVC Mono-color Coil Flooring

Soft PVC mono-color coil flooring is commonly homogenous with the same components in the bottom and the surface layer. There are mono-color coil flooring and drawn-marble-pattern flooring with smooth surface or embossed-pattern surface such as straight stripe, rhomb pattern and round pattern to perform the function of anti-skipping. Features of soft PVC mono-color coil flooring are as follows:

1) Soft quality, with certain elasticity and flexibility. It is produced with rolling technique or extruding technique. Due to the processing method, it contains less filler but more plasticizer, so it is softer.

2) Medium resistance to cigarette burning, lower than that of semi-hard flooring tile.

3) It is homogenous, so laying more flatly, no occurrence of warp.

4) Medium stain resistance and denting-resistance, lower than those of semi-hard PVC flooring tile.

5) Higher mechanical strength, not easy to get worn or broken.

### 4. Non-foaming Printed PVC Coil Flooring

It has the same structure as printed PVC flooring, composed of three layers. The surface layer is transparent PVC film, taking the function of protecting the printed-pattern. The middle layer is printed-pattern layer, which is a layer of PVC color-film printed with patterns. The bottom layer is PVC with more filler, some product takes recycled material as basic material to cut production cost. There is embossed-pattern such as orange-peel and round-spot on the surface to decrease its light reflection, but with certain gloss retained. Non-foaming printed PVC coil flooring is mostly produced with rolling-press technique.

Its dimensions and appearance as well as physical mechanical performances are mostly close to those of soft mono-color PVC coil flooring, but the chromatic accuracy error of its printed-pattern is required less than 1mm. Moreover, certain peel strength between layers is also required for printed coil flooring, generally up to 10.5N/cm, and severe warp is not allowed. Non-foaming printed PVC coil flooring is applied to public and residential buildings with less traffic and good maintenance.



### 5. Printed Foaming PVC Coil Flooring

Its basic structure is close to that of non-foaming PVC coil flooring, but its bottom layer is foaming. The most commonly-used is composed of three layers. The surface layer is transparent PVC film; the middle layer is foaming PVC layer; the bottom layer is backing cloth such as asbestos, glass fiber cloth, glass fiber mat and chemical fiber non-woven cloth. Another type of foaming PVC coil flooring is composed of only the transparent layer and the foaming layer, with no backing cloth; there is also another type with the backing cloth between two layers of foaming PVC, which is called reinforced printed foaming PVC coil flooring. Figure 11.5 shows the structures of printed foaming coil flooring.

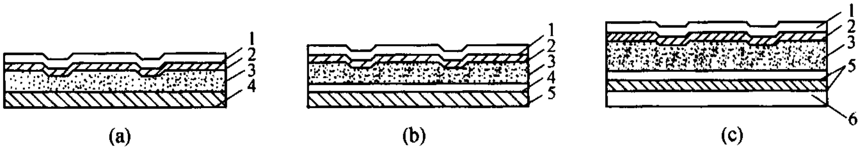



Figure 11.5 Structures of Printed Foaming Coil Flooring

1. PVC transparent layer; 2.Printing ink; 3.Foaming PVC layer; 4. Bottom layer; 5. PVC bottom layer; 6. Glass fiber mat

Such coil flooring adopts plastic-coating technique for production, and paste PVC resin at a higher price must be used. Higher temperature is needed in foaming, which leads to low production rate; some product has backing-cloth, so it is at higher price. Its performance features are as follows:

1) With the foaming layer and high content of plasticizer (60%), it is soft and elastic, feels comfortable when walking on it, and has certain thermal insulation and sound insulation.

2) Besides printed pattern, there is also embossed pattern created with chemically-embossed technique; rich of textures on surface; better decorative effect than any other coil-material.

3) With high content of plasticizer, the surface is less stain-resistant but better scratch-resistant.

4) Good flat-laying performance, commonly no occurrence of edge-lifting or corrugated-edge; can be laid directly on flat ground without using bonding agent.

5) With foamed PVC layer, it is weak in denting-resistance and easy to cause permanent dents; and easy to suffer mechanical damage.

6) Severely vulnerable to cigarette burning, which not only burns the transparent layer, but also burns the foamed PVC and creates dents that can't be restored with sand paper.

7) Excellent Wear Resistance.

Printed foaming PVC coil flooring is mainly applicable to residential buildings.

## 11.4 Plastic Wallpaper

Wallpaper and wall-cloth are the most widely used wall decorative materials both at home and abroad. There are overprinted, printed and embossed patterns, including imitated brocade-pattern, wood-pattern and stone-pattern, and also patterns imitating kinds of fabric or plain brick wall with concave-convex texture and electronics spinning etc.

There are many types of wallpaper and wall-cloth according to many classification methods. For instance, according to decorative effect, it is classified to printed, embossed and relief wallpaper etc.; according to function, classified to decorative, waterproof and fireproof wallpaper etc.; according to construction method, classified to the type requiring to brush glue on-site and the type requiring to pre-coat pressure-sensitive adhesive on its back for direct pasting; according to adopted material, to paper based, textile, natural material and plastic wallpaper etc.

Plastic wallpaper takes paper as base material and polyvinyl chloride plastic as surface layer, and is produced through techniques such as rolling-press or coating and printing, embossing and foaming etc. The resin adopted to make plastic wallpaper is polyvinyl chloride, so it is also called polyvinyl chloride wallpaper. Because it takes cheap raw material and is wear resistant, incombustible, easy to scrub and clean, plastic wallpaper has become the main wallpaper product in countries all over the world.



## 11.4.1 Performances of Plastic Wallpaper

### 1. Technical Requirements, Functions and Dimensions of Plastic Wallpaper

Technical requirements for plastic wallpaper mainly include the appearance quality and the physical performances, which should respectively meet the requirements in Table 11.4 and Table 11.5. In application and selection, the product should be checked based on the stated technical requirements

**Table 11.4 Appearance Quality of Wallpaper**

| Name | Superior quality | First quality | Quality |
|---|---|---|---|
| Color difference | None | No apparent difference | Allow difference, but not affect the use |
| Scar and crease | None | None | Allow apparent crease on the paper base, but no severe crease on the surface |
| Bubble | None | None | No bubble affecting the appearance |
| Registration accuracy | Deviation≯0.7mm | Deviation ≯1mm | Deviation≯2mm |

Continued

| Name | Superior quality | First quality | Quality |
|---|---|---|---|
| Exposure of the grounding | None | None | Allow 2mm exposure of the grounding, but only a few allowed. |
| Blind print | None | None | No blind print influencing application |
| Stain | None | No apparent visible stain | Allow apparent visible stain, but only a few allowed. |

**Table 11.5 Physical Properties of Polyvinyl Chloride Wallpaper**

| Item | | | Index | | |
|---|---|---|---|---|---|
| | | | Superior quality | First quality | Quality |
| Fadedness (level) | | | >4 | ≥4 | ≥3 |
| Color fastness to rubbing(level) | Dry rubbing<br>Wet rubbing | Longitudinal and Horizontal<br>Longitudinal and Horizontal | >4 | ≥4 | ≥3 |
| Shielding property (level) | | | 4 | ≥3 | ≥3 |
| Wet tension load (N/15mm) | Longitudinal<br>Horizontal | | >2.0 | ≥2.0 | ≥2.0 |
| Adhesive erasability (Horizontal) | | | No change after 20 times | No change after 20 times | No change after 20 times |
| Washability | Washable<br>Specially washable<br>Brush and wash available | | No damage or change on the appearance after 30 times of scrubbing<br>No damage or change on the appearance after 100 times of scrubbing<br>No damage or change on the appearance after 40 times of scrubbing | | |

Note: 1) Erasability in the table is defined as the performance: if there is adhesive left on the face of the paper, it should be cleaned off with wet cloth or sponge before it dries, and there should be no apparent trace left.

2) Washability in the table is defined as the performance: during the service life, the washable wallpaper can be washed without getting damaged. It is the operating requirement for wallpaper serving in rooms with pollution or high temperature.

## 2. Functions of Plastic Wallpaper

Wallpaper and wall-cloth are one of the primary approaches for interior decoration. Selecting proper designs and types helps to achieve many kinds of expected effects. The functions of wallpaper mainly include:

1) Indoor atmosphere can be created to meet different requirements by taking advantages of the patterns and color-tones of wallpaper. For instance, for solemn places such as conferences, it is suitable to adopt wallpaper with less bright color and simple patterns.

2) Special effects are created with wallpaper. For instance, wallpaper with imitated wood-pattern and stone-pattern may achieve effects looking like the genuine.

3) Wallpaper is available for many places with special requirements. For instance, special anti-bacterial wallpaper is applied to hospital wards to prevent bacteria from accumulating on the wall.

4) Sound absorption.

5) Easy to wash and clean.

6) Some special wallpaper is water-resistant, fireproof or mildew-proof etc., which is better for the decoration and renovation of hotels, restaurants and advanced public buildings with high requirements.

There are many types of wallpaper with great differences in performances, so it should be selected based on the requirements for decoration and renovation and the product performances.

## 3. Types, Dimensions and Performances of Commonly-used Plastic Wallpaper

Table 11.6 shows the types, dimensions and performances of commonly-used plastic wallpaper.

**Table 11.6 Types, Dimensions and Performances of Plastic Wallpaper**

| Name | Type | Dimensions (mm) | Technical performance | | Remark |
|---|---|---|---|---|---|
| | | | Item | Index | |
| Medium and high-grade wallpaper (Tulip Brand) | Printed, embossed, printed foaming wallpaper, imitated ceramic tile, imitated fabric wall paper, | Breadth: 530<br>Length: 10000<br>Each coil: $5.3m^2$ | Meet the requirements of European Wallpaper Standard (PREN233), International wallpaper Association (IGI1987) and International Straw-mat high grade product requirements. | | |
| High-grade relief wallpaper (Xihu Brand) | Dense-raised embossed wallpaper, printed wallpaper; low, medium and high foaming printed wallpaper | Breadth: 530<br>Length: 10000<br>Each coil: $5.3m^2$ | | | |
| PVC plastic wallpaper (Golden Lion Brand) | Printed wallpaper, embossed wallpaper, foaming embossed, printed-embossed wallpaper, textile-base wallpaper and functional type such as fire-retardant wallpaper etc. | Breadth: 920, 1000, 12000<br>Length: 15000, 30000, 50000 | Rubbing-resistance (dry rubbing for 25 times, wet rubbing for twice)<br>Longitudinal wet strength (N/1.5cm)<br>Fadedness (photo-aging)<br>Application property | No apparent discoloring<br>$\geqslant 2$,<br>no color change or fading<br>good condition, no bulging or peeling off | |

Continued

| Name | Type | Dimensions (mm) | Technical performance |  | Remark |
|---|---|---|---|---|---|
|  |  |  | Item | Index |  |
| PVC wallpaper (Solvay Brand) | Whole sealed, high foaming wallpaper | Breadth:500<br>Plus-minus tolerance≤1%<br>Thickness: 1.0±0.1 | Wear resistance (dry/wet level),<br>Wet strength (N/1.5cm)<br>Fadedness (level)<br>Shielding property (level)<br>Application property | ≥3.6<br>≥2<br>≥3.6<br>≥3<br>No bulging or peeling off |  |
| Plastic Wallpaper (Zhuque Brand) | Embossed, foaming embossed, printed embossed, groove-printed embossed and foaming printed embossed patterns etc. | Breadth:970 1000<br>Length: 50m/coil |  |  |  |

## 11.4.2 Features of Plastic Wallpaper

Plastic wallpaper is a widely-used interior wall decorative material at home and abroad. It is available for the surface decoration of areas such as roofs and columns. Compared with traditional decorative materials, it has features as follows:

1) Certain flexibility and crack-resistant strength. So, the base structure (such as wall surface and roof surface) is allowed to have certain crack.

2) Good decorative effect. The surface of plastic wallpaper can be treated with printing, embossing and foaming processes to create imitated natural stone, wood or brocade patterns; colorful patterns and designs suitable for different environments can be printed on the surface to achieve natural and fluent, plain and elegant appearance.

3) Excellent performances. It can be processed to products with special features such as incombustibility, thermal insulation, sound absorption and mildew-proofing. It is less likely to cause condensation, available for washing and resistant to mechanical damage.

4) Convenient for gluing and pasting. Plastic wallpaper has good strength even in wet state, resistant to pulling and dragging, easy for gluing and pasting with107 bonding agent or milky white glue, also with good air-permeability. It is convenient for construction and easy for replacement after aged.

5) Long service life and easy maintenance. The surface can be washed and has strong resistance to acid and alkali, easy to keep clean.

In a word, compared with other decorative materials, wallpaper is the best in comprehensive index because it is artistic, economical and functional. With various patterns and colors, it fulfills the personalized requirements of different users. Color tones and patterns are main indexes in selection, and the price and technical properties should also be taken into consideration to ensure its decorative effects.

Compared with traditional decorative materials, walls decorated with wallpaper have features as follows:

(1) Artistic

Wall surface takes up 60%-80% of the whole interior decorative area, and is the important part to reflect the decorative effect. It determines the artistic and cultural sense of the room to some extent. Plastic wallpaper applied to decorate the wall surface creates better effect than coating and wood in patterns, colors, luster and texture. Moreover, it creates artistic effect of relief and jewelry luster, and the effect of imitated ceramic, imitated wood, imitated marble and imitated clay brick as well as imitated alloy section. Wallpaper has beautiful and elegant colors and abundant artistic designs, so it is more suitable to serve as wall decorative material compared with coatings and other materials.



(2) Usability

Most plastic wallpaper is available for scrubbing and is stain resistant and wear resistant. Compared with stone, ceramic or metal, plastic decorative material has lower heat-conductivity coefficient, better thermal insulation and preservation, better texture and service performances.

(3) Problems to be noticed in application

Pay attention to the combustibility level and the ageing resistance of plastic wallpaper. The tightness, including water-tightness and air-tightness, should be taken into consideration, because sometimes the tightness of plastic wall material destroys the respiration of brick and concrete wall and the air in the room becomes dry and no longer fresh, then people inside will feel uncomfortable.

## 11.4.3 Applications of Plastic Wallpaper

### 1. Ordinary Wallpaper

Known as paper-base wallpaper, it is made of $80g/cm^2$ paper as base material coated with polyvinyl chloride paste resin (PVC paste resin) at around

$100g/cm^2$, and then processed through procedures such as printing and embossing. It is classified to mono-color printed, printed-embossed, mat gloss and bright printed. It is the most widely used wallpaper with many patterns and colors and largest output which makes it economical and cheap.

**2. Foaming Wallpaper**

It is classified to low foaming wallpaper, low foaming printed-embossed wallpaper and high foaming wallpaper. Foaming wallpaper is made of $100g/cm^2$ paper as base material coated with PVC paste resin at $300\text{-}400g/cm^2$, then processed by printing and foaming procedures. Compared with printed wallpaper, it has elastic concave-convex patterns and designs in many colors and creates stronger 3d effect, good anaglyptic and soft-light effect, and sound absorption effect. But the pattern of foaming PVC is easy to get stained and aged, therefore, such wallpaper is not suitable for places suffering heavy smoke and dust such as waiting rooms.

**3. Special Type Wallpaper**



Also called special purpose wallpaper, it refers to wallpaper with special functions. Commonly-used types are water-resistant, fireproof and special decorative wallpaper etc.

1) Water-resistant wallpaper. It adopts glass fiber mat as base material, (other techniques are the same with plastic wallpaper) mixed with water-resistant bonding agent to meet the decorative requirements of walls in washrooms and bath rooms etc. It can be washed with water. However, if there is water seepage at the joint in application, the water will dissolve the bonding agent, which makes the wallpaper fall off.

2) Fireproof wallpaper. It takes $100\text{-}200g/cm^2$ asbestos paper as base material, and retardant is added to the surface layer PVC to provide the wallpaper with good fire-retarding and fireproofing function. It is suitable for the interior decoration of buildings with high fireproof requirements. Even when burning, it does not release heavy smoke or toxic gas.

3) Special decorative effect wallpaper. Its surface is produced with metallic color sand, silk, linen and wool, and cotton fiber etc. to create artistic effects such as luster, diffusion and jewelry gloss and to provide the decorated wall surface with brilliant appearance. It is applicable to places such as entrance halls, columns, corridors and roofs.

4) Landscape wall painting wallpaper. The surface layer of the wallpaper is printed with pictures of scenic spots or artistic wall paintings. Usually it is composed of many pieces and applied to decorate the walls of halls.

## 11.5 Plastic Doors and Windows

### 11.5.1 Features of Plastic Doors and Windows

Presently, plastic doors and windows in developed countries has become a highly developed production field at huge scale with mature technology, integrated standard and thorough social cooperation. They are reputed as the new generation after wood, steel and aluminum doors and windows.

**1. The Concept of Plastic-steel Doors and Windows**

Plastic-steel doors and windows are made in this way: take polyvinyl chloride (PVC) resin as main raw material, add in certain amount of additives such as stabilizer, modifier, filler and ultraviolet absorbent and process it through extruding procedure to formed material which is then made into door and widow frames and sashes by cutting and welding, and finally match them together with accessories such as rubber sealing strips and metal fittings to produce doors and windows. To enhance the stiffness of the formed material, steel liner is added in its cavity, so plastic doors and windows are also called plastic-steel doors and windows. The types are: side hung doors and windows, sliding doors and windows; special specifications are available for customized production based on requirements of the users. There are two structures: single frame single glass and single frame double glass.



**2. Features of Plastic Doors and Windows**

Plastic doors and windows have merits such as beautiful appearance, stable dimensions, ageing resistance, fastness, corrosion resistance, impact resistance, good airtight and watertight performance and long service life etc. They have been greatly valued by the governments of many countries.

Compared with traditional wood and steel windows, plastic windows have the following features.

1) Water resistance and corrosion resistance. Plastic-steel windows are water resistant and corrosion resistant, so they are applicable to not only rainy

and moist areas but also underground buildings and industrial buildings affected by corrosion.

2) Good performance of thermal insulation. The heat conductivity coefficient of plastic is close to that of wood, but because the frames of plastic-steel windows are assembled with hollow irregular sections, their thermal insulation property is much better than that of steel-wood windows. Table 11.7 is the comparison of the insulation performances of several types of doors and windows, from which we can learn about the excellent thermal insulation performance of plastic doors and windows.

**Table 11.7 Comparison of thermal Insulation Performances of Several Types of Doors and Windows**

| Heat conductivity coefficient of the material 「kcal/(m$^2$·h·℃)」 / 「W/(m·K)」 | | | | | Heat conductivity of the whole window 「kcal/(m$^2$·h·℃)」 / 「W/( m$^2$·K)」 | | |
|---|---|---|---|---|---|---|---|
| Aluminum | Steel | Pine, cedar | PVC | Air | Aluminum window | Wood widow | PVC window |
| 174.45 | 58.15 | 0.17-0.35 | 0.13-0.29 | 0.047 | 5.95 | 1.72 | 0.44 |
| (150) | (50) | (0.15-0.30) | (0.11-0.25) | (0.04) | <5.120> | <1.479> | <0.378> |

3) Good air-tightness and water-tightness. Airtight and watertight requirements of PVC window irregular sections are considered when they are designed. There are sealing strips between the sashes and the frames, so they have good airproof and sound insulation performances.

4) Good decorative effect. PVC plastic can be colored, and presently white is more preferred and adopted; it can be designed and processed to different colors to make buildings more beautiful.

5) Convenient maintenance. PVC windows are free from rust and corrosion, which is different from wood and steel windows that require protective coating. Its surface is smooth and bright, so convenient for cleaning; and some of its fittings can be replaced or changed, so convenient for repair work.

## 11.5.2 Performances of Plastic Doors and Windows

### 1. Thermal Preserving and Energy Saving

Plastic section is in multi-cavity structure and has good performance of thermal insulation. Its heat conductivity coefficient is especially small, only 1/357 that of steel and 1/1250 that of aluminum.

**2. Physical Properties**

1) Air-permeability (air-tightness): under 10Pa pressure, air permeability is less than $0.5m^3/$ (m·h) for unit length of seam, which meets the requirements for the first level in GB 7107.

2) Rain permeability (water-tightness): keep no permeation under high pressure of 100Pa, which meets the requirements for the fifth level in GB 7107.

3) Wind load resistance: wind load resistance is the wind load resistant strength value when the relative deflection of the stress bar is 1/300; security test result is 2500Pa, which meets the requirements for the third level in GB7106.

4) Sound insulation: sound insulation *PW*=32dB, which meets the requirements for the second level in GB8485.

5) Heat conductivity coefficient: $2.45W/(m^2 \cdot K)$, which meets the requirements for the second level in GB8484.

6) Weather-resistance: plastic section adopts special material-formula; accelerating aging test shows that plastic-steel windows are available for long term service in environment with great temperature-difference (-50-70℃); burning sunlight and moisture will not cause the occurrence of quality deterioration, aging or brittleness etc.

7) Fireproof performance: plastic-steel doors and windows are neither combustible nor combustive. They are self-extinguishing, safe and reliable, which enlarges their application scope.

## 11.5.3 Applications of Plastic Doors and Windows

Presently, plastic-steel doors and windows produced in China are classified to five main types including side-hung and sliding doors and windows, floor-spring doors etc., and there are more than 20 series of dimensions. Moreover, corrosion-resistant doors and windows and horizontally pivot hung windows are produced to meet the requirements of special industry buildings. After many years of service, plastic-steel doors and windows have set up a gracious image in the heart of more and more customers.

Series of technological problems in the production of plastic doors and windows, such as raw material formula, window-form design, assembly technology and equipments, metal fittings have already been worked out The rapid development of the industry of plastic-steel doors and windows is greatly related to the worldwide energy crisis, except for their excellent performances. Plastic-steel doors and windows are highly superior to wood, steel and aluminum doors and windows in aspects such as energy saving in production and service and environmental protection.

According to the data provided by China Academy of Building Research Physics Institution, the mean value of heat conductivity coefficient of double glazed plastic-steel windows is $2.3W/(m^2 \cdot K)$, so 21.5kg standard coal is saved per $m^2$ each year. The energy consumption for the production of unit volume PVC is 1/4.5 that of steel, 1/8.8 that of aluminum; in heating areas, 30%-50% energy is saved if plastic-steel doors and windows are adopted, compared with ordinary steel or aluminum windows.

The advantages of the material used to produce plastic doors and windows provide them with excellent performances of thermal preservation, sound insulation, air-tightness, water-tightness and notable energy-saving effect. They also have good corrosion-resistance, good fire retardance and long service life. They cover a considerable application market in our country. As the department in charge of national construction, Ministry of Construction has been encouraging the application of plastic doors and windows and is making big effort to promote the development of plastic doors and windows, which further accelerates the technological progress and optimizes the industrial structure of relevant industries such as petrochemical industry, plastic processing, building material and electric machinery as well as building industry.



## Case of Materials Selection

A practical application of aluminum-plastic composite plate in the renovation of a curtain wall.

**1. Project name**

renovation of exterior curtain wall of the office building in Xingqi Paper Factory

**2. General condition of the project**

Building area: $5000m^2$

Curtain wall area: 2360m$^2$

Building structure: four-story brick-concrete building structure

Design requirements: on the plinth of exterior wall of the building, paste 1.2m high mushroom stone; the wall above the plinth is covered with the combination of aluminum-plastic panel metal curtain wall and spot type glass curtain wall; the entrance is advanced antique-style copper door; imported granite is adopted for the surface decoration and renovation (dry hung) of steps and rain shelters as well as walls at the entrance; machine-planed granite step stones and color aluminum alloy sliding windows are adopted.

### 3. Selection of Material

(1) Selection of the Curtain Wall Framework

Adopt aluminum alloy curtain wall framework, wall thickness 2.0mm. Aluminum alloy curtain wall framework, hold-down strips, structural bonding agents, airtight sealing bonding agents, accessories and joint pieces etc. should meet the design requirements of the curtain wall.

(2) Selection of Aluminum-plastic composite panel

Exterior aluminum-plastic panel (doible-side) is adopted. Panel dimensions are 1220 mm×2440mm, thickness 0.5mm. Market reference price 300. 00Yuan/pcs. Aluminum rivet and silicone weather-resistant glue are used to bond the panel and the skeleton.



## Practice

Learn about the types, dimensions, performances, prices and application statuses of plastic decorative plates. Master the dimensions, performances, prices and application statuses of aluminum-plastic composite plate and melamine laminate sheet (fireproof panel).

### 1. Objectives of Practice

Students are required to go to building decorative material markets and decoration sites to carry out investigation and practice; find out the prices and get familiar with the application statuses of plastic decorative materials; distinguish the names, dimensions, types, prices, application requirements and application scopes of different kinds of material.

### 2. Practice Mode

(1) Investigation and Analysis in Building Decorative Material Market

Student grouping: 3-5 students as one group, go to building decorative material markets to carry out investigation and analysis;

Investigation method: learn how to recognize different plastic decorative plates, find out material prices, collect material samples and master the requirements for material selection mainly by surveying and inquiring.

(2) Research on the application of decorative materials on building decoration and construction sites.

Students grouping: 10-15 people as one team, guided by teachers or persons in charge of the site;

Investigation method: guided by teachers or persons in charge of the site, introduce and explain the application statuses and notices in construction practice adapted to the construction site and its actual condition.

### 3. Contents and Requirements for Practice

1) Complete the research diary carefully;
2) Fill in the material research report (refer to material research report);
3) Write a practice summary.



## Summary

This chapter mainly introduces the components, classifications, performances and applications of plastic decorative materials. During teaching and learning, to plastic decorative materials including different kinds of plastic decorative plate, plastic flooring, plastic wallpaper and plastic-steel doors and windows, students are required to master the components and features of plastic decorative materials and to apply what they have learned to explain the performances and application notices of different kinds of plastic decorative material in the theory-teaching section; in the practice-teaching section, students are required to master the names, performances, applications and application requirements of commonly-used plastic decorative materials. To each kind of the material, students are required to master its name, dimensions, performances, prices and applications associated with the actual application status in construction.

## Questions for Reviewing and Thinking

11.1 What are the components of building decorative plastic and plastic products?

11.2 What are the main types of plastic adopted to produce decorative materials?

11.3 What are commonly-used plastic decorative plates? What are their performances and application requirements?

11.4 What features does plastic wallpaper have? How to make selection?

11.5 What features and performances do plastic-steel doors and windows have?

# 12

# Building Decorative Fiber Fabric and its Products

Building decorative fiber fabric and its products is the indispensable decorative material for the interior decoration of modern buildings. Its color, texture, softness and elasticity etc., directly affect the interior scenery, light, texture and color. Selecting proper decorative fabric and fiber products not only beautifies the indoor environment, but also brings comfortable feelings to people, moreover, it provides magnificent appearance and creates inimitable artistic effect that other decorative materials can't achieve. It mainly includes carpet, tapestry or wall hanging, textile wallpaper and window curtain etc. In resent years, these decorative fabrics have been greatly developed in type, pattern, material quality and performance, and become the excellent material for modern interior decoration.



## 12.1 Basic Knowledge of Fiber

Fiber used for building decorative fabric includes natural fiber, chemical fiber and inorganic fiber. These fibers have different features and different affects to the performances of decorative fabric.

**1. Natural Fiber**

Natural fiber includes wool, cotton, linen and silk.

1) Wool fiber. Wool is warm, soft and high elastic, incombustible, and with fresh and stable luster. Therefore, it is one of the natural fibers used by people since long before. But it's easy to get damaged by worms.

2) Cotton fiber. Cotton fiber is soft, and with good air-permeability and thermal preservation. It is easy to iron flat but likely to pucker and get stained.

Cotton fiber product mainly includes plain and printed wallpaper, window curtain and cushion cover etc.

3) Linen fiber. Linen fiber has high stiffness, high strength and good wear-resistance. It is beautiful and comfortable, but pure linen is costly, therefore, often mixed with chemical fiber to produce different kinds of products.

4) Silk fiber. Silk fiber is the longest natural fiber. Smooth, soft, translucent and mild, it is easy for coloring and has good thermal insulation. It is an advanced decorative material.

5) Other fibers. Besides the above different kinds of commonly-used natural fibers, there are also some rarely-used types, such as cocoanut fiber, wood fiber, reed fiber, jute fiber and bamboo fiber.

**2. Chemical Fiber**

Chemical fiber is classified to artificial fiber (viscose fiber and acetate fiber etc.) and synthetic fiber (polyester, acrylic, chinlon, urethane elastic fiber and polypropylene fiber etc.)



1) Viscose fiber. Viscose fiber is classified to artificial cotton, artificial silk and artificial wool. It is not stain-resistant or wear-resistant, and easy to pucker. Usually it is mixed with other fibers and used as window curtain or cushion cloth.

2) Acetate fiber. It has light stability, incombustible and not easy to pucker. It has silk-like appearance and is mainly used as window curtain.

3) Polyamide fiber (chinlon). Known as nylon before, also called chinlon, its advantages are corrosion-resistance, easy cleaning and unique performance of wear resistance. The disadvantages are low elasticity, easiness to catch dust and to deform, getting partly molten in fire etc.

4) Polyester fiber (terylene). It has good wear-resistance, which keeps the same either in wet state or in dry state. It is less likely to crimple, and with light and heat-resistance. It is blended with many other fibers and cotton yarns to make sheets and curtains etc.

5) Polypropylene fiber (pylen). It has advantages such as lightweight, high strength, good elasticity, mildew-proof and moth-proof, easy cleaning, good wear-resistance and lower production cost.

6) Polyacrylonitrile fiber (acrylic). It is light, soft, moisture-proof, mildew-proof, mothproof and thermal preservative, with good elasticity and resistance

to acid and alkali corrosion; it has the advantage of light- resistance, which is unique and incomparable with natural fiber and most synthetic fibers.

### 3. Glass Fiber

Glass fiber is made from molten glass. Is diameter ranges from several to tens of microns. Glass fiber is brittle, easy to break off, not wear-resistant, but it has good performances of high-temperature resistance, corrosion-resistance and sound-absorption. Being stimulating to human body, it is not suitable for areas people directly touch.

There are many types of fiber in market. Correctly recognizing different kinds of fiber helps to better the application and laying work. There are many methods to distinguish fiber, and a simple and easy method is burning distinguishing, in which fibers are distinguished by comparing the burning speeds, the generated odors and the forms of ash etc. Refer to Table 12.1.



**Table 12.1 Burning Features of Commonly-used Fibers**

| Types of fiber | Burning status | Odors | Colors and forms of ash |
|---|---|---|---|
| Cotton | Burn very fast, generate yellow flame and blue smoke | With paper-burning odor | Little ash, soft and fine ash, grey |
| Linen | Slower burning than cotton fiber, generate yellow flame | With grass-burning odor | Little ash, deeper color than cotton fiber |
| Silk | Relatively slow burning, but shrink and crimple together | With hair-burning odor | Ash is in the form of small dark brown beads scattering when pressed with finger |
| Wool | Incombustible, but smoky and bubbling | With hair-burning odor | A lot of ash, after burnt it becomes black and brittle block with certain gloss, scattering when pressed with figure |
| Viscose fiber | Burn very fast, generate yellow flame | With paper-burning odor | Extreme little ash, fine and soft, in gray or light gray |
| Acetate fiber | Burn very slowly; When taken away from fire after molten, molting and burning, dropping dark brown gel-form liquid | Release tangy odor of acetic acid | Black ash and glossy block, scattering when pressed with figure |
| Chinlon | Slowly burning and melting, fiber rapidly crimple and shrink and melt to gel-form; while it is hot, it can be drawn to thread; burning flame is blue | With celery odor | Ash is in solid and tough brown hard balls, not easy to crush |

Continued

| Types of fiber | Burning status | Odors | Colors and forms of ash |
|---|---|---|---|
| Terylene | When burning, it shrinks and crimples, melting and smoky burning, with yellow flame | With aromatic odor | Ash is in black hard block, crushing when pressed with hand |
| Acrylic | Melting and burning slowly, bright and vigorous white flame, sometimes with slight black smoke | With fishy odor | Ash is in black hard balls, brittle and easy to crush |
| Polypropyl-ene | Rapidly crimples and shrinks and melts when it is burning, generate blue flame | With wax-burning odor | Ash is in hard block., easy to grind and crush |
| Polyvinyl chloride fiber | When ignited, it is almost incombustible; Close to flame, it shrinks and burns; The flame immediately extinguishes when taken away | Release sharp flavor of chlorine | Ash is in irregular black hard block |

## 12.2 Carpet and Tapestry



Carpet is a world-wide decorative product with a long history. Primarily it was used to sit or sleep on and to keep warm or resist cold. Now it has gradually developed to an advanced decorative product with thermal insulation and preservation, sound insulation and unique artistic charm.

Carpet is both useful and enjoyable with the functions such as wind and moisture resistance, dust absorption, floor surface protection and indoor environment beautification. With merits as thermal preservation, sound insulation, anti-skidding and bump alleviation, it presents great artistic value with its tactful and resourceful patterns and designs, color matches and textures. It creates unique decorative effects incomparable to other decorative materials.

### 12.2.1 Types, Grades and Performances of Carpet

#### 1. Classifications of Carpet

(1) Classified based on material

1) Pure wool carpet. Pure wool carpet is mainly made of coarse sheep wool, with features such as sturdy texture, high elasticity, durability in use and high glossiness etc. It creates excellent decorative effects but costs higher, belongs to advanced flooring material.

2) Blended Carpet. Blended carpet is woven and produced by mixing wool fiber with synthetic fiber. Its performance is between that of pure wool carpet and chemical fiber carpet. Generally adding synthetic fiber improves the wear resistance of carpet and reduces its production cost. For instance, by adding 20% polyamide fiber to wool, the wear resistance of the carpet increases by 5 times, and the decorative effect is increased whereas the price is far lower than that of pure wool carpet.

3) Chemical fiber carpet. Chemical fiber carpet, also called synthetic fiber carpet, takes different kinds of synthetic fiber as raw material, which is made into the surface layer with tufting or weaving techniques, and then the surface layer is sewed and combined with the linen-like cloth bottom layer. The appearance and tactility of chemical fiber carpet is extremely the same as that of pure wool carpet. It is wear resistant and highly elastic but costs less than pure wool carpet. Therefore, it is presently the most massively consumed medium or low grade carpet.

4) Plastic carpet. It is mainly made from polyvinyl chloride resin added with auxiliary materials such as fillers and plasticizers. It has features such as soft quality, beautiful luster, good feeling, incombustibility, durability in use and easy cleaning, so is applied to exits or passages of public buildings and washrooms or bathrooms of residential buildings.



5) Natural carpet. It is made by weaving natural material, e.g. sisal carpet, coir carpet and water-grass carpet etc. Sisal carpet takes sisal fiber as raw material. Its product is classified to plain color and dyeing color, with many textures and patterns such as cross grain, ribbed grain, fishbone grain, canvas flat grain and domino grain. It has merits as acid-alkali resistance, wear resistance, no static-electricity and moth-proof, fire retardation and fireproof. Compared with wool carpet, it is more economical and practical in use. With its unique textures and environment-protective features, it is popular in market.

(2) Classified based on dimension

1) Carpet pieces. Carpet pieces are mostly square or rectangle, and also round or oval in various dimensions. Fancy square carpet is composed of 500mm×500mm pieces with different patterns and colors, which is beautiful, practical and adaptive with complete and fluent joining of patterns. It has the features as fire retardation, heat-resistance, anti-static and excellent dimensional stability. Carpet pieces, combined to form different patterns, are

convenient and adaptive for laying work and provide more options to interior designs. Meanwhile, worn out pieces can be replaced freely to achieve an economical and beautiful effect.

2) Carpet coils. Carpet coils are coiled carpet with breadth ranging 1-4m and the length of each coil commonly ranging 20-30m. Sisal carpet, chemical fiber carpet and non-woven wool carpet are usually in coils. Such carpet is suitable for interior fixed full laying, which creates spacious, trim and clean feeling. However it is hard to replace the worn out parts or to clean the carpet.

(3) Classified based on weaving technique

1) Hand-woven carpet. Its surface is processed by hand and with manual tools. According to different weaving techniques, it is further classified to hand-knotted carpet, hand-tufted carpet, hand-knitted thread carpet and hand-sewed thread carpet.

2) Machine-made carpet. Its surface is processed with machinery equipments. According to its weaving techniques, it is classified to woven carpet, tufted carpet, knitted carpet, needle-punched carpet, bonded carpet, needle-seamed carpet, static flocked carpet and braided carpet.



## 2. Grades of Carpet

Based on application places, it is classified to 6 grades. Refer to Table 12.2.

**Table 12.2 Grades of Carpet**

| No. | Grade | Application place |
|---|---|---|
| 1 | Low home-use grade | Applied to seldom used rooms or areas |
| 2 | Medium home-use grade (or low special-use grade) | Applied to main bedrooms or dining rooms |
| 3 | Common home-use grade (or medium special-use grade) | Applied to areas suffering frequent walking such as living rooms, stairs and corridors etc. |
| 4 | Medium home-use grade (or common special-use grade) | Applied to areas in houses suffering heavy wear |
| 5 | High special-use grade | Applied to places with special requirements |
| 6 | Luxurious grade | With long velvet and in luxurious fashion; applied to advanced decorative places |

## 3. Main Technological Properties of Carpet

1) Wear resistance. The wear resistance of carpet, the important index for measuring and evaluating its service durability, is represented with wear-resisting times, namely, under set pressure, the number of wearing times

needed to worn out the surface and expose the backing-cloth. More wear-resisting times stands for better performance of wear-resistance.

2) Elasticity. Elasticity describes how much the thickness is compressed when the carpet receives pressure, which is the important performance to decide how comfortable the carpet may feel. The elasticity of carpet is defined as the percentage of its thickness reduction after certain times of bumping (certain dynamic load).

3) Peeling strength. The peeling strength of carpet describes the combined strength between carpet surface layer and the backing-cloth layer, also describes the water-resistant performance after the combination. It is represented with the backing-cloth peeling force, namely, the maximum force needed to peel the surface layer of 50mm wide sample carpet from its backing-cloth to a length of 50mm with certain instruments and equipments at specified speed.

4) Fluff bonding strength. Fluff bonding strength is defined as the fastness degree of the bonding between the fluffs of the carpet and its backing-cloth. The bonding strength of chemical fiber tufted carpet is represented with the force needed to withdraw its tufts. The withdrawal force needed for loop pile carpet is required to be more than 20N and that for level cut carpet more than 12N.



5) Static resistance. It is defined as the performance of charging and discharging electric. The content of static electricity is related to the electric conductivity of the fiber. After friction, organic high molecular material will generate static electricity. As high molecular material is insulating, which hinders the release of static electricity, more static electricity may accumulate in chemical fiber carpet than in wool carpet. So chemical fiber carpet is more likely to absorb dust and more difficult to clean, even worse, people walking on the surface of the carpet will get the feeling of electric shock. Therefore, certain amount of anti-static agent is added in chemical fiber carpet to enhance its static resistance, which is often represented with surface electric-resistance and static voltage.

6) Ageing resistance. Ageing resistance mainly refers to that of chemical fiber carpet. This is because chemical synthetic fiber is easy to get oxidation due to factors such as light and air, which leads to the deterioration of carpet performance. The ageing resistance is generally evaluated by the changes of its wearing times, elasticity and luster after certain period of ultraviolet illuminating.

7) Fire resistance. Fire resistance is defined as the burning degree within certain period of time when chemical fiber is on fire. Chemical fiber is combustible, so certain amount of fire-retardant is added to in production to create carpet with self-extinguishing or fire-retarding performance. When the sample is tested, if the diameter of its burning area is no more than 17.96cm within 12min, its fire-resistance performance is considered eligible.

8) Micro-organism resistance. Serving as floor surface material, carpet is easy to surfer mildew caused by vermin and germ in service. Therefore, during production, it is required to adopt microorganism-proof or anti-microorganism treatments. It is generally specified that carpet which is resistant to corrosion from eight common mould fungi and five common germs is considered to be with good micro-organism resistance.

## 12.2.2 Pure Wool Carpet

### 1. Types of Pure Wool Carpet



1) Beijing-style carpet. Shortly named "Jing-style carpet" and in traditional style, its patterns and colors are used to set off the main-theme pattern. The patterns are trim and symmetric with elegant and decent color tones in antique style. The surrounded square frame is attractive, and all patterns have special meanings and symbolic significances.

2) Art-style carpet. Features are: with main-theme color, brilliant carpet patterns and colors, rich stereovision, magnificent and palatial artistic style. It employs the features of decoration art in Western Europe, often adopts patterns of colorful flowery clusters such as bloomed roses, tulips, buds and rolling leaves, which brings about a flourishing scene of prosperity to people.

3) Antique finished carpet. It takes patterns and designs, landscapes, flowers and birds of ancient times as main themes to create the feeling of old-fashioned odors and colors, full of primitive simplicity and elegance.

4) Plain embossed design carpet. Plain embossed carpet has plain and light color tone and mono-color embossed patterns. After clipping, the patterns are clear and beautiful like reliefs, with remote silence and stereoscopic impression.

5) Fancy color carpet. Its patterns are fresh and vivid with dark-black as main color and complemented with small flower-patterns. It looks like flower-bird paintings with meticulous detail, reveals the tune of flamboyance, colorful and gorgeous, noble and decent.

**2. Production Techniques of Pure Wool Carpet**

The weaving techniques of pure wool carpet are classified to hand-woven and machine-woven. Hand-woven carpet is an advanced product among the traditional pure wool carpets in China; machine-woven carpet is a relatively advanced type that has been developed in modern times.

(1) Hand-woven Pure Wool Carpet

Hand-woven pure wool carpet adopts special Chinese super wool yarn made from the wool of local species sheep, applies modern dyeing technique to dye it with unfading colors. Then knit splendid patterns with tactful skills, and flatten and trim the carpet surface or rim it with concave-patterns with special machines, finally wash and create silky effect by using chemical techniques.

Hand-woven wool carpet adopts the number of "threads (or yarns)" to determine its density, namely, the weft-layer quantity (one layer is called one thread) within 1 foot along the base-knitting direction (from bottom to top). Therefore, the grade of carpet is in proportion to the thread quantity (yarn number). Ordinary carpet has 90-150 threads, advanced decorative carpet has more than 250 threads, presently the most dense and delicate carpet has 400 threads.



Hand-woven pure wool carpet is soft and comfortable with fresh luster, beautiful patterns and qualified material, revealing the perfect combination of quality and art. Being precious and famous fine working, it is mostly applied to international level and national level hotels, restaurants and advanced conference rooms etc.

(2) Machine-woven Pure Wool Carpet

Machine-woven pure wool carpet has features such as flat and trim carpet surface, good gloss, high elasticity, soft feeling, wear resistance and durability in use. Its performances are similar to those of hand-woven carpet, but its price is far lower than the latter. It is better than chemical fiber carpet in aspects such as rebound elasticity, static resistance, ageing resistance and fire-resistance. Machine-woven sheep-wool carpet is the medium flooring decorative material between hand-woven pure wool carpet and chemical fiber carpet.

Machine-woven pure wool carpet is most suitable for the whole flooring of guest rooms in hotels and restaurants, stairs, passages, banqueting halls, bars and reception rooms as well as gymnasiums and living rooms etc. Moreover, the fire-retardant product of this kind of carpet is available for the interior flooring of buildings with high fireproof requirements.

### 3. Main Dimensions and Performances of Pure Wool Carpet

The main dimensions and performances of domestic pure wool carpet are given in Table 12.3.

**Table 12.3 Main Dimensions and Performances of Domestic Pure Wool Carpet**

| Product name | Dimensions (mm) | Performance features | Producer |
|---|---|---|---|
| Wall-to-wall wool carpet<br>Electric embroidered carpet<br>Artistic tapestry (Gongmei Brand) | Different dimensions | Made of quality wool. Electric embroidered carpet imitates the traditional carpet patterns, old-fashioned odors and colors; modern design patterns with abundant era-sentiment. Artistic tapestry patterns are of boorish and rustic simplicity with multiple styles | Beijing Second Carpet Weaving Mill |
| 90-thread hand-knotted carpet<br>Plain-style wool carpet<br>High-thread artistic tapestry | Different dimensions such as 61×910-3050×4270 etc. | Made of quality wool, gorgeous patterns, soft and comfortable, solid and durable in use | Shanghai General Carpet Weaving Mill |
| 90-thread hand-tufted carpet, jacquard carpet, artistic tapestry (Fengchuan brand) | Different dimensions | Made of Xining quality wool. Patterns include Beijing-style, art-style, floral-style, plain-embossed style, oriental style and antique style | Tianjin Carpet Industry Company |
| 90-thread wool carpet<br>120-thread wool artistic tapestry | Thickness: 6-15<br>Width: processed based on requirements<br>Length: processed based on requirements | Hand-woven with high grade pure wool. Chemically processed. Moisture-proof, moth-proof, sound-absorbing, with beautiful patterns, soft and durable in use | Wuhan Carpet Weaving Mill |
| Hand-tufted carpet (Feitian brand) | Different dimensions such as 2140×610-3660×910 etc. | Made of high grade wool. Products include Beijing-style, esthetic style, floral-style, plain-embossed style, Dunhuang-style and antique-style etc. | Lanzhou General Carpet Weaving Mill |
| Pure wool machine-woven carpet | Different dimensions | Made of Xining wool. With solid texture and quality, many types of patterns, moisture-proof, sound-insulation, heat-preservation, dust absorption, no static-electricity and good elasticity etc. | Qinghai Carpet Weaving Mill |

Continued

| Product name | Dimensions (mm) | Performance features | Producer |
|---|---|---|---|
| 90-thread hand-knotted carpet 140-thread fine-work carpet Machine-woven wall-to-wall wool carpet (Haima brand) | Breadth 4m and other dimensions | Made of quality wool. Many types of patterns and designs, comfortable, moisture-proof, with good feeling, sound-absorption, heat insulation and dust absorption etc. | Haima Carpet Group, Weihai, Shandong |
| Imitated handmade wool carpet (Chufeng brand) | Different dimensions | Made of quality wool. Brand new models and designs, beautiful patterns, elegant luster, palatial and magnificent and durable in use | Zhejiang Artistic Carpet Weaving Mill |
| Handmade pure wool carpet Machine-woven wool carpet (Songhe brand) | Different dimensions | Made of quality domestic wool and New Zealand wool. With features such as good elasticity, anti-static, heat preservation, sound absorption and moisture-proof etc. | Hangzhou Carpet Weaving Mill |



### 12.2.3 Chemical Fiber Carpet

Chemical fiber carpet is a kind of flooring material that has been developed since 1970s. It is made of different kinds of chemical fiber (polypropylene, acrylic, nylon and terylene etc.) by processing and creating the surface layer fabric through weaving technique and tufting technique etc., then combining it with linen-like backing cloth.

**1. Types and Features of Chemical Fiber Carpet**

(1) Types of Chemical Fiber Carpet

According to different weaving techniques, it is classified to tufted carpet, needle-punched carpet, machine-woven carpet, bonded carpet and hand-woven carpet etc, among which tufted carpet goes first in volume of production and marketing, followed by needle-punched carpet and machine-woven carpet.

(2) Features of Chemical Fiber Carpet

Compared with traditional handmade wool carpet, chemical fiber carpet has advantages such as lightweight, wear-resistance, mildew-proof, moth-proof, corrosion resistance, easy cleaning, high elasticity, convenience for laying work and low price etc. But it tends to deform, to generate static electricity and adhesion pollution due to its strong adsorption; when wet with water, part of it becomes molten.

The features of different chemical fibers vary greatly, which should be noted in selection and application. For instance, terylene fiber has weak colorability, so the adhesion of pigment on the fiber surface is very weak, if frequently washed and cleaned, it tends to fade. In wear-resistance, nylon is the best among chemical fibers (20 times of wool); acrylic is the worst. In sunlight resistance, acrylic fiber goes first, followed by terylene fiber; nylon and polypropylene are relatively weaker. In elasticity, polypropylene and acrylic have the best elastic recovery power, within short expanded-range they are close to wool, whereas nylon and terylene are weaker. In static feature, nylon fiber is easier to gather static electricity in dry and hot environment, whereas terylene, polypropylene and acrylic have less static accumulation.

## 2. Dimensions and Performances of Chemical fiber

There are many types of chemical fiber carpet, so it is important to select proper types based on actual factors such as environmental design requirements, furniture and facilities, wall and roof decorative colors etc. Table 12.4 has listed the dimensions, performances and producers of some types of chemical fiber carpet in our country.



**Table 12.4 Types, Dimensions and Performances of Chemical Fiber Carpet**

| Name | Features | Dimensions | Technical Performances | Producer |
|---|---|---|---|---|
| Polypropylene tufted carpet<br>Polypropylene machine-woven jacquard wall-to-wall carpet<br>Polypropylene jacquard art carpet | The surface layer made of polypropylene; three types of backing-cloth: glue backing-cloth, linen-like backing-cloth and polypropylene backing-cloth. Carpet surface is classified to three types: cut-pile, loop-pile and high-low-loop pile.<br>Advantages: fresh and beautiful luster, fastness, wear-resistant, anti-piling, resistant to acid-alkali corrosion, moth-proof, good elasticity, fire-retarding, anti-static, sound-absorbing and anti-noise etc. | (1) tufted carpet<br>Breath: 4m<br>Length: 15m or 25m<br>(2) Jacquard wall-to-wall carpet<br>Breath: 3m<br>(3) Jacquard arts and crafts carpet<br>1.25m×1.66m<br>1.50m×1.9m<br>1.7m×2.35m<br>2.0m×2.86m<br>2.5m×3.31m<br>3m×3.86m | (1) polypropylene tufted carpet<br>Tuft bonding power (N): terry: 25; cut-pile:10<br>Dry breaking tenacity (N)<br>Warp-wise: >500; weft-wise: >300<br>Fastness to sunlight (grade): ≥4<br>Flammability / mm: <75<br>Wear performance: <0.70<br>(2) polypropylene machine-woven jacquard carpet<br>Dry breaking tenacity (N): warp-wise: 400; weft-wise: ≥800<br>Compressive thickness recovery rate (%): ≥55<br>Fastness to sunlight (grade): ≥4<br>Flammability (mm): <75 | Beijing Yanshan Petrochemical Industry Company Chemical Fiber Carpet Weaving Mill |

Continued

| Name | Features | Dimensions | Technical Performances | Producer |
|---|---|---|---|---|
| Polypropylene, nylon tufted carpet (Diamond brand) | Surface layer made of polypropylene and nylon, combined with artificial jute backing-cloth; with features such as soft quality, high elasticity, solid tuft-bonding, good wear resistance, beautiful luster, mothproof and mildew-proof, fire-retarding, antistatic, noise-reducing etc. | Tuft height: 5-7mm Maximum breadth: 4m Designs: velveteen, loop tuft, jacquard, colors selected by users | Dynamic load thickness reducing rate (%) Loop-pile: 9.71; velveteen:14.05 Backing-cloth peeling strength (N) Warp-wise: loop-pile 54.5; velveteen 45.6 Weft-wise loop-pile 53.5; velveteen 49.6 Tuft bonding power (N) loop-pile: 52.2; velveteen: 43.1 Dye fastness (grade): loop-pile: 5; velveteen 6 Heat-resistance damage maximum distance (mm) Loop-pile: 6.0; velveteen:6.1 | Wuxi Flooring Material Factory |
| Tufted chemical fiber carpet (Jinlu brand) | Made of chemical fiber. With features such as dustproof, sound insulation, heat preservation, elastic, wear-resistance, easy cleaning and fire-retarding etc. | Tuft height: 3-12mm Designs: velveteen, loop tuft, jacquard Color: different colors Breadth: 2m Length: 125m / coil | Tuft bonding power (N) Loop-pile: 27.46; velveteen:1961 Tuft unit mass (g/m$^2$) Loop-pile: 300; velveteen: ≥350 Peeling strength (N): loop-pile: 28.4 velveteen: ≥27.5 Thickness reducing rate (%) Loop-pile: ≤25; velveteen: ≤40 Fire-resistance: meeting requirements | Lanzhou Carpet Weaving Mill |

## 3. Applications of Chemical Fiber Carpet

Chemical fiber carpet is the largely used medium and low grades carpet with features such as mildew-proof, moth-proof, corrosion-resistance, lightweight, high elasticity, good feeling, low moisture-absorption, easy cleaning and low price etc. It can be spread or bonded on the surface of wood floor, mosaic floor, terrazzo-concrete floor and cement concrete floor etc. It is applied to the floor decoration of hotels, restaurants, rest houses, reception rooms, ship-crafts, vehicles and planes etc. Chemical fiber carpet with shag piles, high density and novelty style as well as beautiful patterns is suitable for three-star or above hotels. Machine-woven jacquard art square is of advanced products, whose appearance is competitive to that of pure wool carpet.

### 12.2.4 Tapestry

Tapestry is also called wall carpet, which is an interior wall hanging artwork for enjoyment, so also called artistic wall hanging. Tapestry requires beautiful pattern designs, therefore, is usually made of super material such as pure wool and linen etc. In recent years, blended fiber or chemical fiber is largely used to produce tapestry.

Besides practical functions such as sound absorption, thermal preservation and insulation, tapestry induces aesthetic feeling in people. There are many kinds of dimensions, and customized dimensions are also allowed. Tapestry has rich pattern themes. Beautiful mountains and rivers, fine paintings, animals, flowers and birds, photographic works are all contents for the pattern designing of tapestry. Decorated with tapestries, the room will be filled with not only elegant artistic and esthetic feeling, but with easeful and peaceful atmosphere.

Super tapestries have been precious and elegant presents, for instance, the lounge hall in the United Nation building is decorated with a 6m×6m large size tapestry "The Great Wall" presented by our country, which not only reveals the cultural history of Chinese people, but also represents the tactful technological level in tapestry weaving in China.



## 12.3 Wall Decorative Fabric

Surface decorative fabric softens the space and beautifies the environment with its unique soft quality and special color effect, and creates warm, harmony and pacific atmosphere, which provides spiritual comfort to people suffering from busy work.

With the rapid development of modern decoration, fabric has become a kind of very important material. As interior decorative material, it can be coordinated with the interior textiles such as curtains, table cloth, tapestries and cushions to improve the interior atmosphere, styles and fashions, artistic conception and service functions and to enhance the interior decoration effects. Therefore, different kinds of fabric are more and more widely applied to building decoration. Presently, wall decorative fabrics produced in China include textile wallpaper, glass fiber printed wall cloth, non-woven wall cloth, chemical fiber decorative wall cloth, cotton decorative wall cloth and tapestry satin etc.

## 12.3.1 Fabric Wallpaper

Fabric wallpaper is made in this way: firstly, make thick or thin yarns or fabrics in different colors, glosses and designs of natural or chemical fiber such as cotton, linen, silk and wool; then yarns are stuck on the base paper with different spinning techniques or color yarn twisting process methods to create textile fiber wallpaper with many different patterns; also natural materials such as ribbon straws, bamboo filaments or hemp bark strips are bleached and dyed, interwoven together with cotton yarns and then stuck on the base paper to produce plant fiber wallpaper. Fabric wallpaper mainly includes paper-based wallpaper and hemp-straw wallpaper.

### 1. Paper-based Fabric Wallpaper

Paper-based fabric wallpaper is produced by making thick and thin yarns or fabrics with different luster and patterns out of natural and chemical fibers such as cotton, wool, linen and silk, then bonding the yarns or fabrics with the base paper. The patterns are arranged with yarns in different colors or created by mix spinning with gold or silver threads to provide the wall surface with gold-spot flickering appearance, thus to achieve the decorative effect. Also such wallpaper is available to be embossed into relief patterns to create unique styles.

Features of paper-based fabric wallpaper are soft and elegant colors, strong stereoscopic impression of the wall surface and great effect of sound-absorption. It is sunlight resistant, unfading, nontoxic and harmless, with no static-electricity, but with good air-permeability and moisture-adjustment performance. It is suitable for the interior wall decoration of hotels, restaurants, office buildings, conference rooms, reception rooms, computer rooms, broadcasting studios and bedrooms.



### 2. Hemp Wallpaper

Hemp wallpaper is an interior decorative material made by taking paper as base layer and woven hemp as surface layer, and then processing them together. Such wallpaper is sound absorbing, fire-retarding, moisture-dispelling, dustproof, non-deforming, and without any side effect to human body. It is rich of natural beauty such as natural and primitive simplicity as well as boorishness, which brings people the feeling of living in the nature. It is suitable for the wall surface decoration of conference rooms, reception rooms, bars, dancing halls and guestrooms in restaurants and hotels.

### 12.3.2 Cotton Decorative Wall Cloth

Cotton decorative wall cloth is made of plain cloth of pure cotton after procedures such as processing, printing and wear-resistant resin coating etc. It is dull, nontoxic, odorless, beautiful and decent with high strength, small static and creep, and good sound absorption. It is suitable for the decoration of hotels, restaurants and other public buildings as well as advanced residential buildings, and also can be stuck or hung on the wall surface made of mortar, concrete, white mortar, plasterboard, veneer board, fiberboard and asbestos cement.

Cotton decorative wall cloth also serves as curtains. Thin curtains in light color create peaceful and comfortable atmosphere in summer, no mater naturally drooping, or pulling to both sides to semi-arch form.



### 12.3.3 Non-woven Wall Cloth

Non-woven wall cloth is a new-type wall decorative material made of natural fibers such as cotton and hemp or synthetic fibers such as terylene FE-TP and acrylic PAN, processed through non-woven molding, resin coating and color pattern printing.

Such wall cloth is smooth and straight, elastic and less likely to break due to its age resistant fiber that has no side effect to skin. It has fresh and beautiful colors, elegant patterns and certain air-permeability and moisture-proof performance. It is easy to clean but unfading, and also works easily. It is suitable for the interior wall decoration of different kinds of buildings. Especially terylene cotton non-woven wall cloth not only has all performances of linen non-woven wall cloth, but has fine, clean and smooth quality, especially suitable for advanced hotels and residential buildings.

### 12.3.4 Other Wall Decorative Fabrics

#### 1. Chemical Fiber Decorative Wall Cloth

Chemical fiber decorative wall cloth is made of chemical fiber cloth (single fabric or multiple fabrics) after being processed and printed. Commonly-used chemical fibers are viscose fiber, acetate fiber, polypropylene fiber, acrylic, nylon and terylene etc. The so-called "multiple fabrics" means wall cloth made of many kinds of fibers that are blended spun with cotton. Such product is nontoxic, odorless, air-permeable, moisture-proof and wear-resistant, and is available for hotels, restaurants, office buildings, conference rooms and residential buildings.

**2. Advanced Wall Decorative Fabric**

Advanced wall decorative fabric refers to brocade, velour and worsted etc. Due to different fiber materials and weaving techniques as well as processing techniques, they create different textures and decorative effects, therefore, bring people different feelings of beauty.

Brocade, also called satin brocade or tapestry satin, has various patterns woven on its surface which look colorful, fine and primitive. Together with its own silk texture and silky effect, it looks more elegant and noble, magnificent and palatial. It is commonly applied to advanced interior wall surface. But due to its disadvantages such as high price, easy deformation, difficult operation in construction, unavailable for scrubbing or washing, easy to get dirty and moldy, its application is limited to a certain range.



Velour has gorgeous colors, solid and warm textures and elegant styles. It is mainly applied to advanced buildings as curtains, soft partitions or float hangings to create honorable and luxurious atmosphere.

Coarse wool or imitated wool chemical fiber fabric and linen fabric, whose textures are coarse, solid and sturdy, provide warm feelings and have good sound absorption and thick and primitive simplicity revealed from the texture. They are suitable for the column surface decoration in public halls of advanced hotels and so on.

**3. Leather and Artificial Leather**

Leather and artificial leather is an advanced wall decorative material, the best of which is genuine sheep leather. But because of its high price, artificial leather with imitated patterns of sheep leather is commonly adopted. There are many patterns and colors, highly imitative to genuine but at lower price and with rather good decorative effects.

Wall surface decorated with leather or artificial leather has excellent performances such as softness, sound attenuation, warm and wear resistance, and reveals elegant and noble decorative effects. Such product is suitable for interior walls with bumping-proof requirements in gymnasiums and kindergartens etc.; and also in rooms with higher acoustic requirements such as recording studios and telephone booths. In interior decorative projects, artificial sheep leather is often used to make soft partitions and sound-absorbing doors with both decorative and practical effects.

# 12.4 Decorative Curtains

## 12.4.1 Functions of Curtain Antependium

With the development of modern construction, curtain antependium has become one of the indispensable parts in interior decoration.

Except for decorative functions, it is used to block external light, protect carpet and other textiles and decorative materials from fading and deteriorating due to sunlight; to prevent dust invasion, retain clean and tidy, keep interior peace and silence and eliminate or insulate noise. Thick fabric curtains in large dimensions and with more puckers enhance the effect of sound insulation and at the same time adjust the interior temperature, which leads to warm and comfortable indoor environment.



## 12.4.2 Classifications of Curtains

The raw material for curtain antependium has already developed from natural fiber fabrics such as cotton and linen to artificial fiber fabrics or blended fabrics. Its main types include cotton cloth, blended linen fabrics, viscose fiber fabrics, acetate fiber fabrics and polyacrylonitrile fiber fabrics etc.

### 1. Classified Based on Material

Curtain antependium is commonly classified to four types.

1) Heavy material. Including wool, imitated wool chemical fiber fabric and linen fabric etc., it is thick and heavy fabric. Features are: good thermal preservation, sound insulation and light shading etc., with simple and decent style or antique and solemn style.

2) Velvet material. Including velveteen, striped velvet, velour and towel cloth etc., it is soft and fine fabric. Features: fine and dense grain, soft texture, naturally drooping, thermal preservation, light shading and sound insulation etc.; serves as monolayer curtain or the thick layer of double-layer curtains.

3) Light material. Including patterned cloth, poplin, silk cloth, Dacron, georgette and nylon cloth etc., it is thin light fabric. Features are: thin and light

in material quality, good hanging effect with pleats, also easy for washing and cleaning, but weaker in light shading, thermal preservation and sound insulation etc. solely used as curtains or coordinated with thick curtains.

4) Lace.

**2. Classified Based on Structure**

According to structure, window curtain is classified to exterior, middle and interior curtains.

1) Exterior curtain. It is the layer closest to the window glass to prevent sizzling sunlight and block the vision from exterior. The curtain is required to be light and thin as well as transparent, commonly adopting thin and translucent fabric.

2) Middle curtain. Commonly adopt translucent fabric such as fancy yarn fabric, jacquard fabric, jacquard printed fabric, imitated linen and linen blend fabric etc.

3) Interior curtain. It is to beautify the indoor environment and is highly required in material quality, patterns and colors and in further processing of the curtain. Interior curtain is required to be non-transparent with functions such as thermal insulation, light shading and sound absorption and generally adopts boorish style and medium or thick fabrics such as cotton, linen and different kinds of blended fabrics.



### 12.4.3 Selection of Window Curtains

To select proper colors and patterns of window curtain is an important step to achieve the goals of interior decoration. The color of the curtain should be considered and decided based on factors such as the interior integrity, different weathers, surroundings and lights. For instance, it is better to use bright and thin curtain in summer and dark and thick curtain in winter. In addition, the colors of interior wall surface, furniture and lighting should be taken into consideration in curtain selection to keep the entire harmony.

Patterns are another important thing that should be considered in curtain selection. Patterns or stripes in vertical direction make windows look smaller than its real size, whereas scattered patterns make windows look bigger. Big patterns make windows look smaller and small patterns make them look larger. Therefore, curtain patterns should be chosen according to the size of the window, the height and color tones of the room. In addition, the length of curtains is also a factor affecting the selection of curtain patterns.

### 12.4.4 Hanging Modes of Window Curtains

There are many hanging modes: monolayer and double-layer; mono-layer horizontal pulling, double-layer horizontal pulling, whole curtain vertical pulling and up-part and down-part vertical pulling based on opening method; according to fittings, classified to pelmet-box-set, curtain bar exposed and curtain bar unexposed; according to the forms after pulling apart, to naturally drooping and semi-arch form etc.

## Practice

Learn about the types, dimensions, performances, prices and application statuses of wall decorative fabrics and carpets. Focus on the types, dimensions, performances, prices, selections and applications of wallpaper and wall cloth.

**1. Objective of Practice**



Students are required to go by themselves to the building decorative material markets and building decoration and construction sites to carry out investigation and practice, find out the prices of wall surface decorative fabrics and flooring carpets, get familiar with the application statuses of such materials and exactly recognize the names, dimensions, types, prices, application requirements and application ranges of different materials.

**2. Practice Methods**

(1) Investigation and Analysis in Building Decorative Material Markets

Student grouping: 3-5 students in one group; carry out investigation and analysis in building decorative material markets;

Investigation method: get to know different kinds of decorative fabrics, investigate on material prices, collect material samples and master the requirements of material selection mainly by surveying and inquiring.

(2) Research on the application of decorative materials on construction and decoration sites.

Students grouping: 10-15 students in one group and guided by teachers or persons in charge of the site;

Investigation method: guided by teachers or persons in charge of the site, introduce and explain the application status and notices in construction practice adapted to the construction site and its actual conditions.

**3. Contents and Requirements for Practice**

1) Complete the research diary carefully;

2) Write a material research report;

3) Write a practice summary.

# Summary

Carpet is an advanced flooring decorative material with many types and different classification methods; for instance, classifications based on patterns, materials, processing techniques, dimensions and application places etc. The commonly-used are pure wool and chemical fiber carpet. Pure wool carpet is advanced and classified to hand-woven and machine-woven according to weaving techniques.

Pure wool carpet has fresh and beautiful luster, sturdy material quality and high elasticity. It is soft and comfortable, durable in use and with good decorative effects and resistance to stain, wearing and lodging, but it is weak in flame retardance and tends to generate static-electricity. Chemical fiber carpet is composed of surface layer, protection layer and backing-cloth. Its main technical performances include peeling strength, tuft bonding strength, wearing resistance, static resistance, ageing resistance and flame retardance etc.

Wall decorative fabrics refer to wallpaper or wall cloth made of woven and knitted fabrics as surface. Fabric wallpaper includes paper-based fabric and hemp wallpaper. Wall cloth includes glass-fiber based and non-woven wall cloth, chemical fiber and cotton decorative wall cloth as well as advanced decorative wall fabrics etc.



# Questions for Reviewing and Thinking

12.1 What are the types and main features of building decorative fiber?

12.2 Which five types is carpet classified to according to material? What are their features?

12.3 What types does wall decorative fabric include?

# 13

# Architectural Coatings

Coating is defined as the material that covers the surface of building units by adopting operational techniques such as brushing, radiating, spraying, trowelling and catapulting, and adheres well with the later to create integral protective film that will prolong the service life of buildings. It has features such as rich colors, vivid texture, convenient operation, convenient maintenance and renovation etc. Therefore, it is the simplest and most economical approach to adopt coatings for the decoration and protection of buildings.

## 13.1 Introduction of Decorative Coatings

### 13.1.1 Components of Coatings

Each component in coatings has different functions, but the basic components include primary, secondary and auxiliary film-forming matters. Refer to Figure 13.1.

**1. Primary Film-forming Matter**

Primary film-forming matter is also called "adhesive or sticking agent". It sticks other components together and adheres on the surface of the substrate to form a strong protecting film. With high chemical stability, most adhesives are macromolecular compounds (such as resin) or organic substances (oil materials) creating macromolecular compounds after filming.

(1) Oil

It is the main raw material for some oil coatings or oil-based coatings. Vegetable oil is mainly adopted. Based on whether it dries to form film and its film-forming speed, it is classified to drying oil, semi-drying oil and non-drying oil.

Drying-oil (tung oil, stillingia oil and perilla oil etc.): coated on the surface of objects, some time (within one week) after oxidation by atmospheric oxygen, it forms hard oil-film, which is water resistant and highly elastic.

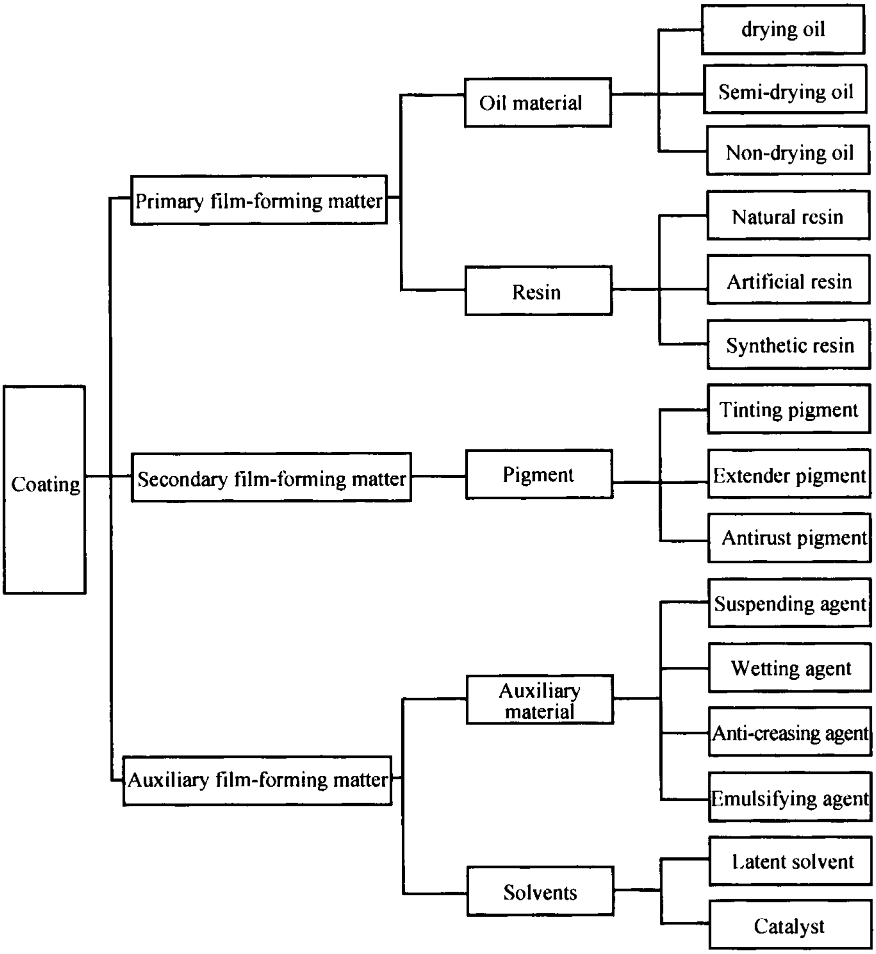



Figure 13.1 Components of Coatings



Semi-drying oil (bean oil, sunflower oil and cottonseed oil etc.): it needs longer drying time (more than one week) and forms soft and sticky oil-film.

Non-drying oil (peanut oil and castor oil etc.): it doesn't dry by itself in normal condition, and can't be used directly to produce coatings.

(2) Resin

Coatings can be made only from oil material, but the film formed by such coatings doesn't meet higher requirements in performances such as hardness, glossiness, water-resistance and acid-alkali resistance, so it is necessary to adopt resin with great performances as the film-forming matter of coatings. Resin is classified to natural resin (shellac and Chinese lacquer etc.), artificial resin (ester gum and nitrocellulose) and synthetic resin (alkyd resin, polyacrylate, epoxide resin, polyurethane, chlorosulfonated polyethylene, polyvinyl condensations, polyvinyl acetate and its copolymers etc.).

To meet the multifunctional requirements for coatings, it is available to apply combination of multiple types of resin in one kind of coating, or to combine it with oil material as primary film-forming matter.

**2. Secondary Film-forming Matter**

Secondary film-forming matter refers to different kinds of pigments in coatings. Pigment itself does not form film, but it serves as the component of the film with the aid of the bonding of primary film-forming matter. It has functions such as coloring the film, increasing the texture of the film, improving the properties of the film, developing different types of coatings and reducing the cost of coatings etc.

There are many types of pigment. According to different chemical compositions, it is classified to organic and inorganic pigments; according to different sources, classified to natural and artificial pigments; according to different functions of different pigments in coatings, to tinting pigment, extender pigment and antirust pigment.

(1) Tinting Pigment

Tinting pigment is mainly to provide certain color and hiding ability to the film. Moreover, inorganic pigment also has certain resistance to ultraviolet penetration, which alleviates the aging of organic macromolecular primary film-forming matter and enhances the weather-resistance of the film. Architectural coating is often applied to alkali surface layers (such as mortar or concrete surface) and exposed to atmospheric environments, therefore, its tinting pigment is required to have better resistance to alkali and to light. Organic pigment has weaker anti-ageing performance, so it is rarely adopted as the tinting pigment for architectural coatings. As to commonly-used tinting pigments, refer to Table 13.1.

**Table 13.1 Commonly-used Tinting Pigments in Coatings**

| Color | Chemical composition | Type |
|---|---|---|
| Yellow pigment | Inorganic pigment | Lead-chrome yellow, ferrite yellow |
| | Organic pigment | Anti-solar yellow, benzidine yellow etc. |
| Red pigment | Inorganic pigment | Iron oxide red, vermilion |
| | Organic pigment | Toluidine red, lithol red |
| Blue pigment | Inorganic pigment | Erlangen blue, cobalt blue, ultramarine blue |
| | Organic pigment | Phthalocyanine blue etc. |

Continued

| Color | Chemical composition | Type |
|---|---|---|
| Black pigment | Inorganic pigment | Carbon black, mineral black, ferrite black |
| | Organic pigment | Aniline black |
| Green pigment | Inorganic pigment | Chrome green, zinc green |
| | Organic pigment | Phthalocyanine green etc. |
| White pigment | Inorganic pigment | White iron pigment, zinc oxide, lithopone |
| Metal pigment | | Aluminum pink, aluminum powder, copper powder etc. |

(2) Extender Pigment

Extender pigment, also called filler, is white powder. With lower hiding power in coatings, it is nearly transparent and can't prevent light from transmitting the film. It is only used to increase the thickness of the film, enhance its texture and enhance its wear-resistance, ageing-resistance and durability etc.

Extender pigment mainly includes some alkaline-earth metallic salts, silicate and ytterbium as well as cobalt metallic salts, such as barium sulfate, calcium carbonate, talc powder, mica powder and porcelain clay etc.



(3) Antirust Pigment

Antirust pigment provides the film with good antirust property to prevent rust corrosion on the surface of the coated metal. Antirust pigment mainly includes red lead, zinc yellow, iron oxide red and aluminum powder etc.; antirust pigment for iron includes red lead, aluminum and aluminum-magnesium alloy etc.; for light metals, zinc yellow is used.

## 3. Auxiliary Film-forming Matter

Auxiliary film-forming matter can't form film solely, but has important affects to the production of coatings, coating construction and film forming procedure. Auxiliary film-forming matter in coatings includes dispersion mediums and additives.

(1) Dispersion Medium (Thinning Agent)

In construction, coating is usually liquid with certain consistency, invasiveness and fluidity. Therefore, it should contain large amount of dispersion medium, also called thinner. In coating production, dispersion medium serves as the material to resolve, disperse and emulsify primary film-forming matters or the raw materials of primary film-forming matters; in coating construction, it provides coatings with certain consistency and fluidity, also enhances the penetration power of the primary film-forming matters to the substrate. During the film-forming procedure, a little part of dispersion medium will be absorbed by the substrate, and the most part will escape to the atmosphere instead of remaining in the film.

Dispersion medium used in coatings includes organic solvent and water.

Organic solvent not only resolves primary film-forming matters such as resin and oil material, but also controls the Mongolia degree of coatings and makes them convenient for coating construction. Moreover, it has certain volatility. Commonly-used organic solvent includes turpentine, alcohol, No. 200 solvent naphtha, benzene, xylene and acetone. Coating adopting organic solvent as dispersion medium is called solvent-based coating. Water serves as the dispersion medium for many types of coating, called water-based coating. Tap water with less content of mineral impurities can be used to dilute water-based coatings.

(2) Additive

Additive is auxiliary material added to improve the performances of coatings and to enhance the film quality. There are many types of additives. Only a little amount creates prominent effects on the improvement of coating performances. Commonly-used additives in coatings mainly include several types as follows.



1) Drying Agent. Drying agent is applied to coatings with oil material as primary film-forming matter. It is to accelerate the oxidation, polymerization, drying and film-forming procedure of coatings, and to improve the quality of coating film to some extent. Commonly-used drying agent is mostly the oxide or salt of transition-metal elements such as lead, cobalt, manganese and zinc etc., or the metallic soaps created by the reaction between these elements and oleic acid, linoleic acid and naphthenic acid etc.

2) Plasticizer. Plasticizer is applied to coatings with synthetic resin as primary film-forming matter. It is ester compound with smaller molecular weight (around 300-500) which inserts between molecular-chains, weakens the bonding force among macromolecules, and thus enhances the plasticity and flexibility of the film. Commonly-used plasticizers are phthalate esters and fatty acid esters.

3) Curing agent. Curing agent is the substance reacting with the primary film-forming matter of coatings and making it solidify to form the film. Different primary film-forming matter in coatings needs different curing agents. For instance, silicate paint needs condensed aluminum phosphate as

curing agent, room temperature curing epoxy resin mostly adopts polyene and polyamine curing agent such as diethylenetriamine and triethylenetetramine.

4) Rheological agent. Rheological agent is mainly applied to emulsion type coatings to set up a thixotropic structure in the coatings. Such structure has the following features: in coating operation, due to the influence of shearing force, it decreases the viscosity and increases the fluidity of coatings, which helps coating leveling; after coating operation, the wet coating-film rapidly recovers to loose reticulate condensed state with its viscosity greatly increased and its fluidity largely decreased, which effectively prevents the wet coating-film from dripping and sagging. Commonly-used rheological agents are alkali metallic oxide, bentonite, polyvinyl alcohol and acrylic copolymer etc.

5) Dispersion agent, thickener, foam killer and antifreezer. These additives added to emulsion type coatings respectively play such roles: increase the dispersion degree of film-forming matter in the solvent; increase the viscosity of the emulsion, retain the stability of the emulsion and improve the leveling of the coating; remove bubbles; improve the internal anti-freezing property of the emulsion and decrease the film-forming temperature.

6) Ultraviolet absorbent, antioxidant and antiager. These additives are to absorb the ultraviolet in sunlight, restrain and delay the degradation and oxidation destructive process of the macromolecular compounds, enhance the film of its gloss retention, color retention and aging-resistance and to prolong the service life of the film.

There are some other additives, such as anti-mildew agent, preservative agent and fire retardant etc. They are applied to architectural coatings with special functional requirements.



## 13.1.2 Classifications, Types and Nomenclature of Coatings

### 1. Nomenclature of Coatings

National standard "*Classification, Nomenclature and Type of Coating Products*" (GB2075-92) has specified the nomenclature of coatings as follows.

The nomenclature principle is:

Full name of coating= color or pigment name + primary film-forming matter + basic designation

Color should be placed at the beginning of the full name. If the pigment plays prominent function to the performances of the film, its name can replace the color name.

The name of primary film-forming matter in the full name should be shortened properly, for instance, polyurethane is shortened as PU. If the coating contains many types of film-forming matter, the name of the main type is taken.

Basic designation is accepted name, e.g. red alkyd enamel and iron red phenolic antirust paint.

Table 13.2 has listed the basic designations and codes of some coatings.

**Table 13.2 Basic Designations and Codes of Some Coatings**

| Code | Basic designation | Code | Basic designation | Code | Basic designation |
|---|---|---|---|---|---|
| 00 | Boiled oil | 14 | Clear lacquer | 61 | Heat-resistant paint |
| 01 | Varnish | 15 | Speckle paint, crackle lacquer, orange-pattern lacquer | 62 | Thermo-indicator paint |
| 02 | Paste paint | 19 | Flare lacquer | 66 | Photo-cured coatings |
| 03 | Mixed paint | 24 | Appliance coatings | 77 | Interior wall coatings |
| 04 | Lacquer enamel | 26 | Bicycle coatings | 78 | Exterior wall coatings |
| 05 | Powder coatings | 23 | Can coatings | 79 | Roof water-resistant coatings |
| 06 | Priming paint | 50 | Acid-resistant paint, alkali-resistant paint | 80 | Floor paint, terrace paint |
| 07 | Putty | 52 | Anti-corrosive paint | 86 | Signal paint, traffic paint, road marking paint |
| 08 | Chinese lacquer | 53 | Antirust paint | 98 | Glue solution |
| 11 | Electro-phoretic paint | 54 | Oil-proof paint | 99 | Others |
| 12 | Latex paint | 55 | Water-resistant paint | | |
| 13 | Water soluble paint | 60 | Fire-proof paint | | |

Note: Principle of above codes: represented with numbers 0-99 in double digits. 0-99 stands for basic designation; 10-99 stands for pattern paint; 20-29 stands for light industrial paint; 30-39 stands for insulating paint; 40-49 stands for marine paint; 50-59 for anti-corrosion paint; 60-69 for others.



## 2. Types of Coatings

### (1) Representation of Coating Types

Coating type is represented with three parts: the first part is the code of its primary film-forming matter, represented with Chinese pinyin letters, refer to Table 13.3; the second part is the basic designation, represented with double digits, refer to Table 13.2; the third part is its sequence number, representing different types of coating with different components, mixture ratios or applications in the same product category. Each type only represents one kind of coating, take C04-2, in which "C" stands for alkyd resin (primary film-forming matter), "04" stands for lacquer enamel (basic name) and"2" stands for sequence number.

Example:

```
C     04 -  2
|     |     └─basic designation
|     └─primary film-forming matter
└─ color
```

**Table 13.3 Types of Coatings**

| Sequence number | Type | Primary film-forming matter | Code |
|---|---|---|---|
| 1 | Oil | Natural vegetable oil, synthetic oil etc. | Y |
| 2 | Natural resin | Rosin and its derivatives, shellac, lactic casein, Chinese lacquer and its derivatives etc. | T |
| 3 | Phenolic resin | Phenolic resin, phenol-formaldehyde resin modified | F |
| 4 | Asphalts paint | Natural asphalt, petroleum asphalt, coal-tar asphalt etc. | L |
| 5 | Alkyd resin | Glycerol alkyd resin, modified alkyd resin | C |
| 6 | Amine resin | Urea-formaldehyde resin | A |
| 7 | Nitrate | Nitrocellulose, modified nitrocellulose | Q |
| 8 | Cellulose | Ethyl-cellulose, butyl-cellulose, cellulose acetate, hydrocellulose etc. | M |
| 9 | Perchloro-ethylene resin | Chlorinated polyvinyl chloride, modified chlorinated polyvinyl chloride | G |
| 10 | Alkenes resin | Vinyl chloride copolymer, polyvinyl acetate and its copolymer, polystyrene resin, chlorinated polypropylene resin etc. | X |
| 11 | Acrylic resin | Acrylic resin and its copolymer modified resin | B |
| 12 | Polyester resin | Saturated polyester resin, unsaturated polyester resin | Z |
| 13 | Epoxide resin | Epoxide resin, modified epoxide resin | H |
| 14 | Urethane resin | Polyurethane | S |
| 15 | Element organic polymer | Organosilicon, organic titanium, organic aluminum etc. | W |
| 16 | Rubber | Natural rubber and its derivatives | J |
| 17 | Others | Other film-forming matters excluded by the above 16 categories, such as high molecular material etc. | E |

(2) Representation of Auxiliary Material Types

Auxiliary material is represented with two parts: the first part is auxiliary material type, represented with Chinese pinyin letters; the second part is the sequence number. Classified based on applications, its types and codes are: thinner-X; moisture-resistant agent-F, drying agent-G, paint remover-T, curing agent-H.

**3. Classifications of Coatings**

Commonly-used classification methods are as follows.

1) Classified Based on Different Application Areas

Architectural coatings are used on different areas of buildings, and are classified to exterior wall, interior wall, ceiling, floor and roof waterproof coatings etc.

2) Classified Based on Different Primary Film-forming Matters

According to different film-forming materials, coatings are classified to organic, inorganic and organic-inorganic composite coatings.

Architectural coatings with organic high molecular material as primary film-forming matter are called organic coatings. Some inorganic cementing materials (mainly include water glass and silica sol) also serve as the primary film-forming matter of coatings, such coatings are inorganic coatings. Those compounded with the above two types (such as polyvinyl alcohol water glass coatings) are called organic-inorganic composite coatings.



3) Classified Based on Different Dispersion Mediums

According to different dispersion mediums, coatings are classified to solvent-based and water-based coatings (latex type coatings, hydrosol coatings and water soluble paint).

Solvent-based coatings are those whose primary film-forming matter is resolved to actual solution state in the dispersion medium.

Water-based coatings are those taking water as dispersion medium. According to different dispersing modes of primary film-forming matter in water, they are further classified to emulsion type coatings, hydrosol coatings and water soluble coatings.

4) Classified Based on Different Building Functions

Coatings are classified to decorative coatings, waterproof, anti-corrosive, mildew resistant, anti-fogging and fireproof coatings etc.

5) Classified Based on Different Textures of Coating Layers

Coatings are classified to thin, thick and stratified architectural coatings etc.

### 13.1.3 Main Technical Performance Requirements for Architectural Coatings

The function of architectural coatings to buildings is revealed in two aspects: first is the decorative function. Different colors, textures are created by adopting different coatings and decorating techniques to meet different decorative artistic requirements for different types of buildings; second is the protective function. In service, structural materials of buildings tend to suffer the destructive influences from the media in the environment, so architectural coatings are applied to alleviate such destruction and to prolong the service life of buildings. These two functions are realized by the film with excellent performances formed by coatings. Factors affecting the performances and internal quality of the film are mainly the components and systematic features of coatings, so architectural coatings and their film formed after coating procedure should meet certain technical performance requirements.

### 1. Main Technical Performance Requirements for Coatings

The main technical performance requirements for coatings include state in vessel, viscosity, solid content, fineness degree, drying time and minimum filming temperature etc.

(1) State in Vessel

Its state in vessel reflects the storage stability of coating systems. All kinds of coatings stored in vessel are required to be no hard lump and to be in homogeneous condition after blending.

(2) Viscosity

Coatings are required to have certain viscosity to ensure easy leveling but not sagging. The viscosity of architectural coatings depends on the self viscosity and the content of primary film-forming matter.

(3) Solid Content

Solid content is defined as the percentage of the amount of non-volatile matter to the overall amount of the coating. It not only affects the viscosity of coatings, but also influences the film in performances such as strength, hardness and glossiness as well as hiding power etc. The solid content of thin coatings is not less than 45%.

(4) Fineness Degree

Fineness degree is defined as the granular size of secondary film-forming matter in coatings, and it affects the uniformity of the color as well as the flatness and glossiness of the surface of the film. The fineness degree of thin coatings is required no more than 60mm.

(5) Drying Time

It is classified to surface drying time and hard drying time, which affects the time schedule of coating procedure. Generally, the surface drying time is required no more than 2h; hard drying time, no more than 24h.

(6) Minimum Filming Temperature

Minimum filming temperature is an important performance of emulsion type coatings. The film of emulsion type coatings is formed in this way: with the dispersion of the medium (vaporization of water) in coatings, fine granules are getting close gradually and setting to form the film. This film-forming procedure is realized only at certain low temperature called minimum filming temperature. The minimum filming temperature for emulsion type coatings is required to be 10℃ and above.

Moreover, to different types of coatings, there are some different special requirements such as the aggregate setting of sand-wall-like coatings and the low-temperature stability of emulsion-resin type coatings etc.

**2. Main Technical Performance Requirements of Film**

There are physical mechanics performances and chemical performances, mainly including film color, hiding power, adhesion, bonding strength, freeze-thaw resistance, stain resistance, weather resistance, water resistance, alkali resistance and scrub resistance etc.

(1) Film Color

Compared with standard sample, film color is required to comply with chromatic aberration range.

(2) Hiding Power

Hiding power reflects the covering power of the film to the color of the substrate and is related to the tinting power and content of tinting pigment in coatings. It is represented with mass per unit area $g/cm^2$ needed to cover the specified black and white squares (the squares on the black and white check board). The hiding power of architectural coatings ranges around 100-300$g/cm^2$.

(3) Adhesion

Adhesion stands for the fastness of bonding between the film of thin coatings and the substrate, measured with grid test. Make standard film sample of the coating, draw cross lines on it every 1mm both horizontally and vertically with a sharp cutter to make 100 small squares, with the cutter cutting through the film; then brush it to-and-fro for 5 times along the diagonal line with a soft brush and observe with a magnifier if there is fall-off (peeling or flaking) phenomenon on the small squares of film. Adhesion is represented with the percentage of the remaining small squares. The adhesive index of high quality film should be 100%.

(4) Bonding Strength

Bonding strength is the performance index of bonding fastness between the substrate and the film of thick architectural coatings or multilayer architectural coatings. The film formed by coatings with high bonding strength is less likely to peel or flake and has good durability.

(5) Freeze-thaw Resistance

The film surface of exterior wall coatings contains absorbed water in its capillaries, in winter it may suffer repeated freezing-thawing cycles, which leads to cracking, powdering, bubbling or flaking-off of the film. So to exterior wall coating-film, certain freeze-thaw resistance is required. The freeze-thaw resistance of film is represented with the maximum freeze-thaw cycles that the standard film sample can endure at the temperature ranging −20-23 ℃.The more cycles endured, the better freeze-thaw resistance the film has.

(6) Stain Resistance

Stain resistance is defined as the ability to resist the contamination from atmospheric dust, and it is an important performance of exterior coatings. Coatings exposed to atmospheric environment suffer three types of dust pollution: the first is sediment pollution, namely, the dust naturally deposits on the surface of coatings, whose pollution level is related to the flatness of the film; the second is intrusive pollution, namely, the dust and colored substances etc. intrude in the capillary bores of the film along with water, whose pollution level is related to the dense and compactness of the film; the third is adhered pollution, namely, the surface tends to absorb dust due to its own static electricity or oil stain. Among them the second is the most serious to the film. Stain resistance of the film is represented with the declining percentage of its light reflection coefficient after it has received specified times of pollutant stains. The less the declining percentage is, the better its stain resistance will be.



(7) Weather Resistance

After exposed to light, heat and ozone for a long time, high molecules in the primary film-forming matter of organic coatings tend to degrade or crosslink, which makes coatings become sticky or brittle and lose its primary strength, flexibility and gloss, and at last get damaged. Such phenomenon is called the ageing of coatings. The anti-ageing ability of coatings is called weather resistance, which is represented with state indexes of chalking, cracking, bulging, peeling or discoloration of the film after certain time of accelerated aging treatment.

(8) Water Resistance

After long term contact with water, coatings tend to suffer such phenomenon as bubbling, powder falling, tarnishing or discoloration etc. The ability to resist such destructions caused by water is called the water resistance of coatings. It is measured with soaking test, namely, immerse 2/3 of the hard dry film sample in (25±1)℃ distilled water or boiled water and check if there is any above destructions happening to the film after the specified period of time. Coatings with weak water-resistance are not allowed to be used in moist environment.

(9) Alkali Resistance

Most architectural coatings are applied on the surface of alkali contained materials such as cement concrete and cement mortar, under the action of alkali medium, the film tends to suffer destructive phenomenon such as bubbling, powder falling, tarnishing or discoloration. Therefore, coatings must have certain ability to resist the destruction from alkali medium, which is called alkali resistance. The measurement method of alkali resistance is: immerse the film sample in $Ca(OH)_2$ saturated water solution for a certain period of time and check if there is any above destructive phenomenon happening to the film surface and decide the degree of the destruction, which is adopted to evaluate the alkali resistance of coatings.

(10) Scrub Resistance

Scrub resistance is defined as the performance of retaining no destruction after long term of being washed and scrubbed with water. The measuring method is: brush the film on the sample plate repeatedly with a brush dipped with soap water of certain concentration under certain pressure and to certain times, and check if the film is worn out and if the ground-color of the plate is exposed. The scrub resisting times for exterior coatings are required more than 1000 times.

The above stated technical requirements are not all necessary to all coatings. For instance, freeze-thaw resistance, stain resistance and weather resistance are the important technical performances to exterior wall coatings, but not necessary to interior coatings. In addition, to different coatings, there are some special requirements, for instance, to floor coatings, higher wear-resistance is required; to multicoated architectural coatings, high-low temperature cycle resistance and impact resistance are required.

### 3. Limit on the Hazardous Substances Contained in Solvent-based Woodenware Coatings Serving as Decorative Materials

Coatings, including different kinds of paint, interior and exterior coatings etc. are presently the top consumed material in home decoration and renovation industry in our country. However, polyester resin paint and polyurethane paint are available for use only after adding curing agent, and adding thinners and adhesives when necessary. Many consumers have already noticed that benzene compounds in thinners are harmful to human health. When buying and using auxiliary thinners, they ask for those without benzene. But, the residue of toluenediamine (TDI) left by curing agent is more toxic and hazardous to human health and the environment.

The main raw material for curing agent is TDI, and its amount is close to 40% of the total amount. TDI is poisonous chemical compound, so when used for the curing of polyester resin paint or polyurethane paint, it must be converted into nontoxic substance first, which is the curing agent available for production use. However, due to the limit of production technique and equipment level, there is always some TDI unconverted and left in the curing agent. The residue amount of TDI in curing agent determines the toxic level of curing agent. According to the standard for chemical lines specified by Ministry of Chemical Industry, the division between toxic and nontoxic is 2% IDI residue amount. Presently, with 5%-8% TDI residue amount, some even up to 10%, most curing agents in the market are toxic. If coatings made of such curing agent are used to paint furniture or decorate houses, its toxic substances will gradually emit into the air. The technical requirements on the limit of hazardous substances contained in solvent-based woodenware coatings serving as decorative materials are given in Table 13.4.

**Table 13.4 Technical Requirements on the Limit of the Hazardous Substances Contained in Solvent-based Woodenware Coatings Serving as Decorative Materials**

| Item | Content limit | | |
|---|---|---|---|
| | Nitrocellulose paints | Polyurethane paints | Alkyd paints |
| Volatile organic chemical compound (VOC)① (g/L) (≤) | 750 | Gloss(60°)≥80,600<br>Gloss(60°)<80, 700 | 550 |
| Benzene②(%) (≤) | 0.5 | | |
| The total content of both methylbenzene and dimethyl benzene ②(%) (≤) | 45 | 40 | 10 |
| Free toluenediamine (TDI)③(%) (≤) | — | 0.7 | — |

Continued

| Item | | Content limit | | |
|---|---|---|---|---|
| | | Nitrocellulose paints | Polyurethane paints | Alkyd paints |
| Heavy metal (only for pigmented paint) (mg/kg) (≤) | Soluble lead | 90 | | |
| | Soluble cadmium | 75 | | |
| | Soluble chrome | 60 | | |
| | Soluble mercury | 60 | | |

Since "the eighth five-year plan", our country has listed the research and development of nontoxic curing agents in the brainstorm projects. However, the key technological difficulties haven't been solved completely during "the eighth and ninth five-year plans". Now, non-toxic curing agents sold in market are almost imported. However the difficulties in nontoxic curing agent production are gradually overcome in China.

① Measure (measure the content of hazardous substance) after mixing according to the mixture ratio and dilution ratio. If thinner amount is specified to a certain range, the recommended maximum amount should be taken.

② If the product already has specified dilution ratio or it is composed of bi-component or multi-component, the content of thinner and its content in each component should be measured respectively, then calculate the total content in the coating according to the specified ratio of the product. If thinner amount is specified to a certain range, the recommended maximum amount should be taken.

③ If polyurethane paints have specified dilution ratio or they are composed of bi-component or multi-component, the content in curing agent (containing the prepolymer of toluenediamine diisocyanate) should be measured first, then calculate the content after mixing in coatings according to the specified ratio of the product. If the amount of thinner is specified to a certain range, the recommended minimum dilution amount should be taken.

## 13.2 Interior Wall Coatings

Interior wall coatings are also available for serving as ceiling coatings, which have both decoration and protection functions for interior walls and ceilings. To achieve good decorative effects, interior coatings are required to have rich and concordant colors, soft and mild color-tones, smooth and fine textures and performances such as good air permeability, alkali-resistance, water resistance, powder resistance and stain resistance etc. In addition, convenience for brush coating, easy repairing and maintenance and reasonable price are also required.

Commonly-used interior wall coatings include synthetic resin emulsion interior wall coatings, water soluble interior wall coatings and multicolor textured interior wall coatings.

**1. Synthetic Resin Emulsion Interior Wall Coatings**

Synthetic resin emulsion interior wall coating, also called latex paint, is made by adopting synthetic resin emulsion as the primary film-forming matter, adding tinting pigments, extender pigments and additives, and then mixing and grinding to a thin coating applied to interior walls.

(1) Features of the Coating

1) Take water as dispersion medium, dry and form the film along with the vaporization of water, no inorganic solvent spilling out in construction, therefore nontoxic and capable to avoid fires during construction.

2) The film has good air permeability, so without bubbling caused by the temperature difference between the internal and external of the film. It is brushed on the cement mortar and plaster wall surface of new buildings. Used as an interior wall coating, with no condensation of moisture.



(2) Types of Emulsion Paint

There are polyvinyl acetate emulsion paint, acrylic ester emulsion paint, vinyl acetate- acrylic emulsion paint, styrene-acrylic emulsion paint and polyurethane emulsion paint etc.

1) Polyvinyl Acetate Emulsion Paint.

The primary film-forming matter of polyvinyl acetate emulsion paint is homo-polymer created by the monomer of polyvinyl acetate through emulsion polymerization process. Then add coloring pigments, fillers and additives to the homo-polymer and produce the emulsion paint by grinding or dispersing treatment.

Such coating is nontoxic and odorless, with fine and smooth film, mat gloss, good air permeability and many colors. It is convenient for construction and creates great decorative effects. It is weaker than other copolymer emulsions in aspects such as water resistance, alkali resistance and weather resistance, belongs to medium-grade interior wall coatings.

2) Acrylic Ester Paint.

Its primary film-forming matter is the copolymer emulsion of acrylic ester, it adopts methyl methacrylate, ethyl acrylate, butyl ester and acrylic acid, and methacrylic acid as monomers, then gets pure acrylic acid series of copolymer emulsion through emulsion copolymerization process.

Acrylic ester paint creates the film with soft and mild gloss, excellent weather-resistance, light and color retention and good durability. It is a super interior wall coating.

Pure acrylic ester emulsion paint is very expensive, so the monomer of acrylic acid series as main material is often taken to carry out emulsion copolymerization with other monomers such as vinyl acetate and vinyl benzene(styrene) to produce medium-grade interior coatings with good performances and at reasonable price, mainly including acetate-acrylic coatings and styrene-acrylic coatings.

3) Acetate-acrylic Emulsion Paint.

Acetate-acrylic emulsion paint is the abbreviation of vinyl ethylene-propylene copolymer emulsion coating. It is better than polyvinyl acetate emulsion paint in aspects such as alkali-resistance and water-resistance.

4) Styrene-acrylic Emulsion Paint.

Styrene-acrylic emulsion paint is the abbreviation of styrene- acrylic copolymer emulsion coating. Its primary film-forming matter is the ternary copolymer of styrene, acrylic ester and metacrylic acid ester. The white raw material in its tinting pigment commonly adopts rutile titanium dioxide with good light-fastness and alkali resistance added with extender pigments such as precipitated barium sulfate and wollastonite powder to improve its hiding power and tinting power. Its alkali resistance, water resistance and scrub resistance as well as durability are slightly lower than those of pure acrylic ester emulsion coating, but better than those of other interior coatings.

Technical performances of synthetic resin emulsion interior wall coatings should meet the requirements in Table 13.5.



**Table 13.5 Technical Requirements of Synthetic Resin Emulsion Interior Wall Coatings**

| No. | Technical performance | Performance index |
|---|---|---|
| 1 | State in vessel | No hard lump, in homogeneous state after blending |
| 2 | (solid content) (%)(120℃±2℃, 2h) | ≮45 |
| 3 | Low-temperature stability | No flocculation, no caking, no peeling or flaking |

Continued

| No. | Technical performance | Performance index |
|---|---|---|
| 4 | Hiding power(g/cm$^2$), in white or light color | $\ngtr$250 |
| 5 | Color and appearance | Flat surface, meet the color difference range |
| 6 | Drying time (h) | $\ngtr$2 |
| 7 | Scrub resistance (times) | $\nless$300 |
| 8 | Alkali resistance, 48h | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| 9 | Water resistance, 96h | No bubbling, no powder-lose, allow slight tarnish and discoloration |

Note: Adopted from national standard "*Synthetic Resin Emulsion Coatings for Interior Walls*" (GB/T9756-2001).

Synthetic resin emulsion interior wall coatings (emulsion varnish) are available for substrates made of concrete, cement mortar, cement type wallboard and aero-concrete etc. The substrate should be clean, flat, solid and not too smooth to enhance the bonding power between the coating and the wall body. The water ratio of the substrate should be no more than 8%-10% and its pH value should be within the range of 7-10, to prevent the coating layer from discoloring, bubbling, peeling or flaking caused by too much moisture and too much strong alkali in the substrate. The best weather condition for coating construction is: temperature 15-25℃; relative air humidity 50%-75%.



**2. Water-soluble Interior Wall Coatings**

Water-soluble interior wall coating is made of water-soluble chemical compound as basic material added with certain amount of fillers, pigments and additives and processed by grinding and dispersing. It belongs to low-grade coatings and is applied to the interior wall decoration of common residential buildings. It is classified to I-type and II-type; I-type is available for coating interior walls in bathrooms and kitchens; II-type is available for coating ordinary interior walls of buildings. The technical quality requirements for different kinds of water-soluble interior wall coatings should comply with the specifications in "*Water Soluble Coatings for Interior Walls*" (JC423-1991), refer to Table 13.6.

Commonly-used water-soluble interior wall coatings include polyvinyl alcohol silicate interior wall coatings (known as 106 interior wall coatings), polyvinyl formal interior wall coatings (known as 803 interior wall coatings) and modified polyvinyl alcohol coatings etc.

**Table 13.6 Technical Quality Requirements for Water Soluble Interior Wall Coatings**

| No. | Item | Technical quality requirements | |
|---|---|---|---|
| | | I-type | II-type |
| 1 | State in vessel | No caking, settling or flocculation | |
| 2 | Viscosity (s) | 30-75 | |
| 3 | Fineness degree (μm) | ≤100 | |
| 4 | Hiding power (g/m$^2$) | ≤300 | |
| 5 | Whiteness (%) | ≥80 | |
| 6 | Film appearance | Flat and trim, even color and gloss | |
| 7 | Adhesion (%) | 100 | |
| 8 | Water resistance | No peeling or flaking, no bubbling or wrinkling | |
| 9 | Dry rubbing resistance (level) | | ≤1 |
| 10 | Scrub resistance (times) | ≥300 | |



### 3. Multicolor Textured Interior Wall Coatings

Multicolor textured interior wall coating, also named "multicolor interior wall coating", is a relatively new kind, and is composed of non-interblended continuous phase (dispersion medium) and dispersed phase. Wherein dispersed phase has two types or more colored particles in different sizes which are suspending uniformly and in stable uniform state in the dispersion medium containing stabilizing agent. In application, patterns in different colors are created by spraying with different coating techniques. After drying, they become multicolor textured coating layer.

Multicolor textured interior wall coating has features as follows: the coating layer has elegant color and gloss, rich in 3d stereoscopic sensation and good decorative effects; the film is thick and with solid texture, good elasticity, integrity and durability; it is resistant to oil, water, corrosion and scrub. Available for many kinds of surface layer made of cement concrete, mortar, plaster board, wood, steel and aluminum etc., from interior walls to ceilings of buildings.

According to its manufacturing mechanism, multicolor textured interior wall coating is classified to four basic types, refer to Table 13.7. Among them, oil-in-water type has the best storage stability and is most widely-used.

**Table 13.7 Basic Types of Multicolor Textured Interior Wall Coatings**

| Type | Dispersed phase | Dispersion medium |
|---|---|---|
| O/W type (oil-in-water) | Solvent-based coatings | Hand-protective water solution |
| W/O type (water-in-oil) | Water-based coatings | The solvent or the component soluble to solvent |
| O/O type (oil-in-oil) | Solvent-based coatings | The solvent or the component soluble to solvent |
| W/W type (water-in-water) | Water-based coatings | Hand-protective water solution |

Presently, our country has successfully developed water-in-emulsion multicolor coating. It is the new generation of water-in-water type, and at a lower price, its decorative effect is similar to that of oil-in-water multicolor coating.

The technical quality indexes of multicolor textured interior wall coatings should comply with the specifications in "*Multicolor Interior Wall Coatings*" (JG/T3003-93), refer to Table 13.8.

**Table 13.8 Technical Indexes of Multicolor Textured Interior Wall Coatings**

| Item | | Technical index |
|---|---|---|
| Performances of the coating | State in vessel | Uniform after blending, no caking |
| | Storage stability, 0-30℃ | 6 months |
| | Nonvolatile content (%) | ≥9 |
| | Viscosity (25℃) value | 80-100 |
| | Constructional convenience | No difficulty in spraying |
| Performances of the coating layer | Hard drying time (h) | ≤24 |
| | Appearance | The same as the standard sample |
| | Water resistance (96h) | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| | Alkali resistance (48h) | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| | Scrub resistance (times) | ≥300 |

## 4. Wallpaper Paint

Wallpaper paint is a kind of environment-friendly wall decorative coating which adopts modern high and new technology in production. It has overcome the disadvantages of ordinary emulsion paint such as single color or no stereovision and the disadvantages of wallpaper such as easy discoloration, edge lifting and bubbling, with joint marks and short service life etc. It has the merits of both emulsion paint and wallpaper. Directly applied to the wall surface, the paint will achieve silk-like effect through the delicate combination of special substrate material and roll-patterned surface material.

Wallpaper paint has features as follows.

1) The main raw material for wallpaper paint adopts the surface shells of natural shellfish creatures, which are nontoxic and harmless, so genuinely natural and environment-friendly.

2) Good constructional performances; strong hiding power; excellent water resistance and scrub resistance; good air permeability.

3) Available for individualized pattern designs based on different customer requirements, fulfill the individualized requirements in the market.

4) Seamless joining, no color fading, no peeling, never cracking, with the merits of both wallpaper and coating. Provide the wall body with full stereoscopic and stream-like dynamic sensation.

### 5. Commonly-used Coatings for Interior Walls and Ceilings

The product types, features, technical performances and applications of several commonly-used types of ceiling and interior wall coatings, refer to Table 13.9.



**Table 13.9 Types, Features, Applications and Technical Properties of Ceiling and Interior Wall Coatings**

| Type and feature | Item | Technical index |
|---|---|---|
| 1. Expanded Perlite Spray Ceiling Coatings<br>It is a spray coating with coarse texture; its decorative effect is similar to that of stucco, but the texture is better than that of stucco, low requirement for the substrate, good hiding power | Suitable for ceilings of guest rooms, corridors, office rooms, conference rooms, small clubs and residential houses etc. | Solid content: 241.7%; apparent density: 0.86/cm$^3$; viscosity: 25.5s; bonding strength: 0.11MPa; water resistance: 1.5h no change; heat resistance: temperature 47℃, 168h no change |
| 2. Matted Surface Ceiling Coatings<br>The coating surface has certain matted texture; have certain hiding power to alleviate the unevenness of ceiling and good decorative effect, require simple constructional technique, high spray efficiency and less labor needed | Classified to high, medium and low grades, suitable for the ceiling decoration of large space rooms or corridors in public buildings such as hotels, restaurants, theaters and office buildings etc. | Water resistance: 48h no peeling or flaking; alkali resistance: 8h no change, 48h no peeling or flaking; water permeability: no water leakage; scrub resistance: 250 times no lose-powder; storage stability: deposit after half a year |

Continued

| Type and feature | Item | Technical index |
|---|---|---|
| 3. 106 Interior Wall Coating (polyvinyl alcohol water glass interior wall coating)<br>Made of the water solution of polyvinyl alcohol resin and water glass as basic material mixed with certain amount of fillers, pigments and additives, produced by blending and grinding as well as dispersing.<br>Nontoxic and odorless, applied to slightly wet wall-surface, with certain bonding power to the wall. Create a layer of glossless film. There are colors such as white, milky white, lake blue, apple green, egg cyan and sky blue etc. | Suitable for the decoration of interior walls of buildings such as residential houses, commercial marketplaces, hospitals, hotels, theaters and schools etc. | State in vessel: after blending, no caking, settling or flocculation phenomenon.<br>Viscosity: 35-75s<br>Fineness: no more than 90<br>Whiteness: no more than 80<br>Film appearance: flat and smooth with even color<br>Adhesive power: no square fall off in the cross cut test<br>Dry scrub resistance: no bigger than Grade 1 |
| 4.107 Scrub-resistant Interior Wall Coating<br>Take modified 107 glue as basic material; have prominent features such as fast drying, bright, smooth, clean and beautiful coating layer, water and stain resistance. | Suitable for interior wall decoration of different kinds of residential and public buildings | Dry time: normal temperature 1h<br>Water resistance: 48h no change<br>Heat resistance: 80℃ 7h no change<br>Hiding ratio: $<250g/m^2$<br>Scrub resistance: $>150$ times<br>Storage stability: 1-2 months |
| 5. Polyvinyl Acetate Emulsion Interior Wall Coating<br>Interior wall coating taking polyvinyl acetate as primary film-forming matter; odorless, nontoxic, incombustible, easy for construction; good air permeability, strong adhesion, good water resistance, fresh and beautiful color | Suitable for interior wall decoration of different kinds of residential buildings | Solid content $\geqslant 45\%$<br>Heat resistance: 80℃ 6h no change<br>Drying time: normal temperature hard dry $\leq 2h$<br>Water resistance: 96h no change to film |
| 6. Vinyl Interior Wall Latex Paint<br>Taking vinyl acetate and acrylic ester for copolymerization and production; fine and delicate appearance, good durability and water resistance as well as color retention | Suitable for advanced interior wall decoration, also available for wood doors and windows | Drying time: surface drying $\leqslant 30min$, hard drying 24h<br>Glossiness: $\leqslant 20\%$<br>Water resistance: 5% breakage immersed in water for 96h<br>Minimum filming temperature: $\geqslant 15℃$<br>Hiding power: $\leqslant 170g/m^2$ |

## 13.3 Exterior Wall Coatings

Exterior coatings are applied to decorate and beautify buildings, achieve ideal harmonization of the buildings and the surroundings, simultaneously protect the exterior walls from the corrosion of atmospheric environment and prolong their service life.

Exterior walls directly contact with different kinds of medium in the environment, therefore, coatings for exterior walls are required to have better color retention, water resistance, stain resistance and weather resistance. Moreover, they are required to be convenient for constructional operation when applied to large area exterior walls.

Commonly-used exterior wall coatings include synthetic emulsion exterior coating, synthetic resin emulsion sand-textured exterior wall coating, synthetic resin solvent-based exterior wall coating, exterior wall inorganic architectural coating and multicoated architectural coating etc.



### 1. Synthetic Resin Emulsion Exterior Wall Coating

Synthetic resin emulsion exterior wall coating is made of synthetic resin emulsion as the primary film-forming matter, mixed with tinting pigments, extender pigments and additives and processed by blending and grinding. According to its texture, it is classified to thin emulsion coating (emulsion varnish), thick coating and colored sand-textured coating etc.

The main features of synthetic resin emulsion exterior coating are as follows.

1) Take water as dispersion medium, no flammable or toxic organic solvent in the coating, no contamination to the environment and unlikely to cause fire accidents, less toxicity to human health.

2) Easy operation, available for many coating techniques. Constructional instruments are cleaned with water.

3) The film has good air permeability and the coating contains a lot of water. It is available for application on slightly wet surface, very suitable for application on construction sites.

4) Good weather resistance. Especially high quality acrylic ester emulsion exterior wall coating, the performances of its film such as brightness, weather resistance, water resistance and durability are competitive to those of solvent-based acrylic ester exterior wall coating.

Presently, the main problem of emulsion exterior coating is that it does not form good film at too low temperature, usually requiring temperature more than 10℃. So it is not convenient for application in winter.

The main technical indexes of synthetic resin emulsion exterior wall coatings should meet the specifications in national standard "*Synthetic Emulsion Coatings Criteria*" (GB9755-88). Refer to Table 13.10.

**Table 13.10 Technical Indexes for Synthetic Resin Emulsion Exterior Wall Coatings**

| Item | Technical index |
|---|---|
| State in vessel | No hard lump, in uniformity state after blending |
| Solid content (%) (120℃±2℃,2h) | ≥45 |
| Low-temperature stability | No flocculation, no caking, no peeling or flaking |
| Hiding power (g/cm) (whit and light colors) | ≤250 |
| Color and appearance | Flat surface, match the color-difference range |
| Drying time (h) | ≤2 |
| Scrub resistance (times) | ≥1000 |
| Alkali resistance, 48h | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| Water resistance, 96h | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| Freeze-thaw cycle resistance, 10 times | No powering, no bumping, no cracking, no peeling or flaking |
| Artificial ageing resistance, 250h<br>Powering (level)<br>Discoloration (level) | No bubbling, no peeling or flaking, no cracking<br>≤1<br>≤2 |
| Stain resistance, white or light colors<br>The decline rate of reflection coefficient after 5 cycles | ≤30 |



## 2. Color Sand-wall-like Exterior Wall Coating

Color sand-wall-like exterior wall coating, also called color sand coating or color stone paint, is made of synthetic resin emulsion as the primary film-forming matter and color sand as aggregate. It is sprayed on the exterior walls of buildings to create the matt-surface thick coating layer.

Synthetic resin emulsion adopted in the coating is styrene-acrylic latex. The coloration of coating mainly relies on the tinting aggregate or natural sand, stone powder and pigment. Tinting aggregate is made by sintering crushed color-rock or quartz sand mixed with mineral pigment. After crushed, the color of color-rock apparently become lighter, therefore its tinting effect is not ideal. Whereas the tinting effect of artificial sand which is made by sintering the mixture of quartz sand, metal oxide and mineralizing agent is better. Artificial color sand is used together with natural aggregate such as quartz sand and dolomite powder to acquire the stereovision of color tones and the textures of natural decorative stone, and to reduce the production cost. To alleviate the settling phenomenon of aggregate in latex, thickener is adopted in the coating. It also contains film-forming agents (to reduce the minimum filming temperature), anti-mildew agents and preservatives etc.

The technical performances of color sand-wall-like coating should meet the specifications in national standard "*Synthetic Resin Sand-wall-like Architectural Coatings*" (GB9135-88), refer to Table 13.11.

**Table 13.11 Technical Indexes of Sand-wall-like Architectural Coatings**

| Item | Technical index |
|---|---|
| State in vessel | In uniformity state after blending, no caking |
| Aggregate settling (%) | <10 |
| Low-temperature storage stability | After 3 times of test, no caking or flocculation, no change of component |
| High-temperature storage stability | One month after test, no hard lump, no mildew, no flocculation or change of components |
| Drying time (h) | ⩽2 |
| Color and appearance | Compared with the sample, no apparent difference in color and appearance |
| Water resistance | After 240h test, the coating layer has no cracking, bubbling, peeling or flaking, deposit derived from softening; compared with the untested part, allow slight change in color and gloss. |
| Alkali resistance | After 240h test, the coating layer has no cracking, bubbling, peeling or flaking, deposit of softening; compared with the untested part, allow slight change in color and gloss |
| Scrub resistance | After the test of 1000 times of scrub, no change to coating layer |
| Stain resistance rate | After five times of staining test, stain rate is lower than 45% |
| Freeze-thaw cycle resistance | After 10 freeze-thaw cycles, the coating layer has no cracking, bubbling, peeling or flaking; compared with the untested sample, allow slight change in color and gloss |
| Bonding strength (MPa) | ⩾0.69 |
| Accelerated weather resistance | After 500h of test, the coating layer has no cracking, bubbling, peeling or flaking, chalking. Color change is level 2 |

Features of the coating are nontoxic, no solvent-contamination; fast drying, incombustible, resistant to strong light, unfading; by adopting different components and combinations of aggregate, it is able to create coatings with different color levels, achieve the textures and decorative effects similar to those of natural stone.

### 3. Water-emulsion Epoxy Resin Emulsion Exterior Wall Coating

Water-emulsion epoxy resin emulsion exterior wall coating is another type of emulsion coatings. It takes the stable emulsion as the primary film-forming matter, which is made of epoxy resin mixed with certain amount of emulsifying agent, thickener and water, processed by blending and dispersing with a high speed machine. Then add pigments, fillers and additives and mix them together to produce the exterior wall coating. It takes water as dispersion medium, nontoxic and odorless, safe and with less contamination to the environment. Presently in our country, emulsion coating for exterior wall decoration is mainly water-emulsion epoxy resin exterior wall coating.

Water-emulsion epoxy resin exterior wall coating is bi-component coating. Bisphenol A epoxy resin E-44 mixed with emulsifying agent, thickener and water is blended and dispersed with a high speed machine into epoxy resin emulsion with good stability, then mix this emulsion with the selected pigment and filler to make a kind of thick paste as the component A for the coating. In application the component A is mixed with curing agent (component B in the coating), after thorough blending, it is sprayed to form decorative coating layer with imitated stone patterns (such as granite patterns) with a special double-barred spray gun. It is one of the high-grade exterior wall coatings.

The features of water-emulsion epoxy resin exterior coating are: good bonding strength to wall-surface substrate, no peeling off or flaking off; good decorative effect; excellent ageing and weather resistant coating layer; good durability. In foreign countries, there are cases covered with the coating for over 10 years, whose appearance is still beautiful and intact. But such coating is of high price and being bi-component, it is not convenient for application.

Main technical performances of water-emulsion epoxy resin exterior wall coatings are listed in Table 13.12.



**Table 13.12 Main Technical Performances of Water-emulsion Epoxy Resin Exterior Wall Coatings**

| Item | Index |
|---|---|
| Pattern design | Concave-convex patterns with bi-color or multicolor granite decorative effect; the convex part is 0.5-1mm thick |
| Spray-coating amount ($kg/m^2$) | 1.0-1.2 |
| Storage duration | Normal temperature (room temperature) 6months |

Continued

| Item | Index |
|---|---|
| Crack resistance | In 77m/s air flow condition, no crack created to coating layer within 6h |
| Water resistance | After water immersion for 10d, no cracking, bubbling, wrinkling, peeling or flaking etc. |
| Alkali resistance | After immersion in saturated $Ca(OH)_2$ water solution for 10d, no change, no cracking, bubbling, peeling or flaking, hole, softening or dissolving etc. |
| Bonding strength (MPa) | In standard state, bigger than 1.8 for 7d age |

## 4. Synthetic Resin Solvent-based Exterior Wall Coating

Solvent-based coating takes high molecular synthetic resin as the primary film-forming matter, and organic solvent as dispersion medium. Then add certain amount of tinting pigment, extender pigment and additive, processed by mixing, blending, resolving and grinding to produce the coating. After brushing, the solvent contained in the coating is volatilized, the film-forming matter together with other nonvolatile components form a homogeneous and continuous coating layer. The film is dense and has features such as high glossiness, hardness, water resistance, acid resistance and good weather-resistance, stain resistance, so it is mainly applied to the exterior wall decoration of buildings. But because of the volatilization of large amount of combustible solvent, it tends to contaminate the environment. Moreover, it is more expensive than common emulsion coating. Therefore, it is less adopted than any other emulsion exterior wall coating at home and abroad.



At present, commonly-used solvent-based exterior wall coating include chlorinated-rubber exterior wall coating, polyurethane acrylic ester exterior coating and acrylic ester organosilicon exterior wall coating etc. Among them, polyurethane acrylic ester and acrylic ester organosilicon exterior coatings have better weather-resistance, decorativeness and stain resistance, and their durability is more than 10 years. The technical performances of synthetic resin solvent-based exterior wall coatings should meet the specifications in national standard "*Synthetic Resin Solvent-based Exterior Wall Coatings*" (GB 9757-88), refer to Table 13.13.

**Table 13.13 Technical Performances of Synthetic Resin Solvent-based Exterior Wall Coatings**

| Item | Performance index |
|---|---|
| State in vessel | Uniform after blending, no caking |
| Solid content (%) | ≥45 |
| Fineness degree (μm) | ≤45 |

Continued

| Item | Performance index |
|---|---|
| Constructional convenience | No difficulty in construction |
| Hiding power ($g/cm^2$) (white and light colors) | ≤140 |
| Color and appearance | Flat and trim surface, within color-difference range, match the sample plate |
| Drying time | Surface drying 2h, hard drying 24h |
| Water resistance, 144h | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| Alkali resistance, 241 l | No bubbling, no powder-lose, allow slight tarnish and discoloration |
| Freeze-thaw cycle resistance, 10 times | No powering, no bulging, no peeling or flaking |
| Artificial ageing resistance, 250h<br>Powering (level)<br>Discoloration (level) | No bubbling, no peeling or flaking, no cracking<br>≤2<br>≤2 |
| Stain resistance, after 5 cycles,<br>The decline rate of reflection coefficient (%) | ≤15 |
| Scrub resistance (times) | ≥2000 |



**5. Fluorocarbon Paint**

Fluorocarbon coating has features such as strong adhesion, chemical attack resistance, high-temperature resistance, ageing resistance, oil resistance and water resistance. Decorative material coated with fluorocarbon paint has features such as lightweight, dustproof, fireproof, shockproof, heat insulation, sound insulation, no cracking, no peeling or flaking, no color difference and unfading. For instance, aluminum curtain wall panel coated with fluorocarbon coating is light, dustproof, waterproof, fireproof and shockproof, and with good sound insulation, heat insulation and even color gloss etc.

Fluorocarbon coating has overcome the disadvantages of different kinds of former exterior decorative materials. It is a kind of ideal high-grade modern decorative building material, providing brilliance to many large-scale buildings all over the world with its beautiful and solemn appearance and its long-lasting weather-resistance.

## 13.4 Coatings for Doors, Windows and Furniture

In decoration projects, coating is also applied to doors and windows as well as furniture to play the function of decoration and protection. The primary film-forming matter in the coating is mainly oil grease, synthetic resin or mixture resin dispersing in solvent, so it is accepted as "oil paint". There are a lot of types with different performances, most of which is thinned (diluted) with solvent, so it is also called organic solvent-based coating.

**1. Oil-based Paint**

Oil-based paint is made of dry oil or semi-dry oil as the primary film-forming matter. It is convenient for decorative coating, with good permeability, low price, little odor or toxicity; after drying and curing, its coating layer has good flexibility. But its coating layer dries slowly, and it is soft and with weak strength, not resistant to grinding or polishing, and has weak high-temperature resistance and chemical resistance. Commonly-used types are as follows.

(1) Boiled Oil

Boiled oil is made of tung oil as main raw material heated and polymerized to certain consistency, then added in drying agent. It dries faster and the film is bright, flexible and fatty, but is rather soft. Boiled oil is adopted to make oil-based paint, paste paint, primer and putty.

(2) Paste Paint

Known as lead-oil, it is a thick paste made by grinding drying oil, tinting pigment and extender pigment together. The adopted drying oil should be heated to polymerize, so also called polymer paste paint. Before application, it should be added in thinner and drying agent, generally certain amount of boiled tung-oil and turpentine to dilute it to serviceable consistency. It is used for priming or making putty.

(3) Oil-based Mixed Paint

Oil-based mixed paint is made by grinding drying oil and pigment together and adding in drying agent and solvent. With strong adhesion, the film is less likely to peel or flake, with less cracking or powering and durable in use. But it dries slowly and is soft. Therefore, it is applied to outdoor surface coating.

**2. Natural Resin Paint**

Natural resin paint is made by mixing different kinds of natural resin and dry vegetable-oil, and after that adding in drying agent, dispersion agent and pigment etc. Commonly-used natural resin paint is shellac paint and Chinese lacquer etc.

(1) Shellac Varnish

Shellac varnish is also called polish or alcohol varnish or abbreviated as shellac. It is made by collecting, processing and resolving in alcohol the secretion of a parasitic insect piled on tree branches. Such paint is convenient for use and dries fast. Its film is solid and bright. The disadvantages are weak water resistance, weather resistance and alkali resistance, tarnishing after suffering heavy sunlight, whiten after immersion in hot water. It is used for interior decoration.

(2) Chinese Lacquer

Chinese lacquer, also called earth lacquer, natural lacquer or oriental lacquer, is classified to raw lacquer and processed lacquer. It is a brown-yellow Mongolia thick fluid made by partially dehydrating and filtering the sap of the lacquer tree. Its main component is the complicated alkyd resin. It creates solid and firm film and strong bonding power to the substrate and is rich of gloss, durable, insulating, thermal resistant (250℃) and resistant to wear, oil, water and corrosion. Disadvantages are inconvenient construction due to high viscosity (especially raw lacquer); the film is in dark color and is brittle, not resistant to direct sunlight, weak resistant to oxidation or alkali. Raw lacquer is toxic and its film is coarse after drying, so it is rarely for direct use. After being processed, raw lacquer becomes processed lacquer; or after being modified, it is used to make different kinds of refined lacquer. Processed lacquer is applied to moist environment protection. The lacquer film has good gloss, good tenacity, high stability and strong acid-resistance, but dries slowly, even needs 2-3 weeks. Refined lacquer include Chinese lacquer-tung oil blend and varnish etc., whose lacquer film has good performances such as high tenacity, water resistance, heat resistance, durability and corrosion resistance and creates vivid gloss. Processed lacquer is highly decorative and applicable to wood furniture, arts and crafts as well as some architectural products etc.

Chinese lacquer is yielded from lacquer tree, which grows only in China, mainly in provinces such as Shanxi, Sichuan, Hunan, Hubei and Guizhou, and also in Fujian, Zhejiang and Anhui etc.

### 3. Varnish

Varnish is an oil-form transparent coating without pigment. It takes resin or resin and oil as the primary film-forming matter. Oil-based varnish is made by mixing synthetic resin, drying oil, dispersion matter and drying agent etc. When more oil material is adopted, the film is softer and more flexible and durable and richer of elasticity, but dries more slowly; when less oil material is adopted, the film is harder, firmer and brighter, and dries faster, but is more brittle and more likely to crack. Oil-based varnish includes ester rosin varnish, phenolic resin varnish and alkyd resin varnish etc. Resin varnish is mainly shellac varnish.

(1) Ester Rosin Varnish

Ester rosin varnish, also called water resistant varnish, is made of dry oil and glycerin rosin as the primary film-forming matter. Its film is bright with good water resistance, but its gloss is not durable and with weak drying performance, which is available for the coating of wood furniture, doors and windows and board partitions etc., and for the glazing work of metal surface.

(2) Phenolic Resin Varnish

Phenolic resin varnish is made of dry oil and modified phenolic resin as the primary film-forming matter. Features are: fast drying, firm and durable film, good gloss, and resistance to heat, water, weak acid and alkali, convenient construction and low price. Disadvantages are: film dries slowly, dark color, easy to get yellowed, not available for sand polishing, low smoothness and fineness; the coating layer has slight viscosity after drying. It is adopted for the surface coating of interior and exterior woodenwares and metal wares.

(3) Alkyd Resin Varnish

Alkyd resin varnish takes dry oil and modified alkyd resin dispersing in solvent as the primary film-forming matter. It is better than ester rosin varnish and phenolic rosin in performances such as adhesion, glossiness and durability; the film dries fast, with high hardness and good insulation; available for polishing and sanding, with bright color and luster; but the film is crisp, with weak heat resistance and weather resistance. Alkyd varnish is mainly applied to paint doors and windows, wood flooring and furniture. It is not suitable for outdoor use.

(4) Nitrate Varnish

Nitro varnish, known as lacquer or painting, is of another varnish type. It dries along with the volatilization of the solvent, without complicated chemical change. It is made by taking nitrocellulose as the primary film-forming matter and adding in other synthetic resins, plasticizers, solvent agents and thinners. Such varnish has advantages such as fast drying, firm and solid film, brightness, wear resistance and durability etc., but weak light-fastness. It is an advanced coating and available for the multi-layer coating on wood and metal surfaces and mainly applied to doors and windows, wallboards and handrails in advanced buildings. Nitro varnish is costly and difficult to apply; the solvent is toxic and easy to volatilize. In application, ventilation and labor protection should be especially considered.

**4. Enamel Paint**

Enamel paint is made by adding inorganic pigment in varnish. Its film is bright, hard and solid, extremely similar to that of porcelain ware, so it is called enamel paint. It has abundant colors and glosses, strong adhesion, available for interior decoration and furniture, and for exterior steel and wooden surfaces. Commonly-used types include alkyd enamel paint and phenolic enamel paint etc.

**5. Polyester Paint**

Polyester paint is an advanced paint coating taking unsaturated polyester as the primary film-forming matter. Unsaturated polyester dries fast; the film is fatty and solid with high gloss and light-retention; the film is with high hardness, so with good wear resistance, high-temperature resistance, cold temperature resistance, weak-alkali resistance and solvent resistance. Unsaturated polyester paint is made of many types of components, and only available for the decoration of static and flat surfaces. If applied to areas such as vertical surface, side-edge and concave-convex line, it tends to sag and drip; it does not allow to adopt shellac varnish and shellac putty for priming, otherwise the adhesive power of the film will be reduced.



## 13.5 Functional Architectural Coatings

Functional architectural coatings are defined as those with some other special functions such as waterproof, fireproof, mildew-proof, thermal insulation and sound insulation besides the decorative function of ordinary architectural coatings. They are also called special coatings.

Architectural functional coatings are required to have good alkali resistance, water resistance, good bonding strength to cement surface layers or wood materials, certain decorative function and some special performances, convenient construction and repair as well as maintenance and easy recoating. Commonly-used functional architectural coatings include waterproof coating, fireproof coating, mildew-proof coating and anti-corrosive coating etc. This passage only introduces waterproof coating and fireproof coating.

### 1. Waterproof Coating

Architectural waterproof coating refers to the coating whose film is able to prevent the leakage of rain water or underground water, mainly including roof waterproof coating and underground-project waterproof coating. According to the state of film-forming material and the form of film-forming, it is classified to: emulsion type, solvent-based and reactive.

Emulsion type waterproof coating is mono-component coating. After painted on building surface, the film is formed along with the volatilization of water. With solvent released in construction, it is safe and nontoxic, pollution free and less likely to burn. Emulsion type waterproof coating includes water-emulsion reclaimed-rubber asphalt waterproof coating, cationic neoprene latex asphalt waterproof coating, acrylic emulsion asphalt waterproof coating, chlorine-partial copolymer emulsion series and VAE emulsion waterproof coating that has been developed in recent years etc.

Solvent-based waterproof coating is made by taking high molecular synthetic resin dissolved in organic solvent as primary film-forming matter and adding in pigments, fillers and additives etc. After painted on building surface, the film is formed along with the evaporation of organic solvent. It has excellent waterproofing effect and is available for the construction at fairly low temperature. However in construction, there is much combustible, toxic organic solvent released out to pollute the environment. Solvent-based waterproof coating includes: neoprene waterproof coating and chlorosulfonated polyethylene waterproof coating etc.



Reactive waterproof coating is bi-component coating, and its waterproof film is formed through the reaction between the primary film-forming material and the curing agent in the coating. It has good water resistance, ageing resistance and elasticity, and is presently one kind of waterproof coating with good performances, including polyurethane and epoxy resin series etc.

### 2. Fireproof Coating

Fireproof coating is also called fire-retardant coating. When painted on the surface of some combustible materials of buildings, it is able to enhance the fire resistance of the materials and provide people with certain period of time to put out the fire.

According to its components, fireproof coating is classified to non-expansive and expansive. Non-expansive fireproof coating is composed of fire-resistant or noncombustible resin as the primary film-forming material, fire retardant and fireproof filler etc. Fire-resistant resin is high molecular synthetic resin containing halogen, phosphor and nitrogen etc., such as halogenated alkyd resin, polyester, epoxy, chlorinated rubber, neoprene latex and acrylic resin emulsion, which are mixed with fire retardant to make the coating layer more difficult to combust. Fire retardant is to increase the fire resistance of the film, including organic and inorganic retardant containing phosphor or halogen, such as chlorinated paraffin, borax and aluminum hydroxide. Generally, inorganic pigment and filler are fire resistant, which enhances the fire resistance and fire-retardation of the coating layer.

Expansive fireproof coating is composed of nonflammable resin, fire retardant and carbon-forming agent, dehydration carbon-forming catalyst and foaming agent etc. The coating layer will expand at high temperature to create the carbon foam layer with a thickness several dozen times of the previous coating layer, which effectively protects its substrate material and keeps it away from the external heat sources, thus, blocks the further expansion of the fire. Its fire prevention effect is better than that of non-expansive fireproof coating.



Its primary film-forming material not only has good service performances at normal temperature, but also is adaptive to high temperature foaming. Commonly-used synthetic resin includes acrylic resin emulsion, polyvinyl acetate emulsion, epoxy resin, polyurethane and epoxy-polysulfide resin etc. Carbon-forming agent is defined as the substance that is rapidly carbonized under the action of flame and high temperature, which is primary for the formation of carbonized foam layer. Commonly-used carbon-forming agent is polyols with high carbon content such as starch, pentaerythritol and hydroxyl organic resin etc. Dehydration carbon-forming catalyst has the main function of accelerating the dehydration of hydroxyl organic compounds to create nonflammable carbon layer. Such catalyst mainly includes poly ammonium phosphate, ammonium dihydrogen phosphate and organophosphate etc. Foaming agent releases large amount of fire-extinguishing gas when the coating layer is heated and enables the coating layer to expand and form sponge cellular structures. Such agent includes tri-ammoniac gum, bi-ammoniac gum, chlorinated paraffin, poly ammonium phosphate, ammonium borate and bi-ammoniac gum formaldehyde resin etc. Inorganic fuel and filler with good non-flammability are usually adopted as the filler, almost the same material used for non-expansive fireproof coating.

Presently in China, the main type of expansive fireproof coating is expansive acrylic emulsion fireproof coating. It takes acrylic latex as the primary film-forming material, ammonium carbonate, tri-ammoniac gum and pentaerythritol as fireproof foaming agent and water as the dispersion medium, then added in nonflammable pigment, filler, fire retardant and mixed together. It has good decorative effect at normal temperature, whereas releases large amount of inert gas at high temperature or on fire, simultaneously becomes bubbling and foaming to form fire insulation coating film.

# Tests on Building Decorative Materials

## Test One  Test on the Viscosity of Coatings

(1) Instruments and Equipments

The upper part of the viscosimeter is cylindrical, its bottom is cone-shaped, there is a discharge outlet at the bottom of the cone, and a groove at the upper part for the overflowing of excessive sample, refer to Figure 13.2. The viscosimeter is placed on the rack with adjustable horizontal screws. It is made of metal or plastic, the smoothness of its inner wall is ∇8 , capacity is (100+1)ml. The discharge outlet is made of stainless steel with its hole (4±0.02)mm high and its internal diameter(4+0.02)mm. The inside angle of the cone is 81° ±15′. The total height of the viscosimeter is 72.5mm. Metal viscosimeter is preferable.



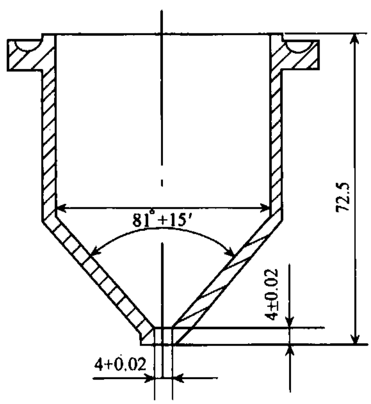



Figure13.2  Viscosimeter

(2) Test Procedures

1) The sample and the viscosimeter are kept at (23±1)℃ for more than 4h.

2) Before the test, clean the viscosimeter with pledget and alcohol and make it dry. Adjust the horizontal screws to make the viscosimeter at horizontal level. Put a 150ml beaker 100mm away from the outlet under the viscosimeter.

3) Plug up the outlet with a finger, pour the sample into the viscosimeter until it is full, scrape the foam and excessive test sample into the groove with a glass sheet, and then remove the finger to let the test sample flow out. At the same time start the second-counter, when the stream close to the outlet stops flowing, immediately stop the second counter. Make a record of the out-flowing time, be accurate to 1s.

(3) Test Result

Take the mean value of two tests as the test result. The difference between the values of the two tests should be no more than 3% of the mean value. It is deemed qualified if the mean value meets the standard specification.

In addition, the viscosity of coatings is also tested with ISO2431 flow cup and Stormer viscosimeter, depending on different standards for coatings.



## Test Two Test on the Hiding Power of Coatings

(1) Instruments and Equipments

Balance, accuracy 0.1g;

Wood board, dimensions 100mm×100mm×(1.5-2.5)mm;

Paintbrush, 25-35mm;

Glass sheet should meet the requirements in "*Sheet Glass*" (GB4871-1995), dimensions are 100mm×100mm×(1.2-2)mm and 100mm×250mm×(1.2-2)mm.

Black and white glass check board (refer to Figure 13.3): Adopt a piece of 100mm×250mm glass sheet and cover one end of it for 100mm×50m (for handholding in test), then spray a layer of black nitro-lacquer on the rest 100mm×200mm area; after it dries, scrape off every other 25mm×25mm squares with a small cutter, and spray those squares with white nitro-lacquer. The glass sheet has 32 squares in black and white respectively. Cover the sheet with a smooth and bright brown paper, and coat a layer of epoxy glue (to avoid the penetration of solvent and protect the black and white paint film from damaging) on the paper surface, and solid black and white check board is created.

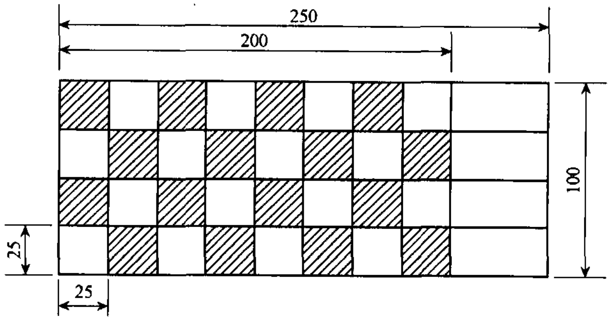



Figure 13.3 Black and White Glass Check Board

Black and white wood check board (refer to Figure 13.4): Spray a layer of black nitro-lacquer on the surface of 100mm×100mm wood board, after it dries, paste the paint-coated surface with a piece of smooth white paper in the same size, then scrape off every other 25mm×25mm squares with a small cutter; spray a layer of white nitro-lacquer, after it dries, uncover the paper on the rest of the squares. Finally make a black and white check board with 16 squares.



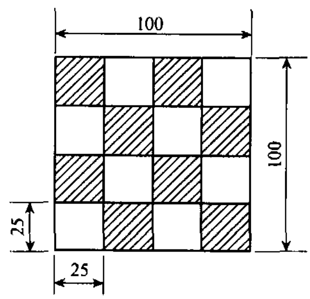



Figure 13.4 Black and White Wood Check Board

Wooden dark box: The interior of a 600mm×500mm×400mm box is divided to upper and lower parts with a piece of 3mm thick frosted glass with its frosted surface downward. To make uniform light source, two 15W fluorescent lights are parallel installed in the upper part of the dark box. In front of the lights is installed a light barrier plate. The front of the lower part is open for inspection, and the interior wall is coated with Berlin black.

(2) Test Procedures

Make test-sample based on the Mongolia degree specified in product standard (if the viscosity is not suitable for brushing, adjust the test sample to the viscosity that allows brushing, but the amount of thinner should be deducted when calculating the hiding power).

Weigh the total mass of the cup filled with the coating and the paintbrush; paint the coating evenly with the paintbrush on the surface of the white and black check board, then put the board inside the dark box 150-200mm from the frosted glass, the end of the check board with black and white squares is inclined to a 30° -45° cut angle with the level plane, and observe it in daylight. Go on brushing until the black and white squares are totally invisible. Measure the weight of the cup with the rest of the coating and the brush, and calculate the mass of coating brushed on the surface of the black and white check board. The coating should be painted rapidly and evenly without any coating left on the edge of the board.

(3) Test Result

Hiding power $X$(g/cm$^2$) is calculated following the formula (based on wet coating film):

$$X = \frac{W_1 - W_2}{A} \times 104 = 50(W_1 - W_2)$$

In the formula: $W_1$ is the total mass of the cup filled with the coating and the brush before painting (g);

$W_2$ is the total mass of the cup filled with the rest of the coating and the brush after painting;

$A$ is brushed area of the black and white check board (cm$^2$).

Carry out two parallel determinations, if the difference between the results is no more than 5% of the mean value, take the mean value as the end result, otherwise retest is required.



## Test Three Test on the Scrub Resistance of Coatings

(1) Instruments and Equipments

① Scrub tester (refer to Figure 13.5): Its brush moves to-and-fro straightly on the surface of the coating layer on the test sample board, scrubbing and washing the layer.

The brush moves 37 to-and-fro cycles per minute, each cycle is 300mm, for the middle 100mm the brush moves at a constant speed. The brush is made by uniformly punching 60 small holes with the diameter of 3mm in a 90mm× 38mm×25mm hard and flat wooden plate (or plastic plate), then vertically inserting and planting black bristles to the small holes and level cutting the bristles to around 19mm long; before use, the brush should be immersed 12mm deep in 20℃ water for 30min and swished until it is dry, then immersed 12mm deep in qualified scrubbing medium for 30min. Thus the brush is available for use. When the bristle length is worn to less than 16mm, the brush cannot be used any longer.

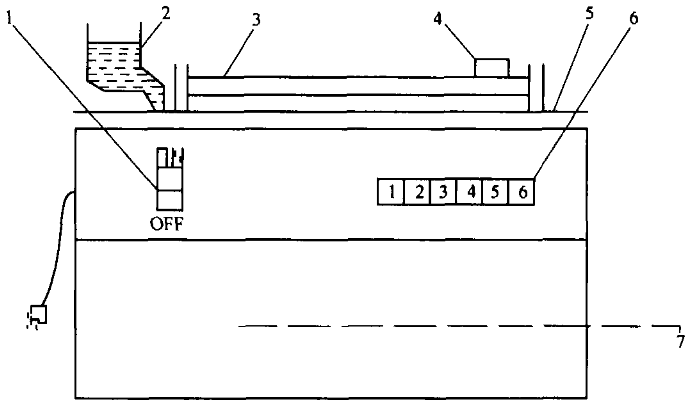



Figure 13.5 Structural Chart of a Scrub Tester

1. Power switch; 2. Vessel for adding scrub medium; 3. Sliding rack; 4. Brush and holder; 5. Test bedplate; 6. To-and-fro times display; 7. Electric motor



② Washing liquor: Resolve washing powder in distilled water, mix them to 0.5%(on mass basis) washing liquor, its pH value is 9.5-10.0.

(2) Test-sample Preparation

Take a 430mm×150mm×3mm cement asbestos board as the substrate, spray a lane of C06-1 iron oxide red alkyd priming paint or a lane of C04-83 white alkyd matted enamel on its surface, dry it at (105±2)℃ for 30min. The dry film is (30±3)μm thick. Wet paint the coating to be tested on the surface of the priming paint coated board.

For water-based coating, brush two layers of the coating with 55% solid content. The coating weight of the first layer is (150±20)g/cm$^2$; the second layer (110±20)g/cm$^2$ (if the solid content of the coating is less than 55%, convert it into equivalent amount of film-forming matter), the interval between the two layers is 4h. After finishing the second layer, put the coating surface of the sample board upward and dry it for 7d in standard test conditions.

(3) Test Procedures

Test should be carried out at (23±2)℃, and only on the same test sample.

Lay the coated side of the test sample board upward, and fix it on the test bedplate horizontally, put the pretreated brush on the test sample board, then the sample board bears a load around 450g (total weight of the brush and the holder), repeatedly scrub the coating film to-and-fro, simultaneously drip in (speed 0.04g/s) the specified scrubbing medium to keep the scrubbing surface wet.

According to the product requirements, scrub to specified times or scrub until the priming paint color is exposed at the mid-length area of the sample board, take down the sample board from the tester and wash it with tap water.

(4) Test Result

Scrub to the specified times, the coating film of at least two pieces of the 3 tested boards remains not worn out and no priming paint color is exposed, it is deemed qualified in scrub resistance.



# Practice

Learn about the types, performances, prices and application statuses etc. of decorative coatings. Master the types, performances, prices, selection and applications of synthetic resin emulsion interior wall coatings and solvent-based interior and exterior wall coatings.

## 1. Objectives of Practice

Students are required to go to the market of building decorative materials and building decoration and construction sites to carry out investigation and practice, learn about the prices and get familiar with the applications of decorative coatings; recognize the names, dimensions, types, prices, application requirements and application scopes of different coatings.

## 2. Practice Methods

(1) Investigation and Analysis in the Market of Building Decorative Materials

Student grouping: 3-5 students in one group; carry out investigation and analysis in the market of building decorative materials;

Investigation method: learn how to recognize different kinds of decorative coatings, find out material prices, collect material samples and master the requirements of material selection mainly by surveying and inquiring.

(2) Research on the applications of decorative materials on building decoration sites

Students grouping: 10-15 people as one team, guided by teachers or persons in charge of the site.

Investigation method: guided by teachers or persons in charge of the site, introduce and explain the application statuses and notices of materials in construction practice adapted to the construction site and its actual condition.

**3. Contents and Requirements for Practice**

1) Complete the research diary carefully;

2) Write a research report;

3) Write a practice summary.

## Summary

This chapter mainly introduces the components, classifications, performances and applications of decorative coatings. In teaching and learning, students are required to master the components and features of decorative coatings and learn to explain the performances, features and application notices of the materials with what they have learned; they are also required to master the names, performances, applications and application requirements of commonly-used decorative coatings in practice. The name, dimensions, performances, price and applications of each material should be learned and mastered combined with its applications in construction practice.



## Questions for Reviewing and Thinking

13.1 What are commonly-used coatings composed of? What functions does each of them have in coatings?

13.2 What features should interior wall coatings have? Which types are they usually classified to?

13.3 What features should exterior wall coatings have? Which types are they usually classified to?

13.4 What should be noticed in the application of solvent-based interior wall and exterior wall coatings?

13.5 What types of synthetic resin emulsion interior wall coatings are there? What features does each of them have?

# 14

# Adhesives

Substance being able to firmly bond together two kinds of materials together is called adhesive. With the development of chemical industry, the types and performances of adhesive are greatly developed, and adhesive have become an indispensable supplementary material in building projects. It is not only widely applied to building operations and interior and exterior decoration projects such as the bonding work in the decoration of walls, floors and suspended ceilings, but also is often adopted for the bonding work of waterproof roofs, waterproof floors, pipeline projects, new and old concretes and the repair work of metal components and foundations etc. It is also used to produce different kinds of new building materials. The application of adhesive requires simpler techniques and less labor and material, with the advantages of uniform stress distribution, airproof and corrosion resistance at the joints.



## 14.1 Introduction of Adhesives

### 14.1.1 Components of Adhesives

The primary components of adhesive include binder, curing agent, filler and thinner etc.

**1. Binder**

Binder is the primary component, also called basic material, which decides the bonding performance of adhesive. The binder of synthetic adhesive adopts synthetic resin, synthetic rubber, or their copolymer or mechanical mixture. Adhesive applied to structural force-bearing areas mainly adopt thermosetting resin; adhesive to non-force-bearing areas and areas with large deformation mainly adopts thermoplastic resin and rubber.

**2. Curing Agent**

Curing agent enables primary adhesive substances to form netlike or three dimensional structures to increase the cohesive strength of the adhesive layer. Commonly-used curing agents include amines, acid anhydrides, macromolecules and sulfurs etc.

**3. Filler**

Filler improves the performances of adhesive (such as improve strength, reduce shrinkage and enhance thermal stability). Commonly-used fillers are metal and its oxide powder, cement, kapok and glass etc.

**4. Thinner**

Thinner is often added to improve technologic properties (decrease viscosity) and prolong service life. Thinners are classified to reactive and non-reactive, the former takes part in the curing reaction but the later does not, only playing the thinning function. Commonly-used thinners include propylene oxide and acetone etc.

In addition, other additives such as flexibilizer, anti-aging agent and plasticizer are added in to provide adhesive with more excellent performances.



### 14.1.2 Classifications of Adhesives

"*Classification of Adhesives*" (GB/T 13553-1996) has specified that adhesives are classified based on main binders, physical forms, setting methods and adherent materials.

**1. Classified Based on the Properties of Main Binders in Adhesives**

The main binders in adhesives are classified to seven types.

1) Animal glues (subclasses: blood glue, bone glue, casein glue and lac etc.)

2) Vegetable glues (subclasses: cellulose derivative, polysaccharide and its derivative, natural resin, vegetable protein and natural rubbers etc.)

3) Inorganic substances and minerals (subclasses: silicates and other inorganic substances, petroleum asphalt and resin etc.)

4) Synthetic elastomers (subclasses: polyolefins, halocarbons, silicon and fluorine rubbers, urethane rubbers and polysulfide rubbers etc.)

5) Synthetic thermoplastic materials (subclasses: vinyl resins, polystyrenes, acrylic ester copolymers, polyesters and polyurethanes etc.)

6) Synthetic thermosetting materials (subclasses: epoxy resins, amine resins, silicone resins, polyurethanes, phenolic resins and furan resins etc.)

7) Composite of thermosetting, thermoplastic materials with elastomers (subclasses: phenolic composite structural adhesives, epoxy composite structural adhesives and other composite structural adhesives etc.)

**2. Classified Based on Physical Forms of Adhesives**

According to physical forms, adhesives are classified to seven types: solvent-free liquid (code number 1); organic solvent liquid (code number 2); water-based liquid (code number 3); ointment and paste (code number 4); powder, granular and lump (code number 5); lamellar, film, reticulation and banding (code number 6); filament, strip and bar (code number 7).

**3. Classified Based on Setting Methods of Adhesives**



According to setting methods, adhesives are classified to eleven types; low temperature hardening (code number a ); normal temperature hardening (code number b); heating hardening (code number c ); hardening adaptive to different temperatures (code number d); setting when reacting with water (code number e ); anaerobic setting (code number f ); radiation (light, electron beam, radiation) setting (code number g); melt and chill hardening (code number h); pressure-sensitive adhesion (code number i); coagulation or agglomeration (code number j); others (code number k).

**4. Classified Based on Adherents in Adhesives**

Adherents in adhesives are classified to twenty-two types: multiple materials (code number A); wood (code number B); paper (code number C); natural fibers (code number D); synthetic fibers (code number E); polyolefin fibers (not including E type, code number F); metals and alloys (code number G); metals hard to bond (gold, silver copper etc., code number H); metal fibers (code number I); inorganic fibers (code number J); transparent inorganic materials (code number K); non-transparent inorganic materials ( code number L); natural rubbers (code number M); synthetic rubbers ( code number N); rubbers hard to bond ( silicone rubber, fluoro-rubber and butyl rubber, code number O); rigid plastics (code number P); plastic films (code number

Q); leathers, synthetic leathers (code number R); foam plastics (code number S); plastics and films hard to bond (fluoro-plastic, polyethylene and polypropylene etc., code number T); body constituent skeletons and dentine materials (code number U); others (code number V).

### 14.1.3 Performances of Adhesives

To bond materials together firmly, adhesives are required to have the following primary performances.

1) Good manufacturability: such as sufficient fluidity to make sure the surface of adherents adequately wetting-treated; available to adjust viscosity and hardening speed etc. Manufacturability is the general evaluation of the bonding operation of adhesives.

2) Adequate bonding strength is the primary performance index for evaluating the quality of adhesives.

3) Good durability and weather-resistance, less likely to get aged.

4) Good stability, less swelling or shrinkage deformation.

5) No harm to human health is a must. The content limit of harmful substances should comply with "*Limit of Harmful Substances in Adhesives for Interior Finishing Materials*" (GB 18583-2001).

6) Other performances such as thermal stability, chemical stability and storage stability etc.



## 14.2 Bonding Mechanism and Factors Affecting Bonding Strength

### 14.2.1 Bonding Mechanism of Adhesives

The reason why adhesives firmly bond together the same or different kinds of material is that it has bonding power. Bonding mechanism mainly appears in the following aspects.

1) Mechanical bonding. Namely, chemical reaction does not happen to such adhesives. When coated with adhesives, the surfaces of materials are wet-treated and bond together.

2) Chemical reaction. Some molecules of adhesives react with the molecules of materials and become hardened, therefore adherends are bond together.

3) Physical adsorption power. Physical adsorption power, namely Vander Waals power, exists between the molecules of adhesives and the molecules of materials and bonds them together.

Actually, as to the properties of bonding power, when surfaces of adherends are smooth and dense, the bonding power usually comes from the physical adsorption power; when the surface are porous, adhesives penetrate into the pores of adherends, and become "inlaid" together after hardening. At the same time, the rough surfaces of adherends enlarge the contact area and the bonding power is increased.

## 14.2.2 Factors Affecting Bonding Strength

Bonding strength is defined as the maximum force born by unit bonding area, which mainly depends on the own strength of adhesives (cohesive power) and the adhesive strength (adhesive power) between adhesives and adherends. Factors affecting the bonding strength are those affecting the cohesive and adhesive powers, mainly including: types of adhesives, surface status of adherends and process conditions for bonding etc.



**1. Selection of Adhesives**

Selecting suitable adhesives is the key factor affecting the bonding strength. It is primarily considered in aspects as follows.

(1) Bonding Strength

There are kinds of material requiring bonding together in building decoration projects, such as all kinds of metal, glass, ceramic, wood, plastics, rubber and fiber. Each adhesive has different bonding power to different materials, so firstly it is selected based on the properties of the adherends. When bonding rubbers or rubber with other nonmetal material, peeling strength is mainly taken into consideration; when bonding rubber with metal, even pull-off strength as well as peeling strength should be taken into consideration; as for bonding metals, shearing strength is the main considered factor. Moreover, adhesives should be carefully selected according to application requirements: for bonding forced structural components, adhesives with high strength and good toughness should be adopted; when for common bonding, process location or repair work in construction, general adhesives are used.

(2) Working Temperature

The thermal stability of adhesives with high molecular synthetic as basic material is limited. For instance, the working temperature of rubber adhesives is −60-+80℃; the working temperature of adhesives with bisphenol A epoxide resin as basic material is −50-+180℃; whereas inorganic adhesives are available for long term service at +500℃. Therefore, the temperature limit of adhesives should not be lower than the working temperature of the adherends, otherwise the bonding strength will sharply decline and even worse totally fail.

(3) Curing Condition

Different curing temperatures and curing pressures may affect the application scopes of adhesives. High temperature curing is better to achieve high bonding strength. But some materials can't bear high temperature or can't be heated in large scale decoration projects, so room temperature curing adhesive is preferable. It is also used to materials with great differences in bonding expansion coefficient, because heat curing causes too big internal stress. Some adherends are in complicated shapes or in crisp quality, not available for pressurizing, therefore, additives with low contact pressure can only be applied.

(4) Expense

In decoration construction, the consumption amount of adhesives is very large and should be well managed to avoid waste. To decoration projects consuming large amount of adhesives or to cheap bonding pieces, it is better to adopt cheap adhesives made with simple techniques.



**2. Surface Status of Adherends**

The surface status of adherends directly affects the adhesive power, which greatly affects the bonding strength.

(1) Surface Cleanliness of Adherends

The surfaces of adherends are required to be clean and dry, with no oil stain or corrosive rust or paint residue. Water, dust or attaching substances such as oil stain, corrosive rust on the surface will decrease the wettability of the adhesive and resist the contact between the adhesive and the surfaces of adherends. And, the cohesive power of these substances is far smaller than that of the adhesive-layer, which is very likely to decrease the bonding strength.

(2) Surface Roughness of Adherends

Certain roughness on the surface helps to enlarge the bonding area, increase the mechanical bonding power and prevent the expanding of micro-crack in the adhesive-layer. But excessive roughness will affect the wettability of adhesives. Especially, bubbles are likely to remain at the concave areas on the surface, which may decrease the bonding strength. Different types of adhesives require different surface roughness of adherends.

(3) Surface Chemical Properties of Adherends

The surfaces of different materials vary greatly in tension, polarity and dense status of oxidation-film, which may affect the wettability of adhesives and the forming of chemical bonds.

(4) Surface Temperature of Adherends

Certain temperature on the surface of adherends will increase the fluidity and wettability of adhesives, which helps to enhance the bonding strength, but the temperature is required to be neither too high nor too low.



### 3. Process Conditions for Bonding

In bonding construction, process conditions such as the surface cleanliness of adherends, the thickness of the adhesive layer, dry set time and curing degree have certain influences on the bonding strength.

(1) Surface Cleanliness

Before bonding, it is required to carefully clean the surfaces of the adherends; get rid of such substances as water, oil stains, rusty stains and paint residues to ensure bonding quality.

(2) Thickness of the Adhesive-layer

To most adhesives, the thicker the adhesive-layer is, the weaker the bonding strength becomes. Generally inorganic adhesive layer is 0.1-0.2mm thick, organic adhesive layer is 0.05-0.1mm thick. With thin adhesive layer, the adhesive power on the adhesive surface plays the leading role. Because it is often bigger than the cohesive power, cracks or defects are less likely to appear in the adhesive-layer, therefore, the bonding strength is increased. But if the adhesive-layer is too thin, inadequate adhesive may decrease the bonding effect. Therefore, it is required to fully and evenly cover the material with adhesive-layer firstly, and then to make the layer as thin as possible.

(3) Dry Set Time

Adhesives require sufficient dry set time, especially adhesives containing thinners need sufficient dry set time before bonding for the thinners to volatilize, otherwise pores may appear and make the layer get loosened, which reduces the bonding strength.

(4) Curing Degree

The curing of adhesives requires three factors, pressure, temperature and time, which are called "the three factors for curing". During curing, certain pressure is beneficial to the fluidity and wetness of glue solution, ensures the uniformity and density of the adhesive-layer and squeezes bubbles out of it. Temperature is an important factor for curing. Properly increasing curing temperature is beneficial for the infiltration and diffusion of the macro-molecules and for the out-escaping of bubbles, and helps to increase the fluidity of the glue solution. Higher temperature leads to higher curing speed. However, high temperature accelerates the curing procedure, but too high temperature is not good for the wettability of adhesives, and results in lower bonding strength. Certain period of time at curing temperature is beneficial for the diffusion of adhesive macromolecules to the adherends, which leads to full curing reaction and increases the bonding power, which grows even better as time goes. The length of time depends on the properties, curing temperature, curing pressure and curing speed of the adhesives.

(5) Environmental Factors and Joint Forms

If the air humidity in the environment is high, the thinners in the adhesive-layer is not easy to volatile, and bubbles are likely to appear; too much dust in the air or low temperature decreases the bonding strength.

There are many adhesive joint forms which greatly affect the bonding strength. A good adhesive joint should meet these requirements: suitable joint length and width, adequate stiffness of adherends and suitable thickness of adhesive-layer. Thus, stress is uniformly distributed on the surface of the entire bonding area, which minimizes or eliminates the destruction of adhesive surface caused by the unevenness of pull-strength due to the concentration of stress.



## 14.3 Types and Selection of Commonly-used Adhesives

Presently, there are many manufacturers producing different types of adhesives with different performances. How to select proper adhesives according to the properties of materials and the environmental conditions is the key to the bonding quality. Several adhesives commonly-used in decorative construction are introduced for design and selection reference as follows.

### 14.3.1 Types of Adhesives Commonly-used in Decorative Construction

#### 1. Thermosetting Resin Adhesives

(1) Epoxide Resin Adhesives (EP)

Epoxide resin adhesive is composed of synthetic resin, curing agent, filler, thinner and flexibilizer etc. With the improvement of formulas, different adhesives with all kinds of applications are created. Before curing, epoxide resin is linear thermosetting resin, which has extreme active epoxy group ( $\begin{array}{c} O \\ / \quad \backslash \\ -CH-CH_2 \end{array}$ ) and multiple types of polar group (especially —OH) in its molecular structure, so it reacts with many types of curing agents and creates high molecular polymer in netlike three dimensional structure. With very high adhesive power to metal, wood, glass, hard plastics and concrete, EP is reputed as"universal glue".

(2) Unsaturated Polyester Resin Adhesives (UP)

Unsaturated polyester resin is made in this way: unsaturated dibasic acid and saturated dibasic acid are combined to mixture acid, which reacts with dihydric alcohol to create linear polyester, and then the linear polyester is interlinked and cured with unsaturated monomer to produce thermosetting resin which is mainly used to make fiber reinforced plastic, and also to bond ceramic, fiber reinforced plastic, metal, wood, artificial marble or concrete. The joints applying unsaturated polyester resin adhesives have good durability and certain strength, and are highly adaptive to the environment.

#### 2. Thermoplastic Synthetic Resin Adhesives

(1) Polyvinyl Acetate Adhesives (PVAC)

Polyvinyl acetate latex (known as white latex) is made of vinyl acetate monomer, water, dispersing agent, polymerization starter, and other auxiliary materials mixed together through emulsion polymerization. It is a nonstructural adhesive with low price, convenient usage and wide application range. It has good adhesive power to different kinds of polar materials, mainly for bonding different kinds of nonmetal materials, such as glass, ceramic, concrete, fiber fabric and wood. Its thermal stability is below 40℃, and it has weak stability to solvent action, low water-resistance and heavy creep. It is mainly adopted as nonstructural adhesive for projects at room temperature, e.g. pasting materials such as plastic wallpaper, polystyrene or soft polyvinyl chloride plastic plate and plastic flooring etc.

(2) Polyvinyl Alcohol Adhesives

Polyvinyl alcohol is a water solution polymer derived from the hydrolysis of vinyl acetate. Such adhesive is available for bonding wood, paper and fabric etc. Due to its weak thermal stability, water resistance and aging resistance, it is used together with thermosetting adhesive.

**3. Synthetic Rubber Adhesives**

(1) Chloroprene Rubber Adhesive (CR)

Chloroprene rubber adhesive is a solution type adhesive among widely-used rubber adhesives. It is made up of neoprene, magnesium oxide, anti-aging agent, antioxidant and filler etc., mixed and then resolved in solvent. Such adhesive has good resistance to water, oil, weak-acid, weak-alkali, aliphatic hydrocarbon and alcohols, and work at −50-+80℃. It has relatively higher initial adhesive power and cohesive strength, but tends to creep and easy to get aged. It is mostly applied to bond structures or different materials. To improve the performances, oil-soluble phenolic resin is added to make chloroprene rubber phenolic adhesive, which sets at room temperature and is applied to bond varieties of metal and nonmetal materials including steel, aluminum, copper, ceramic, cement products, plastic and hard fiberboards. In construction, it is used to bond and paste plastic or rubber products on the surface of cement mortar walls or floors.

(2) Nitrile Butadiene Rubber (NBR)

Nitrile butadiene rubber comes from the copolymerization of butadiene and acrylonitrile. Nitrile rubber adhesive is mainly used to bond rubber products and to bond rubber with metal, fabric or wood. The prominent features are good oil-resistance and high peeling strength. Its joint has good resistance to aliphatic hydrocarbon and non-oxidizing acid, and together with the high elasticity of rubber, it is more suitable for bonding soft materials or materials whose heat expansion coefficients vary greatly, such as polyvinyl chloride plates and polyvinyl chloride foam plastics. Nitrile butadiene rubber is mixed with other resins to achieve higher strength and elasticity.

## 14.3.2 Selection of Commonly-used Adhesives

### 1. Adhesives for Wallpaper and Wall Cloth

Types, performances, features and applications of commonly-used adhesives for wallpaper and wall cloth are given in Table 14.1.

**Table 14.1 Types, Performances, Features and Applications of Adhesives for Wallpaper and Wall Cloth**

| Type | Performance Index | Feature | Application |
|---|---|---|---|
| 801 glue | Appearance: colorless or slight yellow transparent;<br>Solid content: 11%-13%;<br>Density: 1.05g/cm$^3$;<br>Free-formaldehyde content: <1%;<br>Viscosity: 2~2.5Pa·s;<br>pH value : 7-8 | Made after the poly-condensation reaction of polyvinyl alcohol and formaldehyde in acid medium, and the amination of the result; nontoxic, incombustible, odorless, with low content of free-formaldehyde and no pungent odor during construction; better than 107 glue in wear resistance, peeling strength and other performances | Available for pasting wall cloth, wallpaper, ceramic and cement products etc; serving as the basic material for coatings applied to floors, interior and exterior walls |
| Polyvinyl acetate latex (white latex) | Appearance: milky white thick glue solution<br>Solid content: (50±2)%;<br>Granular diameter: 0.5-5μm;<br>pH value: 4-6;<br>Stability: 1h no delamination | Adopt vinyl acetate as the main raw material; made through emulsion-polymerization; aromatic white milky glue solution; automatic-drying at normal temperature, good film-forming property, good weather resistance, mildew and fungi resistance; with no solvent, no pungent smell | Widely used to paste paper products (wallpaper); applied to cement reinforcing agents, waterproof coatings or wood adhesives |
| SG8104 wallpaper adhesives | Bonding strength>0.4-1MPa, good resistance to water and moisture, no tack failure after immersed in water for a week;<br>Strong initial bonding power; applied to roof, the wallpaper will not sag;<br>Good adaptability to the expansion and contraction caused by changes in temperature and humidity, no tack failure | A kind of nontoxic and odorless glue solution taking polyvinyl acetate as main raw material; convenient for brush coating, less consumption and strong bonding power | Available for pasting paper-based plastic wallpaper on the surface of walls made of cement mortar, concrete, cement asbestos board, plaster board and veneer board etc. |

Continued

| Type | Performance Index | Feature | Application |
|---|---|---|---|
| BJ8505 power wallpaper adhesives | Besides the performances of BJ8504, also have these features: initial bonding power: on the mortar puttied surface, it is better than 8504 glue, 107 glue; drying time: get dried within 3h on the mortar puttied surface; get dried within 2h on paint surface or oil surface | Good bonding power, nontoxic, odorless and convenient usage | Available for pasting wallpaper on the surface of walls made of cement, plastering or plasterboard etc., also available for the surface coated with oil paint or priming oil etc. |

## 2. Flooring Adhesives

Types, performances, features and applications of commonly-used flooring adhesives are given in Table 14.2.

**Table 14.2 Types, Performances, Features and Applications of Flooring Adhesives**

| Type | Performance index | Feature | Application |
|---|---|---|---|
| Water-based No.10 plastic flooring adhesive | Paste calcium-plastic board and cement board:<br>At 40℃ and relative humidity more than 95%, after 100h, no decrease in shearing strength;<br>Viscosity ($LN_9$ type asphalt viscometer, 20℃): ≥25s;<br>Storage temperature not lower than -3℃;<br>Storage duration not more than half a year | Adopt polyvinyl acetate latex as basic material; a kind of mono-component water soluble glue solution with high bonding strength; nontoxic and odorless, fast drying, anti-ageing, oil resistant etc.; at low price; convenient and safe for construction, stable storage | Mainly for adhering polyvinyl chloride flooring or wood flooring to cement ground |
| 8123 polyvinyl chloride plastic flooring adhesive | Appearance: ash white, homogeneous paste;<br>Viscosity: 20-60Pa·s;<br>Solid content: (48±2)%;<br>pH value: 8-9;<br>Tensile strength (24h): ≥0.5MPa;<br>Storage temperature not lower than 0℃;<br>Storage duration: half a year | Adopt neoprene as basic material, add in thickener and filler etc.; a kind of water-emulsion adhesives, nontoxic and odorless, incombustible, convenient for construction; with high initial bonding strength and good waterproof performance | Available for adhering semi-hard, hard or soft polyvinyl chloride flooring to cement ground; also for adhering hardwood parquet to cement ground |
| CX401 adhesive | Appearance: light yellow glue solution<br>Bonding strength (rubber and aluminum alloy)<br>Peeling strength: 24h not less than $20N/cm^2$, 48h not less than 25 $N/cm^2$; | Composed of neoprene rubber, tertiary-butyl phenol-formaldehyde resin and certain amount of rubber ingredients and solvent etc.; | Available for adhering materials as metal, rubber, glass, wood, cement product, plastic or |

Continued

| Type | Performance index | Feature | Application |
|---|---|---|---|
| CX401 adhesive | Pulling strength: 24h not less than 1.1MPa, 48h not less than 1.3MPa | then mix them to make the product; with features such as convenient application and high curing speed etc. | ceramics; commonly applied to adhering rubber, plastic product, plastic flooring or softwood flooring to cement walls or grounds |
| Changcheng Brand 405 adhesive | Shearing strength: iron-iron 4.5MPa, aluminum-aluminum 4.7MPa, copper-copper 48MPa, glass-glass 2.5MPa, plastic-cement (time: 1d) 1.3MPa<br>Peeling strength: rubber-rubber 0.2-0.3 MPa | Composed of organic isocyanate and polyester with its tail end containing hydroxyl group, cures at room temperature; with features such as strong bonding power, water resistance, oil resistance, weak-acid resistance and solvent resistance | Good bonding power to paper, wood, glass, metal, plastics etc.; in building projects, mainly used to adhere plastic and wood; most suitable for waterproof, acid-alkali resistant constructions |
| HN-605 (731) adhesive | Shearing strength (steel No. 45): room temperature≥20MPa, +50℃≥30MPa; -50℃≥15MPa | A kind of bi-component adhesives with epoxide resin and amines curing agent as raw material, without solvent, curing at room temperature; with features such as high bonding strength, acid-alkali resistance, resistance to water and other organic solvents | Available for adhering varieties of materials such as plastic, rubber and ceramic |
| D-1 plastic flooring adhesive | Bonding strength: 0.2-0.3MPa;<br>Water resistance (25℃, 168h): no fall-off<br>Drying time: 40-60min | A water soluble adhesive with synthetic latex as main material; with features such as strong initial viscosity, safe and reliable in application; have good adhesive power to materials such as cement and wood | Available for adhering plastic flooring to cement or wood ground |

### 3. Adhesives for Bamboo and Wood

In building construction, commonly-used types of adhesives for bamboo and wood mainly are:

(1) 8109 Adhesive

8109 adhesive is water solution of urea formaldehyde condensates, added with curing agent ammonium chloride in application. It has features such as normal temperature curing, strong bonding power and low price.

(2) Tiemiao 206 Adhesive

Tiemiao 206 adhesive is made up of phenolic resin as main raw material and certain amount of curing agent. It has advantages such as normal temperature curing and strong bonding power, but its created film is crisp.

(3) SJ-2 Water-based Adhesive

SJ-2 water-based adhesive is a glue solution composed of vinyl acetate-polyacrylate emulsion and additives. It has features such as room temperature drying, convenient application and good initial bonding power and good brushability.

**4. Adhesives for Ceramic Tile and Marble**



Adhesive for ceramic tile and marble is mainly used for laying and pasting and for pointing joints. Commonly-used types in construction are as follows.

(1) JDF-503 General Ceramic Tile Adhesive

JDF-503 general ceramic tile adhesive is a powder made of cement modified by polymer. It has features such as strong water-resistance, good durability, convenient operation and low price, commonly used for laying and pasting ceramic tiles.

(2) JDF-505 Multicolor Pointing Agent

JDF-505 multicolor pointing agent is the auxiliary product of ceramic tile adhesives. It is in different colors and unlikely to crack, water resistant, nontoxic and odorless.

(3) Bi-component SF-1 type Decorative Stone Adhesive

Bi-component SF-1 type decorative stone adhesive is processed with certain techniques by taking soluble silicate as main raw material added with modifying agent, hardening agent, additive and filler. It is applied specially to decorative stones.

**5. Adhesives Specially Used for Glass and Organic Glass**

In building projects, commonly-used adhesives for glass and organic glass mainly include following types.

(1) AE Room Temperature Curing Transparent Acrylic Ester Adhesive

AE room temperature-curing transparent acrylic ester adhesive is abbreviated as AE adhesive, which is a colorless transparent sticky liquid and cures fast at room temperature, generally cures completely within 4-8h. After curing, it is almost in the same luminousness and refraction coefficient as organic glass. It has features such as strong bonding strength, high trans- parency and simple operation.

(2) WH-2 Organic Glass Adhesive

WH-2 organic glass adhesive is a colorless transparent colloidal liquid. It is resistant to water, oil, weak-acid and salt-fog (spray), and is suitable for adhering organic glass products or celluloid products.

**6. Adhesives for Rubber Waterproof Coils**

Adhesives for rubber waterproof coils include many types. The most commonly-used is chlorinated ethylene-propylene rubber adhesive. It adopts chlorinated ethylene-propylene rubber as raw material and methylbenzene as solvent, added with certain amount of additives such as reinforcing agent, cross-linking agent and softening agent. It has features such as good bonding performance, excellent weather-resistance, ozone-resistance, ageing-resistance, water-resistance and chemical-medium resistance, and is mainly applied to ethylene-propylene rubber coils serving as building waterproof material.



**7. Concrete Interface Adhesive**

Concrete interface adhesive is a cementing material used for the surface processing or reinforcing-processing of ordinary concrete, cement mortar and facing tiles etc. Commonly-used types in building projects include follows.

(1) JD-601 Concrete Interface Adhesive

JD-601 concrete interface adhesives is a polymer emulsion mixture used to enhance the adhesion of concrete surface, which greatly improves the bonding power between mortar and new or old concrete. And it replaces the traditional process methods such as green cutting and hacking, not only avoiding the defects of plastering mortar such as hollowing, delaminating or loose bonding, but also improving project quality, speeding up the construction progress and reducing construction expense.

(2) YJ-302 Concrete Interface Treating Agent

YJ-302 concrete interface treating agent is a bonding reinforcing agent for cement mortar applied to the surface coating of new or old concrete or facing tiles (such as tile, glass mosaic and marble etc.) to increase the bonding power of cement mortar with the above materials, and thus to resolve the problems such as the hollowing of plastering mortar, the fall-off of tiles or the delaminating of new or old concrete.

## Case of Materials Selection

【Case】Marble panels are adopted for the decoration of exterior walls in some construction project. The bonding strength of the needed slate-hanging adhesive is up to 20MPa, but its tested bonding strength is far lower than the value; the marble surface is clean enough. Make a discussion and find out why the bonding strength is weak.

【Analysis】 The uncleanness of marble surface is the main reason for weak bonding strength. The reason why an adhesive bonds materials together firmly is the existence of bonding power between the adhesive and the materials. To different adhesives and materials, the main source of their bonding power is different. When mechanical adhesive power, physical adsorption force and chemical bond power carry out coordinative and cooperative action, high bonding strength is achieved. The surface of adherends is required to be clean, dry, with no oil or rusty stains, nor paint residues etc., because all of these may decrease the wettability of adhesives and the contact between adhesives and the surface of adherends. Furthermore these attaching substances have far smaller cohesive power than the adhesive-layer does, which may decrease the bonding strength.

In this case, the marble surface is not clean enough, which decreases the physical adsorption force between the adhesive and the stone surface, so much less chemical bonds are generated, thus the bonding strength can't meet the design requirement. Therefore, the surface of the marble panel should be carefully cleaned before the bonding work. Attaching substances such as water, oil or rusty stains and paint residues should be cleaned out of the surface to ensure the bonding quality.



## Summary

This chapter introduces the components, classifications and performances of adhesives, as well as the bonding mechanism and the factors affecting the bonding strength; also includes commonly-used types of adhesives in decorative projects and the selection of adhesives applied to different decorative materials.

## Questions for Reviewing and Thinking

14.1 What are the main components of adhesives? What functions does each of them have?

14.2 How are adhesives classified?

14.3 What main performances do adhesives have?

14.4 Briefly state the main factors affecting the bonding strength of adhesives.

14.5 What are commonly used adhesives in decorative construction? What features does each of them have?

# 15

# Waterproof Materials

Along with the rapid development of new decorative materials in our country, there are more and more types of waterproof materials applied to the exterior decoration of buildings and the waterproofing projects of roofs and rooms. Apart from commonly-used bituminous waterproof materials, there are also high polymer modified asphalt, rubber and synthetic high polymer water proof materials etc., which have been used in construction projects and achieved very good waterproof and decorative effects.

## 15.1 Asphalt



Asphalt is an organic cementing material and is the mixture of many types of hydrocarbons and nonmetal derivatives such as oxygen, sulfur and nitrogen etc. At normal temperature it is a black or brown solid, semi-solid or viscous liquid.

### 15.1.1 Petroleum Asphalt

Petroleum asphalt is made by processing the residue of petroleum crude oil left after different kinds of clean oil (such as gasoline and diesel etc.) and lubricating oil are distilled. Waterproof materials made by modifying building petroleum asphalt are mainly adopted in construction.

**1. Components of Petroleum Asphalt**

The composition of petroleum asphalt is complicated, including different kinds of macromolecular compounds and derivatives. Moreover, large amount of isomerism of organic compounds results in that asphalts with similar elementary analysis are greatly different in properties. Therefore, in construction practice, asphalt components with similar properties and related physical mechanical performances are classified to a group, called "component", which stands for the content of each component in asphalt. The main components of asphalt are as follows.

(1) Oil

A viscous liquid in light yellow or reddish-brown, content 45%-60%, density 0.7-1.0g/cm$^3$, soluble to most organic solvents, but un-soluble to alcohol. Heated at 170℃ for certain time, oil is likely to volatilize. It provides asphalt with certain fluidity and decreases its consistency to be easily applied.

(2) Resin

A thick viscous fluid in colors from reddish brown to blackish brown, melting point below 100℃, water content 15%-30%, density 1.0-1.1 g/cm$^3$. Most of the resin in asphalt is neutral, and higher content of resin means higher quality of the asphalt. Resin provides asphalt with good plasticity and bonding power.

(3) Asphaltene

A dark brown to black amorphous solid material with density bigger than 1.0g/cm$^3$, asphaltene is the key component that determines the temperature sensitivity and viscosity of petroleum asphalt. Higher content leads to higher softening-point and higher viscosity of the asphalt and the asphalt is harder and more brittle.

(4) Wax

There is wax in petroleum asphalt. It decreases the viscosity and plasticity of asphalt, and is sensitive to temperature, which weakens the temperature stability of asphalt. So wax is a harmful ingredient in petroleum asphalt.



### 2. Main Technical Properties of Petroleum Asphalt

(1) Viscosity (Viscosity Property)

The viscosity of asphalt refers to its ability to resist deformation under external forces, which is the feature reflecting the internal resistance of asphalt to its relative flow. It is one of the primary technical properties of asphalt. The viscosity of different asphalts varies greatly, which is related to the components of asphalt and the environmental temperature. With more asphaltene and certain content of resin but less oil, the asphalt has higher viscosity. Within certain temperature ranges, the viscosity decreases as the temperature rises, and vice versa.

In construction, relative viscosity is taken to show viscosity, which is tested with a penetrometer or a master viscometer. The relative viscosity of sticky petroleum asphalt is shown with needle-penetration degree, which reflects the resisting ability of petroleum asphalt to shearing-deformation; lower needle-penetration degree means higher relative viscosity of asphalt. The needle-penetration degree of sticky petroleum asphalt is defined as: at specified temperature 25℃, after the specified time (5s), the depth penetrated to the sample with the specified 100g standard needle. The relative viscosity of liquid or thin petroleum asphalt is represented with standard viscosity.

(2) Plasticity

Plasticity is defined as the ability that petroleum asphalt deforms but without destruction under external force action, which is one of the important indexes of asphalt properties. The plasticity of petroleum asphalt is related to its components, with more resin and suitable content of other components, asphalt has higher plasticity. Factors affecting plasticity also include the environmental temperature and the thickness of the asphalt film layer etc.

The plasticity of petroleum asphalt is represented with ductility, and higher ductility means better plasticity of the asphalt. The ductility of asphalt is measured in this way: make the test sample into a "8" form standard test model (its smallest cross section area is $1cm^2$) , pull it at specified speed (5cm/min) and at specified temperature (25℃) until it breaks; the length when it breaks is taken as the ductility, represented with "cm" as unit.



(3) Temperature Stability

Temperature stability is defined as the performance that the viscosity and plasticity of asphalt change along with the temperature. Within the same temperature range, different asphalts change differently in viscosity and plasticity. In construction, asphalts are supposed to change slightly in viscosity and plasticity when affected by temperature differences, i.e. asphalts should have small temperature sensibility and only those with better temperature stability can be adopted in construction projects.

The temperature stability of asphalt is represented with softening point, which is measured in this way: fill asphalt test sample into the copper ring of specified size (diameter 16mm, height 6mm), put a standard steel ball (diameter 9.5mm, mass 3.5g) on the sample and immerse the sample in water or glycerol, heat it at specified temperature-rising speed (5℃/min)to make it soft and droop, when it droops to the specified distance 25.4mm, then take the temperature as softening point, represented with "℃" as unit.

(4) Atmospheric Stability

It is defined as the property that the performances of petroleum asphalt don't deteriorate apparently under the long-term actions of external factors such as heat, air and sunlight etc. Atmospheric stability shows the ageing resistance of asphalt under atmospheric influences. The chemical composition of asphalt is complicated and instable, so under the actions of illumination, oxidization and heat, asphalt is likely to be oxidized, condensed or polymerized, which gradually transform its components from low molecular weight compounds to high ones. Then oil and resin in it are gradually lessened, which decreases its plasticity and brittleness until it cracks. Such procedure is called the "aging" of asphalt. In addition, the solubility, flash point and ignition point of asphalt are also factors to evaluate the quality of asphalt and ensure security in construction.

Solubility is the percentage of petroleum asphalt dissolved in trichloroethylene, carbon tetrachloride or benzene. It stands for the content of effective substances in petroleum, namely, purity degree.

Flash point is defined as the critical temperature of asphalt（℃）when the mixture of air and flammable gas generated when asphalt is heated touches a flame in specified conditions and starts to burn (blue flare).

Ignition point is defined as the critical temperature of asphalt (℃) when the mixture of air and flammable gas generated when asphalt is heated touches a flame and keeps burning for 5s.

Flash point and ignition point indicate the possibility of fire crash or explosion, which decides the safety performance of asphalt in transportation, storage and heating for service etc.



### 3. Technical Standards of Petroleum Asphalt

The main technical quality criteria of petroleum asphalt include penetration degree, ductility and softening point indexes etc. Refer to Table 15.1.

**Table 15.1 Quality Indexes of Petroleum Asphalt**

| Item | Road petroleum asphalt | | | | | | | Building petroleum asphalt | |
|---|---|---|---|---|---|---|---|---|---|
| | No.200 | No.180 | No.140 | No.100 A | No.100 B | No.60 A | No.60 B | No.10 | No.30 |
| Penetration degree（25℃, 100g）, 1/10 (mm) | 201-300 | 161-200 | 121-160 | 91-120 | 81-120 | 51-80 | 41-80 | 10-25 | 25-40 |
| Ductility (25℃) (≥) (cm) | — | 100[1] | 100[1] | 90 | 60 | 70 | 40 | 1.5 | 3 |
| Softening point (ring and ball) (≥) (℃) | 31 | 35 | 35 | 42-50 | 42 | 45-50 | 45 | 95 | 70 |

Continued

| Item | | Road petroleum asphalt | | | | | | | Building petroleum asphalt | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No.200 | No.180 | No.140 | No.100 A | No.100 B | No.60 A | No.60 B | No.10 | No.30 |
| Solubility (≥) (%) | Trichloroethylene, chloroform or benzene | 91 | 99 | 99 | 99 | 99 | 99 | 99 | | |
| | Trichloroethylene, chloroform, carbon tetrachloride or benzene | | | | | | | | 99.5 | 99.5 |
| Penetration degree ratio after evaporation ② (%) | | 50 | 60 | 60 | 65 | 65 | 70 | 70 | 65 | 65 |
| Flash point (open) (≥) (℃) | | 181 | 200 | 230 | 230 | 230 | 230 | 230 | 230 | 230 |
| Evaporation loss (160℃, 5h)) (≤) (%) | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Note: 1) At 25℃ the ductility is less than 100cm or at 15℃ductility not less than 100cm, the product is still deemed qualified.

2) After evaporation loss is measured, the ratio of the penetration degree to the previous penetration degree multiplied by 100 is the percent of the residue penetration degree over the previous penetration degree, called penetration ratio after evaporation.



## 15.1.2 Modified Asphalt

Modified asphalt is defined as asphalt product produced by carrying out oxidation, emulsification and catalyzing, or adding in resins or rubbers to improve the properties of asphalt to certain degrees.

### 1. Resin Modified Asphalt

Certain amount of synthetic resin such as polyvinyl chloride, polypropylene or phenolic resin etc. is added to petroleum asphalt to improve and enhance the thermal stability, frost resistance, bonding performance and impermeability of asphalt. Such asphalt is called resin modified asphalt.

### 2. Rubber Modified Asphalt

Certain amount of rubber such as natural, neoprene, butyl, styrene-butadiene or reclaimed rubber is added to provide petroleum asphalt with rubber properties and thus improve its air-tightness, low-temperature flexibility, light-fastness, weather resistance, fire resistance and chemical resistance.

Such modified asphalt is used to make waterproof coils, air-tight materials or waterproof coatings, which are widely applied to decorative construction.

**3. Rubber-resin Modified Asphalt**

Adding certain amount of resin and rubber provides asphalt with features of both resin and rubber, therefore the performances of asphalt are more excellent. Its main waterproof products include coils, sheets, air-tight and waterproof materials.

**4. Mineral-filler Modified Asphalt**

Add certain amount of mineral filler such as lime powder, talc powder, mica powder or diatomite etc. to asphalt to improve its thermal stability, enhance its bonding power and lessen its temperature sensitivity.

## 15.2 Waterproof Coils

### 15.2.1 Modified Asphalt Waterproof Coils



By adding high molecular polymer in asphalt the service performances of waterproof coils are improved and the service life of the waterproof layer is prolonged.

**1. Plastomer Modified Asphalt Waterproof Coils**

Take polyester felt or glass fiber felt as base and atactic polypropylene (APP) or polyolefin polymer (APAO, APO) as modifying agent, then cover the two sides of the base with insulating material to produce the product(generally called APP coils).

(1) Specifications

Its breadth is 1m, polyester-base coils are 3mm and 4mm thick, glass fiber base coils are 2mm, 3mm and 4mm thick. Per-coil area is usually 15 $m^2$, 10 $m^2$ or 7.5$m^2$.

(2) Marking Method

Marking sequence is plastomer modified asphalt waterproof coil, model number, base, front surface material, thickness and standard code. For example, 3mm thick I-type plastomer modified asphalt waterproof coil with sand-surface and polyester base is marked as APP I PY S3 GB18243.

(3) Applications

APP waterproof coil is applied to the waterproofing construction of roofs and undergrounds in industrial and residential buildings, especially suitable for the waterproofing work of buildings in hot environments.

(4) Technical Requirements

Weight, area and thickness of the coil are shown in Table 15.2; the full coil should be wrapped tightly and trimly with less than 10mm irregularity at the ends; the base should be fully impregnate without any stripe left out; the surface of the coil should be flat and trim without holes, broken edges or cracks; each coil is allowed less than 1 joint with the shorter segment no less than 1m, the joint should be trimmed with an extra length of 150mm.

**Table 15.2 Weight, Area and Thickness of the Coil**

| Dimensions (nominal thickness) (mm) | | 2 | | 3 | | | 4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Front surface material | | PE | S | PE | S | M | PE | S | M | PE | S | M |
| Area ($m^2$/coil) | Nominal area | 15 | | 10 | | | 10 | | | 7.5 | | |
| | tolerance | ±0.15 | | ±0.10 | | | ±0.10 | | | ±0.10 | | |
| Minimum coil weight (kg/coil) | | 33.0 | 37.5 | 32.0 | 35.0 | 40.0 | 42.0 | 45.0 | 5..0 | 31.5 | 33.0 | 37.5 |
| thickness | Mean value(≥) | 2.0 | | 3.0 | | 3.2 | 4.0 | | 4.2 | 4.0 | | 4.2 |
| | Minimum unit value | 1.7 | | 2.7 | | 2.9 | 3.7 | | 3.9 | 3.7 | | 3.9 |



(5) Typical Product

APP modified asphalt waterproof coil, the typical product in plastomer asphalt waterproof materials, is a medium-end or high-end waterproof material processed by adopting several technical procedures. It has main features as high tensile strength and high elongation percentage; good thermal stability and heat resistance, adaptive temperature ranges −15-130℃, especially highly resistant to ultraviolet radiation, applicable in hot areas; with stable molecular structure, its molecular structure is not rearranged at high temperature and in sunlight, so it has good ageing resistance; with good hydrophobicity and bonding performance, it is available for cold-bond and hot-melt operations, clean and pollution-free.

## 2. Elastomer Asphalt Waterproof Coils

Take polyester felt or glass fiber felt as base and thermoplastic elastomer styrene-butadiene-styrol copolymer (SBS) as modifying agent, then cover both sides of the base with insulating material to produce the product (shortened as "SBS" coils)

There are two bases: glass fiber felt and polyester felt; three types of surface spread material: fine sand, mineral particles (lamellar) and polyethylene membrane; totally six types of product. Refer to Table 15.3.

**Table 15.3 Types of Elastomer Asphalt Waterproof Coils**

| Base / Front surface material | Polyester base | Glass fiber base |
|---|---|---|
| Polyethylene membrane | PY-PE | G-PE |
| Fine sand | PY-S | G-S |
| Mineral particle (lamella) | PY-M | G-M |

(1) Specifications

Its breadth is 1m; polyester base coils are 3mm or 4mm thick, glass fiber base coils are 2mm, 3mm or 4mm thick; unit coil area is 15 $m^2$, 10 $m^2$ or 7.5$m^2$.

(2) Marking Method

Marking sequence is: elastomer modified asphalt waterproof coil, model number, base, front surface material, thickness and standard code. For instance, 3mm thick I-type elastomer modified asphalt waterproof coil with fine-sand surface and polyester base is marked as SBS I PY S3 GB18232

(3) Applications

This series of waterproof coil is applied to the waterproof and moisture-proof work of roofs, basements and washrooms etc. in industrial and residential buildings, especially to the waterproof work of buildings in cold regions and buildings suffering frequent structural deformation.

(4) Technical Requirements

Weight, area and thickness of the coil are given in Table 15.4; the full coil should be wrapped tightly and trimly with less than 10mm irregularity at the ends; when the full coil is rolled open at any temperature within 4-50℃, there should be no existence of more than 10mm cracks or caking; the base should be fully impregnate without any stripe left out; the surface of the coil should be flat and trim without holes, broken edges or cracks; each coil is allowed less than 1 joint with the shorter segment no less than 1m, the joint should be trimmed with an extra length of 150mm.

**Table 15.4 Weight, Area and Thickness of the Coil**

| Dimensions (nominal thickness) (mm) | | 2 | | 3 | | | 4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Front surface material | | PE | S | PE | S | M | PE | S | M | PE | S | M |
| Area ($m^2$/coil) | Nominal area | 15 | | 10 | | | 10 | | | 7.5 | | |
| | Deviation | ±0.15 | | ±0.10 | | | ±0.10 | | | ±0.10 | | |
| Minimum coil weight (kg/coil) | | 33.0 | 37.5 | 32.0 | 35.0 | 40.0 | 42.0 | 45.0 | 50.0 | 31.5 | 33.0 | 37.5 |
| Thickness | Mean value (≥) | 2.0 | | 3.0 | | 3.2 | 4.0 | | 4.2 | 4.0 | | 4.2 |
| | Minimum unit value | 1.7 | | 2.7 | | 2.9 | 3.7 | | 3.9 | 3.7 | | 3.9 |

(5) Typical Product

SBS modified asphalt flexible tar felt, a kind of waterproof coil, adopts polyester fiber non-woven fabric as base, SBS rubber modified petroleum asphalt as impregnated coating covering-layer (surface layer) and plastic film as anti-adhesive insulating layer. It has features as good elasticity, anti-fatigue, high and low temperature resistance, relatively low price, convenient construction (available for cold-bond and hot-melt operations) and better temperature adaptability and ageing-resistance. It is applied to the waterproof work of roofs and basements.



### 3. Modified Asphalt Polyethylene Base Waterproof Coils

Modified asphalt polyethylene base waterproof coil is made of modified asphalt as basic material, high density polyethylene film as base and polyethylene or aluminum foil as front surface covering material. It is processed through procedures as rolling, hydro-cooling and molding.

(1) Specifications: area 11m$^2$, breadth 1100mm, thickness 2 mm or 4mm

(2) Features

Chlorinated polyethylene waterproof coil has features such as high strength and elongation percentage, good elasticity, fastness to sunlight, long service life and resistance to tearing, ozone-ageing, frost, high-temperature and acid-alkali. It is available for cold operation and pollution free.

(3) Applications

It is applied to the waterproof work of exposed monolayer roofing and roofs and basements with protective layers.

(4) Application Scope

With good heat-resistance and low temperature flexibility, it is suitable for the waterproof work of undergrounds, tunnels, pools and dams etc., but should not be directly exposed to sunlight.

## 15.2.2 High Molecular Waterproof Coils

### 1. Polyvinyl Chloride Waterproof Coil

Polyvinyl chloride waterproof coil is made of polyvinyl chloride as main raw material, including types as non-composite, fibrous single-sided composite and internal fabric reinforced. It has prominent features and outstanding advantages.

1) Good waterproof effect and high tensile strength. Its tensile strength is twice of that of chlorinated polyethylene waterproof coil, and it has strong crack-resistance, good waterproofing and anti-seepage performances.

2) Long service life of up to 20 years.

3) High breaking-elongation. Its breaking-elongation is 300 times of that of paper base tar felt, with high adaptability to the deformation of the base layer such as elongation, shrinkage or cracking.

4) Good high-temperature and low-temperature resistance. Polyvinyl chloride waterproof coil is available for service within −40-90℃, both in cold and hot regions.

5) Available for cold-bond or hot-gas welding techniques in construction. It is convenient for construction and pollution-free.



### 2. Chlorinated Polyethylene (CPE) Waterproof Coils

It is made of chlorinated polyethylene resin as main raw material, including types as non-composite, fiber single-sided composite and internal fabric reinforced. It has features such as high strength, high elongation percentage, good plasticity, fastness to sunlight, long service life and resistance to ozone-aging, frost, tearing, high-temperature and acid-alkali. It is applied to the waterproof work of exposed monolayer roofing and roofs, basements and pools with protective layers.

### 3. Chlorinated Polyethylene-Rubber Blended Waterproof Coils

It takes chlorinated polyethylene resin and synthetic rubber as main material, added with certain amount of softening agents, stabilizers, accelerating agents and filling agents etc., which are processed into the product through procedures such as plasticization, compounding, rolling or extruding molding, vulcanization, cooling, inspection, coiling and packaging etc. Main features are as follows.

1) Good comprehensive waterproof performance.

It provides the product with the properties of both plastic and rubber to blend and modify the raw materials: chlorinated polyethylene resin and rubber, i.e. it not only has features of chlorinated polyethylene such as high strength and ageing resistance but also has features of rubber as high elasticity and high elongation, which improves its comprehensive waterproof performance.

2) Good high-temperature and low-temperature performances. It works at any temperature ranging -40-80℃.

3) Good bonding and fire retarding performances.

4) Good stability and long service life.

5) Available for cold-bond operation. It is simple and convenient for construction and enables higher work-efficiency.



### 4. Ternary Butyl Rubber Waterproof Coils

Ternary butyl rubber waterproof coil, a baseless coil-material, is produced with reclaimed butyl rubber as main material, butyl formate as modifying agent and butyl alcohol as accelerating agent. It has good elastic-plasticity, good ageing-resistance and thermal stability, especially good flexibility at low temperature. It is applied to the waterproof work of industrial and residential buildings and structures, especially suitable for the waterproof construction in cold regions and regions with greater temperature differences.

### 5. High Molecular Waterproof Sheets

It is a uniform high-molecular composite sheet which is made mainly of high molecular material and processed by rolling and extruding. Main features are as follows.

1) Good ageing resistance and long service life. For instance, ethylene propylene diene monomer waterproof sheet has a service life up to 40 years.

2) High tensile strength and elongation percentage. For instance, the tensile strength and breaking elongation of ethylene propylene diene monomer waterproof sheet is around 300 times of those of petroleum asphalt paper base tar felt, so with higher adaptability to the deformation of the base layer such as elongation, shrinkage or cracking.

3) Good high-temperature and low-temperature resistance. For instance, ethylene propylene diene monomer waterproof sheet does not crack at -40-80℃.

4) Convenient and simple construction. Available for monolayer cold-bond operation, which is different from the traditional multilayer waterproof work mode—"two-felt three-oil one-sand" of asphalt felt in hot construction. Thus constructional procedures are simplified and labor efficiency is improved.

## 15.3 Waterproof Coatings

Waterproof coating is fluid or semi-fluid substance coated and spread on the surface of the base layer; after the volatilization of the solvent and water or through the chemical reaction between different components, a continuous film with certain elasticity and certain thickness is formed to insulate the surface of the base layer from water to achieve waterproof or moisture-proof function. According to the film-forming material, it is classified to asphalt and synthetic molecule waterproof coatings.



### 15.3.1 Water Asphalt-base Waterproof Coating

It is a water-emulsion waterproof coating made of emulsified asphalt as basic material and different kinds of modifying material. Main features and applications of commonly-used water asphalt-base waterproof coatings are as follows.

**1. Asbestos Emulsified Asphalt Waterproof Coating**

Asbestos emulsified asphalt waterproof coating, a thick waterproof coating, is made by adding molten asphalt to the suspending liquid composed of asbestos and water and fiercely blending them together. Basic features are as follows.

1) Thick waterproof film: large amount of coating is needed on unit area, after several times of daubing, the thickness reaches up to 4-8mm.

2) Containing asbestos fiber, it is stronger than ordinary emulsified asphalt in aspects such as water resistance, crack resistance and stability etc. But asbestos fiber powder is noxious to people's health.

3) Sealing material is applied for caulked-joint process at structural joint areas previous to its application.

4) Appropriate constructional temperature required. Above 15℃ is appropriate, but at too high temperature it becomes sticky, which hinders the construction; when below 10℃, its film-forming performance is weakened, not propitious for construction.

5) Available for cold operation, applicable to moist base layer, nontoxic and odorless.

**2. Bentonite Emulsified Asphalt Waterproof Coating**

As an emulsified asphalt thick waterproof coating, it is made of quality petroleum asphalt as basic material and bentonite as dispersion agent, and processed through mechanical agitation. Performances and features are as follows.

1) Good waterproof performance, strong bonding performance, high heat-resistance and good durability.

2) Available for cold operation, applicable to moist base layer; simple and convenient operation; pollution-free.



**3. Lime Emulsified Asphalt Waterproof Coating**

As a grayish-brown paste thick waterproof coating, it is produced with petroleum asphalt as basic material, lime paste as dispersing agent and asbestos wool as filler.

1) Thicker coating layer; great amount of coating is needed for unit area.

2) Sealing material is required at structural joint areas previous to its application.

3) Constructional temperature ranges 5-30℃.

4) Resourceful raw material, lower cost.

5) If asphalt is not modified, it is crisp and easy to crack at low temperature, which decreases the quality of the waterproof work.

6) Available for cold operation, applicable to moist base layer; simple and convenient operation; pollution-free.

## 15.3.2 Synthetic High Molecular Waterproof Coating

**1. Polyurethane Waterproof Coating**

Polyurethane waterproof coating is a chemical reacting coating. After sprayed and brushed, it changes directly from liquid to solid and forms a fairly thick waterproof film due to the chemical reaction between its components. With little solvent in the coating, the volume of the film shrinks slightly; it has good elasticity, ductility, extensibility and tensile strength, weather resistance and corrosion resistance, and high adaptability to environmental temperature difference and base-layer deformation. It is a synthetic high molecular waterproof coating with excellent performances. Disadvantages: with certain toxicity, no fire resistance, high cost.

**2. Polyvinyl Chloride Elastic Waterproof Coating**

As a thermoplastic and hot-melt elastic waterproof coating (abbreviated as "PVC" waterproof coating), it is made of polyvinyl chloride as basic material, modifying material and other additives. With good elasticity and ductility as well as high adaptability to structural deformation of the base layer, it is available for cold operation on relatively moist base layer surface. Application temperature ranges −20-80℃, and it has good resistance to frost, heat, weather and corrosion, and good bonding performance. It is also available for large area construction with good integrity waterproof layer, especially suitable for the waterproof work at complicated structural areas.



**3. Other High Molecular Waterproof Materials**

(1) Polymer Emulsion Building Waterproofing Coating

It includes all single-component water-emulsion waterproof coatings produced with polymer emulsion as basic material and other additives; mainly applied to the waterproof and anti-seepage work of roofs, washrooms and basements etc., especially suitable for the waterproof work of roofs in light and thin structures owing to its seamless and closed waterproof layer; available for mixing into coatings in different light colors, which are not only waterproof but also thermal insulating and achieve certain decorative effects.

(2) Silicone Waterproof Coating Applied to Building Surfaces

As a water-based or solvent-based silicone waterproof agent used on building surfaces, it is made of silane and siloxane as main basic material, mostly applied to the waterproof and protective work of porous inorganic base layers (such as layers of concrete, ceramic tile, clay tile or stone etc.) without hydraulic pressure.

(3) Solvent Rubber Asphalt Waterproof Coating

It is suitable for the waterproof and anti-seepage work of buildings, with features such as strong bonding power, strong stretching force, good heat insulation and patching effect. It is available for direct application to moist waterproof-layer made of brick, stone, mortar, concrete, metal or wood etc. and widely applied to waterproof sealing, decoration and patching repair work of new or old roofs, basements, exterior walls and pipelines etc.

(4) Polymer-cement Waterproof Coating

As a hydraulic flexible waterproof material, it is nontoxic and has high bonding strength, good elasticity and airtight effect. With advantages of both organic and inorganic materials such as elasticity, durability and water-resistance, it is available for direct bonding with the surface material such as tile or stone slab etc; available for moist base layer surface; easy to form film; seamless and requiring short construction period. It is mainly applied to areas needing waterproof, moisture-proof, anti-seepage and patching processes, such as roofs, washrooms and basements etc.

## Case of Materials Selection



Case One: Application of Bentonite Waterproof Felt and Drainage Unit (Waterproof Board)

Some skyscraper: the overall building area is around 110 000 $m^2$, overall height is 269.8m and the building area of each basement storey is around 3000 $m^2$. New waterproof technology, the combination of proof and drainage, is applied in the basements. Bentonite waterproof felt is adopted as the bottom board, and drainage unit is applied between concrete diaphragm and chemise walls. Drainage unit and aqueduct lead the possible seepage water from the concrete diaphragm wall to the basement drainage-ditch, thus make the basement waterproof.

Construction procedures of bentonite waterproof felt: pile platform under-layer —stock mould construction of pile cap—basement bottom board: 3-5cm gravel screed 10cm thick; paving and filling 15cm thick stone powder; cement mortar for filling and leveling—waterproof felt applied at internal and external angles, waterproof powder filled around the pile ends—laying and pasting waterproof felt (300mm left in advance at construction joints)—waterproof paste coated around the pile ends—casting concrete under-layer of bottom board (protection layer)—building 6cm thick sand-and-brick protection layer inside the pile platform, rendering 1:2:5 cement mortar to 20cm thick.

Case Two: Exterior Wall Seepage Repair Project of Zhongshan Hot Spring Golf Club Villa

Introduction of the project: the villa is a two-layer brick and concrete structure, building area is $180m^2$, exterior walls are plain ash brick with mortar pointing joint. Since 1988, the seepage had become more and more serious: some interior walls were wholly stained by moisture, many switches became dangerous and water dripped in when it rained. The interior wall surfaces had to be overhauled every year. From the renovation in 1992 to the year 2000, no exterior wall seepage took place, which was highly praised by the building owners.

Material selection guidelines and finalized solutions.

Guidelines for material selection: excellent technical performances, convenient constructional operation and reasonable price. Because the villa looks primitive and simple but actually luxurious, the renovation is to assure there is no seepage in the exterior walls of the whole building and to keep its primary appearance colors and glosses.

Finalized solutions: 1) produce grey acrylic acid sealant in the same color as the villa's; fill up every brickwork joint and wall joint at the seepage areas one by one; 2) Spray two layers of silicone waterproof coating on the above areas.



## Summary

This chapter focuses on the three main types of waterproof material commonly used in building decorative projects: asphalt waterproof coating, waterproof coil and waterproof coating. The section about asphalt mainly introduces the basic performances, commonly-used technical parameters and applications in waterproof projects of petroleum asphalt and petroleum modified asphalt. The section about waterproof coils mainly introduces the performances, specifications, technical requirements and typical products of modified asphalt and synthetic high molecular waterproof coils. The main features and applications of asphalt and synthetic high molecule waterproof coatings are mainly introduced in the last section.

## Questions for Reviewing and Thinking

15.1 What are the main components of petroleum asphalt? What functions does each component take?

15.2 What indexes are adopted in construction to indicate the viscosity, plasticity and temperature stability of petroleum asphalt? How are these indexes measured and determined?

15.3 What are the main performances, features and applications of APP?

15.4 What are the main technical requirements of SBS? What are its main applications?

15.5 What is waterproof coating? What are commonly-used waterproof coatings and what features does each of them have?

# 16

# Acoustic and Thermal Insulating Materials

Both acoustic and thermal preserving and insulating materials are important functional materials. The main measure to save energy in buildings is to adopt thermal preserving and insulating materials. Making effective use of acoustic materials greatly helps to retain good acoustic environments indoors and to reduce noise pollution. The application of acoustic and heat insulating materials play a very important role in the improvement of people's living quality.



## 16.1 Acoustic Materials

### 16.1.1 Introduction of Acoustic Materials

There are different kinds of sound—human voice, music sound and machinery sound etc. in the natural world; among them, sound such as bird twittering and graceful music are ravishing while noise such as noisy crying and machinery booming are upsetting. The former is what we are expecting to hear and enjoy, therefore we should make it more beautiful; the later disturbs our life and work and is what we are not willing to hear, so acoustic material, a special functional material is required in the construction and decoration of our houses. Architectural acoustic material is generally classified to sound absorbing and sound insulating materials.

**1. Sound Absorption Principle and Technical Indexes of the Materials**

Sound is created by the vibration of substance and is spread by sound wave produced through the sympathetic vibration of the medium. When sound is spreading, part of it is gradually diffused and part of it is weakened due to the absorption of air molecules, which are more apparent in the open air; but in indoors sound is much less diffused or weakened, instead it is mainly absorbed by the surface of materials.

When sound wave meets the surface of a material, part of it is reflected, part of it passes through the material, and the rest of it is transferred to the material. The part of sound wave transferred to the material enters the pores of the material and causes the friction and viscosity resistance between the air molecules and the wall of pores, thus certain part of sound energy is converted into heat energy and is absorbed in this way.

Generally sound absorption coefficient is adopted as the index for evaluating the sound absorbing performances of a material. It is the ratio of the sound energy absorbed by a material ($E$) to the overall sound energy previously spread and reaching the surface of the material ($E_0$), also called sound absorption coefficient ( $\alpha$ ). Mathematically it is expressed as:

$$\alpha = \frac{E}{E_0}$$

In the formula: $\alpha$ is the sound absorption coefficient of a material;

$E$ is the sound energy absorbed by material;

$E_0$ is the overall sound energy previously spread and reaching the surface of a material.



Sound absorption coefficient is related to sound frequency and sound incidence direction, it adopts the mean value of absorption to sound from all incidence directions, and the frequency of the sound being absorbed should be explicit. There are usually six frequencies: 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. Any material is capable of absorbing sound; the distinction is that their absorbing capacity is largely different. If the average sound absorption coefficient to the above stated six frequencies $\alpha$ is bigger than 0.2, the material is called sound absorbing material.

Any material has certain ability of sound absorption. What is different is the sound absorbing capacity. Generally, hard, smooth and heavy materials in dense structure have weaker sound absorption quality but stronger reflecting power, such as terrazzo-concrete, marble, concrete, cement rendering wall surface etc.; whereas rough, loose and soft porous materials with interpenetrated pores inside and outside have better sound absorbing performance but weaker reflecting power, such as slag wool, animal fiber, foam plastics and wood wool board etc.

## 2. Factors Affecting absorption quality of Materials

(1) Pore Features of Materials

All porous sound-absorbing materials have high porosity. Materials with more and tinier open pores have better sound absorption effect. The structural features of a porous sound absorbing material are large quantity of interconnected micro pores and continuous bubbles all over the material from the surface to the inner part, which provides the material with certain air permeability. Whereas when its surface is coated with a dense layer or when it absorbs moisture, its sound absorption effect will be largely decreased.

(2) Apparent Density of Materials

Generally when the apparent density of the same material increases, its low frequency sound absorption effect improves, whereas its high frequency sound absorption effect decreases. Therefore, in certain condition, there is a best value of the density of a material. Both too big and too small densities are unfavorable to the sound absorption performance of the material.

(3) Thickness of Materials

To increase the thickness of a porous material will improve its sound absorption effect to low frequency sound, whereas its high frequent sound absorption effect changes slightly.

(4) Air Layer on the Backside of Materials

The existence of air layer increases the effective thickness of a material, especially improves its absorption to low frequency sound. Such way is more effective than applying thicker material to improve the absorption effect to low frequency sound.

To improve the spreading of sound wave indoors and to ensure good acoustic effect and lessen the interference of noise, proper sound absorbing materials should be applied to places such as interior walls, floors and ceilings in music halls, theaters, conference halls, broadcast studios and factory workshops with heavy noise etc.

## 3. Types of Sound Absorbing Materials and Structures.

There are many types of sound absorbing materials and structures. For general classifications, refer to Table 16.1.

**Table 16.1 Types of Sound Absorbing Materials and Structures**

| | | |
|---|---|---|
| Structure type | Porous sound absorbing material | Fiber shape |
| | | Granular shape |
| | | Foam shape |
| | Resonance sound absorbing structure | Single resonator |
| | | Perforated board resonance sound-absorbing structure |
| | | Panel damping sound-absorbing structure |
| | | Film resonance sound-absorbing structure |
| | Special sound absorbing structure | Suspended absorber, acoustic wedge etc. |

## 4. Commonly-used Sound Absorbing Materials

Porous sound absorbing material is the most commonly-used acoustic material. With large quantity of interconnected micro pores and continuous bubbles from the surface to the inner part, it has certain air permeability.

There are many types of porous sound absorbing materials: loose shape materials, such as extra-fine glass wool, mineral wool, seaweed and ramie etc.; some are processed to plate materials, such as glass fiber felt, perforated sound absorbing decorative fiberboard, cork wood fiber board and wood wool board; there are also micro-porous acoustic tile, slag expanded perlite acoustic tile and cellular glass etc. Commonly-used types are given in Table 16.2.

**Table 16.2 Basic Types of Porous Sound Absorbing materials**

| Main type | | Examples of commonly-used material | Application status |
|---|---|---|---|
| Fiber material | Organic fiber material | Animal fiber: wool felt | Expensive, less adopted |
| | | Plant fiber: ramie, seaweed | Weak fireproof and moisture-proof performance, raw material is resourceful |
| | Inorganic fiber material | Glass fiber: medium coarse wool, superfine wool, glass fiber felt | Good performance of sound absorption, heat preservation and insulation, not self-flaming, corrosion-proof and moisture-proof |
| | | Slag wool: loose wool, mineral wool felt | Good performance of sound absorption, loose material and easy to sink due to self-weight, thorny in construction |
| | Fiber material | Mineral wool acoustic board, rock wool acoustic board, glass wool acoustic board | Assembling-type construction; mostly applied to interior sound-absorbing decorative projects. |

Continued

| Main type | | Examples of commonly-used material | Application status |
|---|---|---|---|
| Granular material | Block | Slag acoustic tile, expanded perlite acoustic tile | Mostly adopted to build mufflers with bigger cross-section areas |
| | Board | Expanded perlite decorative acoustic board | Light, nonflammable, heat preservation and insulation, lower strength |
| Foam material | Foam plastic | Polyurethane and urea-formaldehyde foam plastics | Sound-absorbing performance is not stable, sound absorption coefficient should be tested on site before application |
| | Others | Cellular glass | High strength, waterproof, nonflammable, corrosion resistant, expensive |
| | | Aeroconcrete | Micro pores are not interconnected, less adopted |
| | | Acoustic absorbent | Mostly applied to wall surface areas not easy for construction etc |

## 5. Commonly-used Sound-absorbing Structures

(1) Film and Panel Resonance Sound-absorbing Structure

Fix leather, artificial leather or plastic film etc. on the frame, the backside of the frame is left with certain air layer, and a film resonance sound-absorbing structure is created. When sound comes into the film and panel structure, the later vibrates fiercely because sound frequency is close to that of the film and panel, and such mechanical vibration is converted into heat energy, which achieves the sound absorption effect. As low frequency sound is more likely to cause the vibration of the film and panel than high frequency sound, film and panel is a very effective low frequency sound-absorbing structure.

(2) Resonance Sound-absorbing Structure

Porous sound absorbing materials have better absorption performance to low frequency sound. There is certain volume of cavity enclosed in the middle and connected with sound resource through pores of certain depth. When receiving slight shakes from external force, the air inside the cavity will vibrate at certain resonance frequency, at this time the air molecules near the neck of the cavity open will vibrate to-and-fro under the action of the sound wave like a piston, thus sound energy is consumed by the friction to achieve sound absorbing effect. Covering the cavity open with a layer of thin cloth or loose cotton will help to broaden its absorption frequency range and increase its sound absorption amount. Several types of resonators with different resonance frequencies can be adopted at the same time to achieve the same effects. Resonance sound absorbing structure is widely applied to the building of public halls.

(3) Perforated Panel Unit Resonance Sound-absorbing Structure

Such structure is made by creating an air layer on the backside of different perforated panels or slit plates. It is cavity-resonance sound-absorbing structure. The panels and plates are arranged and serve as the combination of several paralleled resonators. With available materials and rather good decorative effect, the structure is used widely. Perforated panel is more suitable to absorb medium frequency sound and its main sound absorption and resonance frequencies are affected by its own thickness, pore diameter, perforation rate, perforation pitch and the thickness of the backside air layer; if the air layer behind the panel is filled with porous sound-absorbing material, the sound absorbing effect will be better.

(4) Suspended Absorber

Suspended absorber is different from other sound-absorbing structures, because it is not combined with ceilings or walls etc. to form the sound-absorbing structure but is suspended in the room to be an independent system. Commonly-used shapes of suspended absorbers include flat panels, columns and cones etc.; according to different application places and actual conditions, it is designed and produced into other shapes, not only to acquire good acoustic effect but also to achieve good artistic effect.



## 16.1.2 Commonly-used Sound-absorbing Boards

### 1. Mineral Wool Decorative Acoustic Board

Mineral wool decorative acoustic board adopts slag wool as main raw material and added in certain amount of bonding agent, dust-preventive agent and water-repelling agent, and then is produced through processing techniques such as pressurizing, drying and finishing etc. It has unique performances such as lightweight, sound absorption, fireproof, heat preservation and insulation and good decorative effect etc. and suitable for the decoration of suspended ceilings in public buildings such as hotels, conference halls, office buildings, departure lounges of airport and theaters etc.

There are many types of mineral wool decorative acoustic board such as knurled, relieved, textured, printed, natural and *-shape grille style etc.; specifications include square and rectangle, dimensions are 500mm×500mm, 600mm×600mm, 610mm×610mm, 600mm×1000mm, 600mm×1200mm and 625mm×1250mm etc., thickness are 12mm, 15mm and 20mm. The physical mechanical properties of such board are shown in Table 16.3.

**Table 16.3 Physical Mechanical Properties of Mineral Wool Acoustic Board**

| Volume density ($kg/m^3$) | Folding strength (Mpa) Board thickness (mm) | | | | Moisture content (%) | Acoustic absorption coefficient | Heat conductivity coefficient [W/(m·K)] | Flammability |
|---|---|---|---|---|---|---|---|---|
| | 9 | 12 | 15 | 19 | | | | |
| ≤500 | ≥0.744 | ≥0.846 | ≥0.795 | ≥0.653 | <3 | 0.4-0.6 | <0.0875 | Grade A (incombustible) |

## 2. Glass Wool Decorative Acoustic Board

Glass wool decorative acoustic board is a suspended ceiling decorative board which adopts glass wool as main raw material and is added in certain amount of bonding agent, moisture-proof agent and preservative agent etc., and then is produced through procedures such as pressurizing, drying and finishing etc. PVC film and aluminum foil with patterns and designs are generally used for its surface processing. Because the film and the aluminum foil have large quantities of open-pores, they have good sound-absorption effect. Its product has features such as lightweight, sound absorption, fireproof, heat preservation and insulation; it is decorative, beautiful and convenient for construction. Glass wool decorative acoustic board is available for the interior suspended ceilings in hotels, halls, theaters, music halls, stadiums, conference rooms, ships and residential houses.

Dimensions and performances of commonly-used glass wool decorative acoustic board are given in Table 16.4.



**Table 16.4 Dimensions and Performances of Glass Wool Decorative Acoustic Board**

| Name | Dimensions: length ×width ×thickness (mm×mm× mm) | Technical performances | | Producer |
|---|---|---|---|---|
| | | Item | Index | |
| Glass wool acoustic board | 600×1200×25 | Density ($kg/m^3$)<br>Thermal conductivity coefficient [W/(m·K)] | 48<br>0.0333 | Beijing Glass FRP Product Factory |
| Glass wool decorative ceiling board | 600×1200×15<br>600×1200×25 | Density ($kg/m^3$)<br>Thermal conductivity coefficient [W/(m·K)]<br>Sound absorption coefficient | 48<br>0.0333<br>0.40-0.98 | Shanghai Sheet Glass Factory |
| Fiberglass wool acoustic board | 300× 300×(10, 18, 20) | Heat conductivity coefficient [W/(m.K)]<br>Sound absorption coefficient | 0.047-0.064<br>0.7 | Chongqing Fiberglass Factory |

Continued

| Name | Dimensions: length ×width ×thickness (mm×mm× mm) | Technical performances | | Producer |
|---|---|---|---|---|
| | | Item | Index | |
| Glass wool suspended ceiling board | 1200× 600 | Density (kg/m$^3$)<br>Normal temperature thermal conductivity coefficient [W (m·K)] | 50-80<br>0.0299 | Zibo Light Thermal Insulation Material Factory |

### 3. Perlite Decorative Acoustic Board

Perlite decorative acoustic board, also called perlite acoustic board, is made by blending together expanded perlite powder, gypsum, water glass and other auxiliary materials, adding in reinforcing material and pressing it to mold, and after heat treating it cures to the product. The product has features such as lightweight, beautiful appearance, sound absorption, heat preservation and insulation etc. and is available for the decoration of interior ceilings and walls.

Perlite acoustic board is classified to ordinary expanded perlite decorative acoustic board (code PB) and moisture-proof perlite decorative acoustic board (code FB). The former is applied to normal environments, and the later to highly moist environments.

The dimensions of perlite acoustic board include 400mm×400mm, 500mm×500mm and 600mm×600mm, thickness 15mm, 17mm and 20mm. Other dimensions are produced according to the agreement between both sides of the supplier and demander.



### 4. Calcium-plastic Foam Decorative Acoustic Board

Calcium-plastic foam decorative acoustic board is made of polyethylene resin and inorganic filler processed by compounding mold-pressing, foaming and shaping. The board is classified to ordinary and fire-resistant in different colors and concave-convex patterns, and can be punched to make patterns.

Calcium-plastic foam acoustic board has dimensions such as 300mm×300mm, 400mm×400mm, 610mm×610mm etc., thickness ranges 4-7mm. Its apparent density is below 250kg/m$^3$ and tensile strength is around 0.8MPa.

The product has advantages such as lightweight, sound absorption, heat resistance, water resistance and convenient construction etc. It is available for interior suspended ceilings in conference halls, television stations, radio studios, theaters, hospitals, factories and commercial store buildings.

**5. Polystyrene Foam Plastic Decorative Acoustic Board**

It is made of polystyrene foam plastics processed through compounding, mold pressing, foaming and shaping. The product has features such as acoustic insulation, thermal insulation and preservation, lightweight and white color etc. It is available for the decoration of interior suspended ceilings in buildings such as theaters, conference halls, hospitals and hotels etc. Its patterns include concave-convex, cross, square and round angle etc., dimensions include 300mm×300mm, 500mm×500mm, 600mm×600mm and 1200mm×600mm etc., thickness ranges 3-20mm.

**6. Acoustic Panel and Perforated Panel**

Commonly-used acoustic panels include veneer, gypsum plate, cement asbestos board, hard fiberboard and metal panel etc. Panel resonance sound-absorbing structure is created by fixing their surrounding edges on the keel with certain air layer left on its backside. The perforated product of the above stated panels can form cavity-resonance sound-absorbing structure with the air layer left on its backside. It increases the sound absorption coefficient at a wide frequency range to fill porous materials into the cavity on the back of the perforated panel.

Metal perforated panel, such as aluminum alloy and stainless steel panels etc., is thinner but with high strength, so it is made into product with high perforation rate and more micro pores. A metal panel with high perforation rate requires to be backed up with porous materials in application. The metal panel contributes to the surface decoration. Panels with pore diameter less than 1mm and the perforation rate 1%-5% are usually applied in double-layer and need no back-lining. Sound absorption effect is achieved by kinetic resistance of the air in the micro pores.

### 16.1.3 Sound Insulating Materials

Materials which are able to weaken or block the spread of sound are called sound insulating materials. According to spreading way, sound to be insulated is classified to airborne sound (generated from vibration of air) and solid-borne sound (generated from solid bumping or vibration). The insulation principles for these two types of sound are different.

The "mass law" in acoustics is the base of air-borne sound insulation, namely, the higher the density of a material is, the more unlikely it vibrates when influenced by sound wave. Therefore, the spreading speed of sound wave passing through the material is sharply weakened, and the insulation effect becomes better. Dense and heavy materials (such as clay bricks, steel panels and reinforced concrete etc.) should be chosen as sound insulating materials, whereas materials with good sound-absorbing performances are light, loose and porous and not suitable to serve as sound insulating materials.

The best approach to insulate solid-borne sound is to cut off the delivering route of sound, namely, add certain elastic padding materials, such as cork wood, rubber, wool felt, carpet or create air insulating layers etc., into the structural layers (such as beams, frameworks, floors, partitions and the joint areas between them etc.) to block or weaken the continual spreading of solid-borne sound wave.



## 16.2 Thermal Insulating Materials

### 16.2.1 Introduction of Thermal Insulating Materials

To retain certain interior temperature suitable for people to study, work and live, enclosing structures are required to have good thermal preservation performance in cold seasons and good thermal insulation performance in hot seasons. These problems are solved by the application of thermal insulating materials—the general name of thermal preserving and heat insulating materials or material complexes which are remarkably resistant to thermal currents. Thermal preservation means to prevent heat from spreading and losing, whereas heat insulation is to prevent external heat from entering.

**1. Heat Transfer Principles and Action Principles of Thermal Insulating Materials.**

In any medium, when there is temperature difference between two areas, heat-transfer will happen. Heat energy is transferred from high temperature to low temperature area. To most thermal insulating materials, the measured value of heat conductivity coefficient is in fact the comprehensive result of conduction, convection and radiation.

Different building materials have different thermal preservation and insulation performances. Generally, a material with good heat preservation and insulation mostly has high porosity. The air and water in the pores of the material play the functions of convection and radiation. Strictly speaking, when thermal current passes through the material layer, its convection and radiation, only small proportion, is not taken into consideration in the heat engineering calculation. The main index for evaluating the performance is heat conductivity and the main index for evaluating the thermal conductance of a material is heat conductivity coefficient $\lambda$.

The equation for $\lambda$ is:

$$\lambda = \frac{Q\delta}{At(T_2 - T_1)}$$

In this formula: $\lambda$ is heat conductivity [W/(m·K)];

$Q$ is heat conduction quantity (J);

$A$ is heat conduction area ($m^2$);

$\delta$ is thickness of the material (m);

$t$ is time of heat conduction (s);

$(T_2 - T_1)$ is the temperature difference between both sides of the material (℃ or K).



Its physical significance is: in steady heat-transfer condition, when the temperature difference between both sides of the material is 1℃, the heat amount that passes through 1m thick material of 1 $m^2$ surface area within 1 hour. Therefore the smaller the heat conductivity coefficient $\lambda$ is, the weaker thermal conductance but the better heat preservation and insulation performance the material has. The requirements for heat insulating materials are: heat conductivity coefficient less than 0.29W/(m·K), apparent density less than 1000kg/$m^3$, compressive strength greater than 0.3MPa.

**2. Main Factors Affecting Heat Conductivity**

(1) Properties and structures of the material

Different materials have different thermal conductivity. As to thermal conductivity value, metal is at the first place, nonmetal comes the second, then liquid, and gas is the last. To the same kind of materials, different internal structures make a great difference in thermal conductivity, in which crystalline structure is at the first place, microcrystalline structure comes next, and vitreous-body structure is the last.

(2) Apparent Density and Pore Features of Materials

Thermal conductivity of solid substance is far greater than that of air, so a material with smaller apparent density has higher porosity, and its thermal conductivity is smaller. When materials have the same porosity, the one with small and close pores has smaller thermal conductivity than the one with big and open pores, due to the weakening of the heat-convection in the air.

(3) Environmental Temperature and Humidity for Materials

When a material gets moistened, there is more diffusion of water vapor and heat conduction of water molecules in pores, which increases the thermal conductivity of the material[ $\lambda_{water}$ =0.58W/(m·K); $\lambda_{air}$ =0.029W/ (m·K), the thermal conductivity of water is 20 times that of air]; whereas when the material gets frozen, water turns to ice, its thermal conductivity becomes greater [ $\lambda_{air}$ =2.33W/ (m·K)]. In conclusion, heat insulating materials must be kept from being moistened or frozen.

Thermal conductivity of a material increases along with the increase of temperature. However, when temperature changes within the range of 0-50℃, its influence is slight, only at high or subzero temperatures, its influence is taken into consideration.

(4) Direction of Thermal Currents

To anisotropic materials such as fibrous material like wood etc., when thermal currents are parallel to the fiber direction, it receives less resistance; when thermal currents are perpendicular to the fiber direction, it receives more resistance.

Heat preserving and insulating materials are adopted in construction to improve the effective utilization of buildings, to lessen the consumption of basic building materials, to reduce the weight of enclosing structures and to remarkably save energy and reduce consumption. Therefore, it greatly helps to promote the development of building industry, relieve the energy crisis and improve the living quality of people.



### 16.2.2 Commonly-used Thermal Insulating Materials

According to chemical composition, thermal insulating materials are classified to organic and inorganic; according to structure, it is classified to fibrous, loose granular and porous texture materials which are produced to different types of products such as panels, sheets, coils or pipe-shells etc. In general, inorganic thermal insulating materials are unlikely to catch corrosion with high apparent density and high-temperature resistance; whereas organic materials are better in moisture-absorption, but not durable or resistant to high temperature, only available for low-temperature thermal insulation.

**1. Inorganic Thermal Preserving and Insulating Materials**

1) Asbestos and its products. Asbestos is a commonly-used thermal preserving and insulating material, which is a fibrous inorganic crystalline material. It has features such as fire-resistance, acid-alkali resistance, heat insulation, corrosion resistance, sound insulation and electric insulation etc. Thermal preserving and insulating products made of asbestos as main raw material are asbestos powder, asbestos coating, asbestos board and asbestos felt etc., which are applied to building projects as high efficient thermal preserving and fireproof coverings etc.

2) Glass wool and its products. Glass wool, a kind of glass fiber, is a fibrous material which is made by melting glass or crushed-glass. Glass wool not only has the advantages of inorganic mineral wool thermal insulating material, but also can be produced into more efficient superfine wool. Its price is close to that of mineral wool. It is used to produce asphalt-bonded glass blankets and panels, phenolic glass blankets and panels etc., which are applied to thermal power equipments at low temperature and the thermal preservation of buildings. It is also a good sound-absorbing material.



3) Mineral wool and its products. Rock wool and slag wool are generally called mineral wool. Rock wool is made of minerals such as basalt and volcanic rock, which are melt in a furnace-cupola or an electric-furnace and processed with compressed air blowing technique or centrifugation technique; slag wool takes industrial waste slag as main raw material, which is made into a wool-like fibrous material after molten and processed with super-centrifugal technique or compressed air blowing technique. Mineral wool has performances such as lightweight, incombustibility, heat insulation and electric insulation etc., and its raw material is resourceful and at low cost. It can be produced to mineral wool boards, heat-retaining belts and pipe shells etc. Mineral wool is mainly applied to the thermal preservation of buildings including walls, roofs and floors etc.

4) Expanded perlite and its products. Expanded perlite, honeycomb foam-like white or ash grey particles, is made by crushing, burning and expanding natural perlite. It has features such as small apparent density, low heat-conductivity, good chemical stability, broad range of service temperature, little moisture-absorption, and it is nontoxic, odorless and sound absorbing. It is a light thermal preservation material that has been most widely used in China.

5) Expanded vermiculite and its products. Expanded vermiculite is made from natural mineral vermiculite; being dried, crushed and fired (800-1000℃), in a short period, its volume rapidly expands (6-20 times) into a golden yellow or ash grey granular material. It has features such as small apparent density, small heat conductivity, fireproof, corrosion resistance, stable chemical properties, and it is nontoxic and odorless, so it is an excellent thermal preserving and heat insulating material.

The applications of expanded vermiculite are the same as those of expanded perlite. Besides serving as a thermal preserving and insulating material, it is also used to produce expanded vermiculite products such as cement expanded vermiculite products etc. by bonding it together with cementing materials.

6) Cellular Glass. Cellular glass is a porous thermal insulating lump made by mixing crushed aggregates of glass and foaming agents, and burning the mixture at high temperature. Cellular glass has features such as low thermal conductivity, high compressive strength, good frost-resistance, good durability and easy process etc. It is a kind of advanced thermal insulating material, and is applied to meet various thermal insulating requirements.



**2. Organic Thermal Preserving and Insulating Materials**

1) Carbonized corkboard. Carbonized corkboard is made of the outer bark of a cork-wood oak as raw material. After crushed, it is molded in the mould and hot processed at the temperature around 300℃. The cork wood bark contains countless air bubbles, so it is the ideal material for thermal preservation, heat insulation and sound absorption. It is watertight, odorless, nontoxic, elastic, soft and flexible and durable in use, nonflammable but only getting smoldered.

2) Foam Plastic. Foam plastic is made of synthetic resin as basic material, which is added in certain amount of auxiliary materials such as foaming agent, catalyst and stabilizer etc. and processed through heating and foaming. It is light, thermal preserving and shockproof. Presently foam plastic, with small apparent density and good sound insulation, is widely adopted as a thermal preserving and insulating material in construction. It is available for preservation and insulation projects and humidity and moisture prevention projects of the roofs and the walls of industrial factory buildings, cold storage equipments and pipelines. Foam plastic produced in China at present mainly includes polystyrene, polyvinyl chloride, polyurethane and urea-formaldehyde

resin foam plastics. In the future, the material will become more and more efficient and multifunctional with the improvement of its performances.

3) Plant fiber composite board. It is made of plant fiber as main material added in cementing materials and fillers. For instance, leftovers of wood is made into wood-wool, then it is mixed with sodium silicate solution and ordinary Portland cement; after molding, cold pressing, curing and drying, wood wool board is created. Cane fiber board is a light, sound absorbing and thermal preserving material, which is made of bagasse as raw material processed by steaming, pressurizing and drying. Fiberboard is widely applied to walls, floors and roofs etc. in construction.

## Summary



Thermal insulating materials, materials or material complexes apparently resistant to thermal currents, are the general name for thermal preserving and heat insulating materials. Thermal preservation is to prevent heat from spreading or losing, whereas heat insulation is to prevent external heat from entering. According to chemical composition, thermal insulating materials are classified to inorganic, organic and composite. Inorganic thermal insulating materials adopt minerals as raw materials, usually in fibrous form and porous form, and can be produced into panels, sheets, coils or pipe shells. Organic insulating materials are made of organic raw materials (kinds of resins, corks, wood-wools and wood chips etc.).

Among sound-absorbing materials, hard and smooth materials with dense structure have weaker sound-absorption capacity but stronger reflecting power, e.g. terrazzo-concrete, marble, concrete and cement-rendering walls etc.; porous materials that are coarse, loose and soft, and with interpenetrated micro pores have better sound-absorption capacity but weaker reflecting power, such as glass wool, mineral wool, foam plastic, wood wool boards, semi-perforated decorative acoustic fiberboards and micro porous tiles etc. Factors affecting the sound-absorbing performance of a porous material: ①internal perforation rate and pore features of the material; ②thickness of the material; ③air layer on the backside of the material; ④temperature and humidity influences.

Materials able to weaken or block the spread of sound wave are called sound insulating materials. To insulate air-borne sound, dense, solid and heavy materials (such as clay tiles, steel panels and reinforce concrete etc.) should be taken as sound insulating materials; whereas materials with good sound-absorbing performance are commonly light and loose porous, which are not suitable to serve as sound insulating materials. To insulate solid-borne sound, the most effective measure is to cut off the delivering route of the sound wave.

Commonly-used acoustic boards include mineral wool, glass wool, perlite, calcium-plastic foam and polystyrene foam plastic decorative acoustic boards as well as fiber reinforced calcium silicate boards etc.

## Questions for Reviewing and Thinking

16.1 What are the factors affecting the sound absorption capacity of a material?

16.2 What are commonly-used sound-absorbing boards?

16.3 What are main measures to insulate air-borne sound and solid-borne sound?

16.4 What are main factors affecting the thermal conductivity of a material?

16.5 What are commonly-used thermal insulating materials?

# 17

# New Energy-saving and Environmental Protective Building Materials

In the field of building material and building decoration material, new energy-saving and environmental protective material has already become the demand of the fashion and the age, which is inevitable in the development of architectural material.

## 17.1 Introduction

### 17.1.1 Significances of the Energy-saving of Buildings



Building energy consumption is a vital issue related to the whole development of the social economy. Due to the low efficiency in thermal preservation and insulation of building materials and heating systems, the average heating energy consumption for unit building area in our country is 3 times of the world average value in the same weather conditions. Building is the place where people live and work and where large quantity of energy and resource is consumed. At a time being short of energy, building energy-saving has become an inevitable choice for the strategy of energy-saving in our country. Efforts should be made both for today and for the future.

Building energy-saving is defined as reducing the energy assumption of heat-supplying, air-conditioning, light-picking and illuminating, adjusting interior air and humidity to lessen the energy needed in the improvement of room environments; also includes integrated technology engineering in the utilization of solar energy and geothermal (water) energy.

Building energy-saving is an important part of the energy-saving in the whole society. We have learned from the reality that it is time we insisted on the strategy of sustainable development and developed energy-saving buildings.

The keys to the development of building energy-saving are: the development of systematic energy-saving technology and products of new low energy consuming enclosing structures (including walls, doors and windows, roofs); the development and comprehensive utilization of new kinds of energy, including solar energy and underground energy; the research on energy-saving technology and related devices for interior environmental control.

### 17.1.2 Improve Indoor Environments and Develop Environmental Protective Decorative Materials

"Environmental protection" has long been in every corner of human life, such as the development of green food, green medicine, green materials and green residential buildings etc. (green means safe, healthy, sustainable, environment friendly and protective). People have been learning about and longing for "green" from the harms and even deaths brought to them time and time again, especially in recent years, the application of environmental friendly materials makes home decoration more and more humanized, environment protective and healthy, which has become the theme and requirement of decoration and renovation. People's awareness of "green" residential decoration and their demand for "green" building materials are gradually rising. Therefore, with the strong demand for "green" building materials and the imposed promotion from relevant departments as well as the continual efforts of many building material manufacturers, "green" building material has become the first choice of people in their residential decoration today.

Green environmental friendly decorative material is a new concept employed by people who think highly of ecological environmental protection; it is at first the material applied to the decoration of residential buildings, so it must be assured that high quality living space for people is achieved on the foundation of environmental and ecological protection and that the living space is free from pollution to meet people's requirements for security and health. In application there should be no contamination to both human health and external environments. Green environmental friendly decorative material is classified to three main types.

**1. Nontoxic Harmless Decorative Material**

It refers to natural, pollution free and simply processed decorative materials with no or little toxic or noxious substances, such as gypsum, talc powder, wood and some natural stones etc.

**2. Low-toxic and Low-emitting Decorative Material**

It refers to slightly toxic decorative materials with no harm to human health, whose toxic or noxious substances, controlled by processing and synthesis technique, accumulate and release slowly, such as plywood, fiberboard and block-board etc. with low formaldehyde emission and meeting national standards.

**3. Decorative Materials Whose Toxic Substances and Their Affects Can't be Confirmed or Tested with Scientific Technology or Test Approaches at Present**



Chemical synthetic materials such as environmental friendly paints and emulsion paints etc. are considered nontoxic and harmless nowadays, however, in the future they are bound to be reconsidered and reappraised with the development of science and technology.

Relevant national standards, rules and regulations for environmental friendly decoration have been promulgated, however, they need further improving and promoting, even forcible execution, especially to some highly hazardous decorative materials.

## 17.2 Types, Sources and Main Hazards of Interior Pollutants and Selection of Decorative Materials

### 17.2.1 Types and Sources of Pollutants

Generally, most inorganic decorative materials are safe and harmless, e.g. conventional decorative materials such as keel and its accessories, ordinary sectional materials, floor tiles and glass etc.; whereas organic materials, artificial materials and some synthetics in composite materials are harmful to human health to a certain degree, most of which are polycyclic aromatic hydrocarbons, such as benzene, phenol, anthracene and aldehyde etc. and their derivatives. They release strong pungent odors and cause different kinds of deceases to people both physically and mentally.

The most primary, common and hazardous pollutants in decoration projects include 5 types: formaldehyde, total volatile organic compound (TVOC), ammonia, radon and benzene, among which formaldehyde mounts the top. These pollutants come from three sources: the first is the pollution of the building itself. There is ammonias in concrete antifreeze in winter construction; the second is the pollutants in decorative materials, like artificial board such as plywood, block-board, semi-hard fiberboard and particleboard etc., paint, coating, flooring and plutonic rock (such as some granite and marble) etc. Especially unqualified materials bring about more pollution; the third is the pollutants brought by furniture—furniture made of wood-based panels, and adhesives and fillers in textile sofas.

### 17.2.2 Main Hazards of Interior Pollution

According to surveys and statistics, decoration pollution is listed among the top five environmental problems which cause the most hazards to people. Polluted air indoors directly does harm to human health. It has been proved by concerned departments that presently 68% of the present decorative materials are toxic, which generate more than 300 types of volatile organic compounds and cause more than 30 types of diseases. The most vulnerable are the aged and the kids.



Long intrusion of these pollutants into human body may lead to the following side effects.

1) The pollutants are irritable to eyes, noses, throats and skins of the inhabitants and may cause symptoms such as fatigue, headache and difficult respiration etc., which may result in heterosmia, allergy, pulmonary and liver dysfunction and immunologic function abnormity (decrease the disease resistance of human body) etc.

2) The pollutants may damage the hematopoiesis of human body and induce cancer, leukaemia and fetal malformation etc.

3) The pollutants have manifest mutagenicity, which may induce tumor in human body and typical injury to people's neurobehavioral function, including the damage to memory etc. Benzene is regarded as a highly toxic carcinogen by CIIC (Centro International de Investigationes Sobre et Cancer), which has local irritant effect to skin and mucous membrane and may result in intoxication if breathed in or absorbed by human body.

## 17.3 National Standard "Limit of Harmful Substances of Indoor Decorating and Refurbishing Materials"

Presently, the projects of home renovation and decoration mainly follow "*Code for Indoor Environmental Pollution Control of Civil Building Engineering*" (GB50325-2001) promulgated by Ministry of Construction and "*Limit of Harmful Substances of Indoor Decorating and Refurbishing Materials*" (GB18583-2001) promulgated by General Administration of Quality Supervision, Inspection, and Quarantine of the People's Republic of China.

In order to control indoor environmental pollution caused by the hazardous substances in interior decorative materials and to ensure the physical and mental health of consumers, General Administration of Quality Supervision, Inspection, and Quarantine and Standardization Administration of the People's Republic of China have enacted 10 national standards such as "*Limit of Harmful Substances of Indoor Decorating and Refurbishing Materials*" etc., which have been in the stage of compulsory execution. Products that do not conform to the national standards are no longer allowed to be sold in the market.



Commonly-used standardized names and contents in "*Limit of Harmful Substances of Indoor Decorating and Refurbishing Materials*" (GB50325-2001) are given in Table17.1-Table17.6.

**Table 17.1 "Indoor Decorating and Refurbishing Materials--Limit of Formaldehyde Emission of Wood-based Panels and Finishing Products"** (GB18580-2001)

| Product name | Test method | Limit value | Application scope | Symbol of limit[2)] |
|---|---|---|---|---|
| Medium-hard fiberboard, high density fiberboard, particle-board, oriented strand board etc. | Perforator extraction | ≤9mg/100g | Available for direct indoor application | E1 |
| | | ≤30mg/100g | Require surface treatment before indoor application | E2 |
| Plywood, decorative veneer surface-decorated veneer board, block-board | Drier method | ≤1.5mg/L | Direct indoor application | E1 |
| | | ≤5.0mg/L | Require surface treatment before indoor application | E2 |

Continued

| Product name | Test method | Limit value | Application scope | Symbol of limit[2] |
|---|---|---|---|---|
| Decorative wood-based panel (including impregnated paper laminated wood flooring, solid wood composite flooring, bamboo flooring, impregnated film adhesive veneer | climate chamber method [1] | ≤0.12mg/m$^3$ | Require surface treatment before application in interior | E1 |
| | Drier method | ≤1.5mg/L | Available for direct indoor application | |

1) Climate-chamber method is adopted for arbitration.

2) E1 stands for artificial panels available for direct indoor application; E2 stands for artificial panels requiring surface treatment before indoor application.

**Table 17.2 "Indoor Decorating and Refurbishing Materials - Limit of Harmful Substances in Interior Wall Coatings" (GB 18582-2001)**

| Item | | Limit value |
|---|---|---|
| Volatile organic compound(VOC) (g/L) | | ≤200 |
| Free formaldehyde (g/kg) | | ≤0.1 |
| Heavy metals (mg/kg) | Soluble lead | ≤90 |
| | Soluble cadmium | ≤75 |
| | Soluble chrome | ≤60 |
| | Soluble mercury | ≤60 |

**Table 17.3 "Indoor Decorating and Refurbishing Materials - Limit of Harmful Substances in Solvent Wood Coatings" (GB 18581-2001)**

| Item | Limit value | | |
|---|---|---|---|
| | Nitrate paint series | Polyurethane paint series | Alkyd paint series |
| Volatile organic compound (VOC)[1] (≤) (g/L) | 750 | Gloss (60°)≥80, 600<br>Gloss (60°)<80, 600 | 550 |
| Benzene (≤) (%) | 0.5 | | |
| Total content of methylbenzene and xylene[2] (≤) (%) | 45 | 40 | 10 |
| Free toluene di-isocyanate (TDI)[3] (≤) (%) | - | 0.7 | - |
| Heavy metals (only for color paint) (≤) (mg/kg) | Soluble lead | 90 | |
| | Soluble cadmium | 75 | |
| | Soluble chrome | 60 | |
| | Soluble mercury | 60 | |

1) Measure after mixed according to the product-specified mixture ratio and dilution ratio. If the usage amount of the thinner is at a certain range, take the maximum amount.

2) If the product has specified dilution rate or is composed of bi-component or multi-component, each component and its content in the thinner should be measured respectively, then calculate the total content in the coating according to the product specified ratio data. If the usage amount of the thinner is at a certain range, take the maximum amount.

3) If polyurethane paint has specified dilution ratio or is composed of bi-component or multi-component, the content in the curing agent (containing toluene di-isocyanate prepolymer) should be measured first, then calculate the content in the coatings according to the product specified ratio data. If the usage amount of the thinner is at a certain range, take the minimum amount.

**Table 17.4 "Indoor Decorating and Refurbishing Materials - Limit of Harmful Substances in Adhesives"** (GB 18583-2001)

| Item | Index | | |
|---|---|---|---|
| | Rubber adhesives | Polyurethanes adhesives | Other adhesives |
| Free formaldehyde (≤) (g/kg) | 0.5 | - | - |
| Benzene (≤) (g/kg) | 5 | | |
| Methylbenzene and xylene (≤) (g/kg) | 200 | | |
| Toluene di-isocyanate (≤) (g/kg) | - | 10 | - |
| Total volatile organic substance (≤) (g/L) | 750 | | |

Note: benzene is not applied as a solvent; as an impurity, its maximum content should be no more than the specified amount in the table.

**Table 17.5 "Indoor Decorating and Refurbishing Materials—Limit of Harmful Substances in Wooden Furniture"** (GB 18584-2001)

| Item | | Limit value |
|---|---|---|
| Formaldehyde emission /(mg/L) | | ≤1.5 |
| Heavy metal content (only for color paint) (mg/kg) | Soluble lead | ≤90 |
| | Soluble cadmium | ≤75 |
| | Soluble chrome | ≤60 |
| | Soluble mercury | ≤60 |

**Table 17.6 "Indoor Decorating and Refurbishing Materials—Limit of Harmful Substances in Wallpaper"** (GB 18585-2001)

| Name of hazardous substance | | Limit value/(mg/kg) |
|---|---|---|
| Heavy metal (or other) elements | Barium | ≤1000 |
| | Cadmium | ≤25 |
| | Chrome | ≤60 |
| | Lead | ≤90 |
| | Arsenic | ≤8 |
| | Mercury | ≤20 |
| | Selenium | ≤165 |
| | Antimony | ≤20 |
| Vinyl chloride monomer | | ≤1.0 |
| Aldehyde | | ≤120 |

## 17.4 Several Environmental Friendly Building Decorative Materials

### 17.4.1 Water-based Wood Paint is the Most Environmental Protective

Presently there are three main types of wood paint in the market: polyurethane, nitrate and water-based paints. Polyurethane and nitrate paints are traditional and main products due to the low price and short engineering time needed. But they are gradually replaced by water-based wood paint because they release large amount of hazardous substances. Water-based wood paint came into being at abroad in the early 1990s and has a production history of more than ten years, but it is still a new wood paint in our country and has been applied to woodenwares in recent years.

Traditional woodenware decoration mostly adopts solvent-based paint such as nitrate and polyurethane paints etc., which release large amount of toxic and harmful solvents and free TDI when coated on woodenwares, and some even contain heavy metals. These substances seriously damage people's health and pollute their living, working and studying environments. Water-based wood paint has made a great progress in environmental protection. With water as the thinner, it is nontoxic and odorless, therefore pollution-free to the environments and harmless to people. Moreover, it has features such as resistance to water, wear and acid-alkali, durability in use, labor force saving, fast drying, convenient application and smooth and bright film etc.



Water-based paint is classified to three systems: emulsion, water dispersion and water solution systems. In emulsion system: water serves as continual phase, the polymer is not soluble in water, emulsion forms by taking surfactant as disperse phase and its film is formed mainly by the piling up and laminating of emulsion particles in different diameters. In water dispersion system (also called water thinning system): water serves as continual phase, surfactant is less or not used, it has certain hydrophilicity and exists in the form of dispersion. Water solution system is homogeneous, in which the polymer is turned into ion polymer and is soluble in water through salt-forming method. Presently, water-based paint including imported products in the market is mainly emulsion and water soluble types. Milky white emulsion acrylics product has good durability, but its film has less fattiness, brightness and water resistance. Transparent water-white water soluble product is good in all aspects, but contains certain amount of organic solvents. Presently advanced water-based paint products in the market are mostly imported.

### 17.4.2 New Green Environmental Friendly Building Materials: Mineral Wool Acoustic Board

It is the indispensable decorative material for suspended ceilings in interior decoration. There are many types of ceiling materials for waterproof, sound-insulated and decorative purposes in the market. Mineral wool acoustic board is a new environmental friendly interior material mainly designed for suspended ceilings.



It takes mineral wool as main raw material. Mineral wool is a floccule made from slag melt at high temperature and spun with a super-centrifuge. It is made of waste and is harmless, pollution-free and beneficial to the environment. Its features include follows.

1) Good acoustic performances. Mineral wool board is a porous material with countless fiber micro-pores. When sound wave strikes on its surface, part of it is reflected, part is absorbed by the board and part passes through the board and goes into the empty cavity on the backside, thus the sound reflection is largely decreased, the interior echoing time is effectively controlled and adjusted and noise is reduced.

2) Many decoration styles. Mineral wool acoustic board is rich in surface process styles and creates strong decorative effects. Knurling-type board, known as "caterpillar", has its surface fully distributed with holes of different depths, forms and diameters. Another type, called "Starry", has holes of different diameters and depths on its surface.

3) Efficient in energy saving. Mineral wool acoustic board is light with its weight commonly controlled within 350-450kg/m$^2$, which reduces the self-weight of the building, so people feel safe and at ease. It also has good thermal insulation and fire resistance. With small mean thermal conductivity, it preserves heat and with mineral wool as its main raw material, its melting point is up to 1300℃, so it is highly fire-resistant.

4) Installed in many ways. There are many structure types of mineral wool board suspended ceilings with matched keels and in different kinds of

installation forms, such as: exposed-keel suspended installation, which is convenient for examination, replacement of boards and repair of pipelines, and whose installation work is simple and fast; composite pasting suspended installation, in which multiple patterns and flexible combinations on the same surface and space are realized and good thermal-insulation performance is created; hidden-insert suspended installation, which has no keel exposed and is free to open and can be installed to meet the user's requirements.

### 17.4.3 Green Environmental Friendly Materials: M-color Flexible Ceiling

M-color Tiancai colored flexible ceiling system, a green environmental friendly soft-filmed ceiling decorative material, is made in French. In different qualities and colors, it provides people with elegant designs and inspirations and has become a highlight with excellent interior decorative effects (refer to effect pictures). The weight per square meter is around 180~320g.

Due to its good flexibility, it is available for free customized moldings and designs and applied to places such as curve-contours and open landscapes etc.

Tiancai flexible ceiling is applied to places as follows: commercial, recreational and industrial places, restaurants, swimming-pools, homes, office places, conference rooms, hospitals, schools, concert halls and public halls.

Advantages of the product: ① Safe and durable in use: the ceiling is with high flatness, good uniformity, shake-proof, no surface crack or fall-off phenomenon, its burning performance is grade B1. Hundreds of colors, ribbon-like smooth surface, imaginary free moldings, available for individualized originalities. ②Beneficial to health: it is anti-bacteria and anti-fungi with no emission of hazardous gas. It is an ideal decorative material for hospitals, homes and restaurants.

### 17.4.4 Cellular Glass

Cellular glass, a new environmental friendly building material with thermal preservation and insulation and sound absorption performances, is made of crushed glass and natural lava as main raw materials, added in foaming agents and additives and processed through crushing and high-temperature foaming and molding. With its inorganic silicate qualities and its independent closed micro-porous structure, it has all of the excellent performances of traditional thermal preserving and insulating materials, and is widely used in fields such as petrochemical industry, light industry, refrigeration storage, construction and environmental protection etc. It has features such as low volume-weight, high strength, small heat-conductivity coefficient, no moisture absorption, and it is airtight, incombustible, rodent-proof and vermin-proof, acid-alkali resistant (except hydrofluoric acid), easy for process and free from deformation etc.

## 17.5 New Energy-saving, Thermal Preserving and Insulating Building Materials

With the development of energy-saving of buildings in our country, more and more thermal preserving and insulating materials are entering the market while some are dying out due to their worse performances in energy-saving and thermal preservation etc. The application of suitable thermal preserving and insulating materials not only helps to achieve the objectives of energy-saving and heat preservation, but also prolongs the service life of buildings.



New thermal preserving and insulating materials used in construction should follow the coexistence configuration of many types of materials: mainly develop mineral wool and cellular glass products, and complement with glass wool, expanded perlite and foam plastic products etc.

On-site foaming polyurethane foam plastic, high-density expanded polystyrene and polyurethane foam plastics, different kinds of foam plastic with fireproof performance and high water-resistant foam plastic etc.; such materials with good thermal preservation and CFC-free healthy thermal preserving board will be developed more quickly and applied more widely.

Porous, fibrous and light materials with good thermal insulation are mainly developed. Composite products with multiple functions including light weight, high strength and thermal insulation should be promoted and insulating products matched with materials used to build wall body should also be focused on.

In construction, according to different application places in enclosing structures, thermal preserving and insulating material is classified to interior wall and exterior wall materials; according to different forms, it is classified to panel (solid) and paste materials.

### 17.5.1 Thermal Preserving and Insulating Panels

In general, thermal preserving and insulating panel is used in a broader region and scope, including thermal preservation projects of both exterior and exterior walls. Different materials can be adopted as its main insulating material such as foaming polystyrene board, extruded polystyrene board, rock wool board and glass wool board etc. And it is further classified to singular and systematic insulating materials.

#### 1. Singular Thermal Preserving and Insulating Panels

It is the main material applied to thermal preservation projects and needs to be coordinated with other materials. For instance, to foaming polystyrene board, extruded polystyrene board, rock wool board and glass wool board etc., the following tests should be made before application.

1) Thermal conductivity coefficient [W/(m·K)]. A key index related to the preservation effect of the project.

2) Apparent density. It influences the thermal conductivity coefficient to some extent. Materials with unqualified apparent density have their physical properties decreased, such as strength and dimensional stability etc.

3) Compressive strength (MPa). Refer to the compressive stress of the test sample in the state of 10% of deformation. It affects the durability and impact resistance of its surface-layer system.

4) Dimensional-change rate (mm). High dimensional-change rate may cause cracks on the surface layer of the system.

5) Moisture-vapor transmission coefficient [g/(m·h·Pa)]. This determines its water vapor transmission performance and to some extent, determines if there will be moisture condensation on the wall surface.

6) Oxygen Index. Fire-retarding performance is required. Otherwise it is unqualified in fireproof performance.

Take thermal insulating polystyrene foam plastic (GB10801-89), its requirements include: apparent density $\geqslant$15.0 kg/m$^3$; compressive strength$\geqslant$ 60(kPa); thermal conductivity coefficient$\leqslant$0.041 W/(m·K); water-vapor transmission coefficient$\leqslant$9.5 [g/ (m·h·Pa)]and water absorption$\leqslant$6%(v/v).

#### 2. Systematic Thermal Insulating Panels

Systematic thermal preserving material is defined as the system compounded with singular thermal preserving material and other auxiliary materials. In recent years external wall thermal preservation technology for architectural energy-saving has been developed rapidly. Presently, the main technological systems and materials include: polystyrene board covered with glass fiber mesh reinforced polymer mortar, on-site cast concrete formwork with built-in heat preservation panel and adhesive polystyrene granule insulating mortar covered with glass fiber mesh anti-crack mortar etc. Moreover, polyurethane composite board is also a good material. Commonly-used systematic thermal preserving materials include several types as follows:

(1) Exterior Wall Exterior Insulation System.

1) Color-coated steel sandwich composite panel: polyurethane composite board or polystyrene composite board.

Polyurethane composite board or polystyrene composite board, a color-coated steel sandwich panel, adopts colored profiled steel sheets as the front and back surfaces and automatic-foaming hard polyurethane or polystyrene as the sandwich layer. It is widely applied to exterior walls and roofs of all kinds of buildings.



Color-coated sandwich curtain-wall panel, a new energy-saving decorative metal panel used for curtain walls, is compounded with two layers of hot-galvanized color-coated thin profiled steel plates and polystyrene or rock (mineral) wool thermal preserving and insulating material in between. It adopts standardized design, factory specialized high precision production and assembling high precision installation. It has flat panel surface and is firmly and safely jointed with the framework. Such curtain-wall panel also has good physical properties such as: heat insulation, heat preservation, sound insulation, anti-seepage, cracking resistance, corrosion-resistance, bending resistance, compression resistance and shockproof and it creates extremely good decorative effects. It is an economical curtain wall panel.

2) Polystyrene board covered with glass fiber mesh reinforced polymer mortar. A wall thermal insulation system that takes polystyrene foam panel as main thermal preserving and insulating material and polymer mortar as main bonding and surface-covering material which are reinforced with alkali-resistant glass fiber plastic-coated mesh. That is, foaming polystyrene board (or extruded polystyrene board) + alkali-resistant glass fiber mesh + polymer mortar containing bonding agent. Compared with commonly-used exterior-wall interior thermal preservation system, it has advantages such as higher thermal preservation efficiency and good energy-saving effect (easily

achieve the 65% energy-saving subentry index for buildings in our country), and gives certain protection to buildings. The system has already been widely used all over the world, for instance, Kuwait exterior-wall exterior thermal preservation system, exterior-wall exterior heat-preservation system of China Academy of Building Research in Beijing and Preswitt thermal preservation system etc. To exterior thermal preservation system, items to be tested are as follows.

① Thermal conductivity coefficient. After systematic thermal preserving material is combined with the major structure, its thermal preservation effect may change due to the influences from the construction quality and the environmental temperature and humidity, therefore, on-site test is required to find out the actual effect.

② Resistance to water, freeze-thaw, weather and wind-pressure. Serving as exterior-wall exterior thermal preservation system, its surface is directly exposed to exterior environments to resist the intrusion from different negative factors such as rain, freezing and thawing cycles, impact and strong wind etc. Before application the following tests should be carried out.

Water resistance: $20cm^2$ test piece is sunk in water; the time needed until its entire surface is totally wet ≥2h.

Freeze-thaw resistance: 10 cycles, no crack, no peeling off.

Weather resistance: 500h, no apparent change.

Wind-pressure resistance: 5000Pa, no crack.

Impact resistance: 10J, no damage, no crack, no perforation.

As to the alkali-resistant glass fiber mesh matched with the exterior thermal preservation system, its tensile strength should be more than $200N/cm^2$, its rest strength after alkali resistance test should be no less than 150≥$N/cm^2$; 7d tensile bonding strength of the bonding agent should be greater than 1Mpa and more than 0.9MPa after water resistance and freeze-thaw resistance tests.

(2) Interior thermal preservation system: including foaming polystyrene board (or extruded polystyrene board) + thistle board; rock wool sandwich thermal preservation board; reinforced cement polyphenyl thermal preservation board and GRC thermal preservation board (foaming polystyrene board combined with cement mortar) etc.

To interior thermal preservation system, items to be tested are as follows: thermal conductivity coefficient, moisture-vapor transmission coefficient, water absorbing capacity, shrinkage ratio and oxygen index. The reasons are the same as those mentioned for exterior thermal preservation system.

## 17.5.2 Thermal Preserving Paste

Presently thermal preserving paste is mainly applied to exterior-wall interior thermal preservation, and also available for the thermal preservation and insulation of partitions and separating walls. With proper performances, it is also used for exterior-wall exterior thermal preservation. There are two types of paste material, one is curing paste mainly made of cementing materials; the other is dried paste made primarily through the evaporation of water. As a light insulating material, it is produced by compounding with certain techniques many kinds of components mainly including meerschaum (polyphenyl granules), mineral fiber and silicate. The product is in powder and ointment (paste), but in application, both are pasted on the base layer in the form of paste.

Both thermal preserving and insulating panel and paste have their own features. Only by adapting to their features can we make full use of their advantages and achieve as good building energy-saving effect as possible.



## 17.5.3 Polyurethane Thermal Insulating Material

Ministry of Construction will popularize new building energy-saving technology, and promote the application of polyurethane material as the substitute for traditional building thermal insulating material.

Polyurethane material is a thermal insulating material with the best performances in the world at present. Hard polyurethane has excellent performances such as lightweight, low heat-conductivity coefficient, good heat-resistance, ageing-resistance. It is easy for bonding with other base material and no melting and dripping phenomenon appear when it gets burnt etc. It is widely applied to roofs, walls, ceilings, floors, doors and windows as a thermal insulating material in advanced countries in Europe and America, where around 49% of thermal insulating building material is polyurethane material, whereas in our country the ratio is less than 10%.

As a high molecular material with excellent performances, polyurethane has already become the fifth plastic behind polyethylene, polyvinyl chloride, polypropylene and polystyrene. Popularizing it in the domain of energy saving of buildings will create a huge space for the development of polyurethane industry in our country.

### 17.5.4 FRP Wall Insulating Panels

FRP (glass fiber reinforced plastic) wall insulating panel is composed of glass fiber cloth, magnesium chloride, glue, glass fiber grid and steel-bar polyethylene etc.

Its features are lightweight and excellent energy-saving performance; higher strength reinforced with fiber glass grid cloth and steel-bar, long service life, easy installation, good fireproof performance, ageing-resistance, impact resistance, very slight shrinkage. And it is waterproof, moisture-proof, shockproof, nontoxic, harmless, pollution-free and radiationless. With unique environmental protective performance, it is reputed as a "green building material".

Such product has good market prospects. It meets the development strategy of our country——to adopt wall panels produced by FRP composite material factories as the substitute for common bricks. And it is used to entirely take the place of common bricks, which meets all the functional requirements in "the Tenth Five-year plan" such as high strength, lightweight, energy-saving, earth saving, waste treasuring and environmental protection.



## Questions for Reviewing and Thinking

17.1 Why should we make efforts to develop new energy-saving environmental friendly composite building materials?

17.2 State the names, sources and hazards of the pollutants in interior decoration.

17.3 How do you select proper building decorative materials based on different financial conditions, energy-saving and environmental protective requirements etc.?

17.4 Market survey: what are the problems existing in (home) decoration and renovation? Which of the problems are related to decorative materials? What types are the above problems classified to? How to solve the problems?

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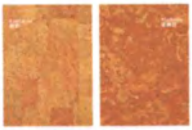
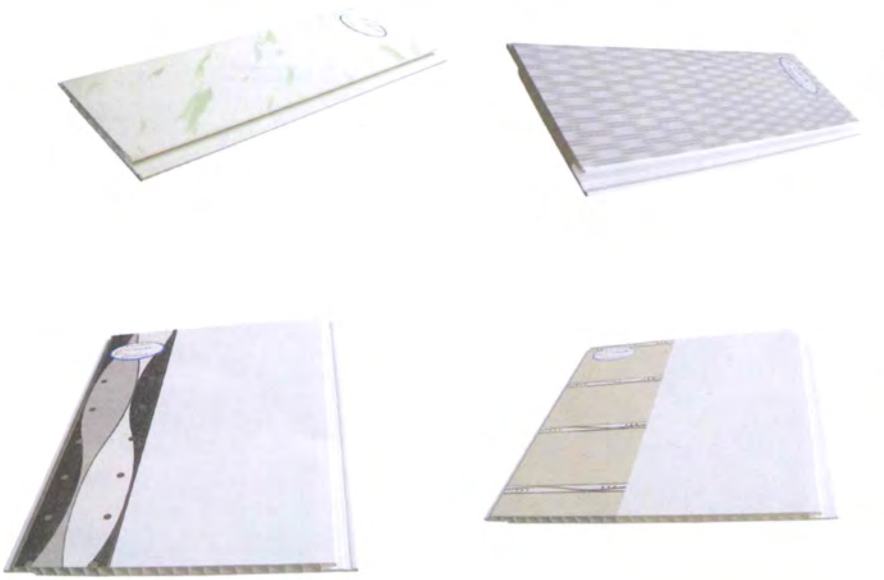
Effect Pictures of Timer Floor Materials

| | | | |
|---|---|---|---|
|  |  |  |  |
| White Sapele | Ice Tree | Maple | Black Wallnut |
|  |  |  |  |
| Red Beech | Red Rose | Red Oak | Red Sakuragi |
|  |  |  |  |
| Shaving Veneer | Red Pure Wood Floor | Pure Wood Floor | Cork Locking Floor |

View of Wall Paper Decoration


**Wall Paper in Different Patterns and Colors**



Ceiling Decorative Materials

Effect Pictures of Ceiling Materials

Pictures of Decorative Stones

| | | |
|---|---|---|
|  |  |  |
| Tiles (shining colorful series) | Fine and Fashionable Interior Wall Tiles | Fine Interior Wall Tiles |
|  |  |  |
| Tiles for Bathrooms | Ashlar Bricks | Art Small Squares |
|  |  |  |
| Art Small Squares (hand painted) | Composite Wall-ceramics | Art Tiles |

# Building Decorative Materials

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# Preface

*Building Decorative Materials* is written to meet the requirements of building up the abilities of students in modern vocational education and providing applied talents in application and management to the field of building decorative materials.

In order to show the development of building decorative materials and their practical applications in construction, the book introduces the performances, properties and applications of the materials, states the connections and differences between decorative and ordinary constructional materials and focuses on the practical applications of decorative materials in construction projects. Furthermore, standards and selections of the materials are especially explained and some new decorative materials are also included such as wallpaper paint, fluorocarbon paint, fiber decorative fabrics, wood composite floor board, plastic flooring, rubber flooring and reinforced plastic windows etc..

The book is based on the latest standards and specifications of building decorative materials. New Energy-saving and Environmental Protective Building Materials are added to keep it up to date.

The training of professional abilities of students is highlighted by the practices, material selection cases and material tests after main chapters.

1, 2, 6 and 13 are written by Yan Li; 5, 7 and 14 are written by Shuxia Ren; 3, 12 and 16 by Xiaofei Ren; 4, 9 and 11 by Hong Xing; 10 and 17 by Jiafu Ren; 15 is written by Pin Zhu and 8 by Youquan Jiao. The book is edited by Yan Li and Shuxia Ren; Xiaofei Ren and Hong Xing are associate editors.

Special thanks are given to the authors of the essays and books listed in *References* at the end of the book for the relative information offered to this book. There must be some errors or shortcomings in the book and we are looking forward to your feedback.

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