Structural detailing in steel

A comparative study of British, European and American codes and practices

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Preface

This steel detailing manual has been prepared to provide practical and up to date information on various aspects of steel construction for educators, designers, draughtsmen, detailers, fabricators and all others who have an interest in structural steelwork.

The text covers the full scope of structural detailing in the UK, Europe and the USA. The text covers the fundamentals of drawing, continuing with draughting practice and connections, the types of fastenings and the conventional methods of detailing components. Individual case studies are included.

The types of structure covered represent the bulk of the typical fabricator's work in commercial and industrial buildings, bridges, tanks, hydraulic and offshore structures and power structures. Examples of steel detailing in CAD format are included in some of the chapters.

Many of the drawings included are typical and, with minimal alteration, can be adopted directly from the book and attached to individual drawings based on a special code.

This book should serve both as a primer for trainee detailers and as a reference manual for more experienced personnel. Engineers, architects and contractors will find the book useful for daily use and practice.

M. Y. H. Bangash

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Metric conversions

Overall geometry	
Spans	1 ft = 0·3048 m
Displacements	1 in. = 25·4 mm
Surface area	1 ft^2 = 0·0929 m^2
Volume	1 ft^3 = 0·0283 m^3
	1 yd^3 = 0·765 m^3
Structural properties	
Cross-sectional dimensions	1 in. = 25·4 mm
Area	1 $in.^2$ = 645·2 mm^2
Section modulus	1 $in.^3$ = 16·39 × 10^3 mm^3
Moment of inertia	1 $in.^4$ = 0·4162 × 10^6 mm^4
Material properties	
Density	1 lb/ft^3 = 16·03 kg/m^3
Modulus of elasticity and stress	1 lb/$in.^2$ = 0·006895 MPa
	1 kip/$in.^2$ = 6·895 MPa
Loadings	
Concentrated loads	1 lb = 4·448 N
	1 kip = 1000 lbf = 4·448 kN
Density	1 lb/ft^3 = 0·1571 kN/m^3
Linear loads	1 kip/ft = 14·59 kN/m
Surface loads	1 lb/ft^2 = 0·0479 kN/m^2
	1 kip/ft^2 = 47·9 kN/m^2

Definitions

The European code EC3 gives a list of terms common to all the Structural Eurocodes, as well as some which apply only to steelwork. The Eurocodes use a number of new or unfamiliar expressions, for example the word ‘action’ is used to describe a load or imposed deformation. The following are the common definitions used in practically all codes dealing with structural steel.

Beam A member predominantly subject to bending.
Buckling resistance Limit of force or moment which a member can withstand without buckling.
Capacity Limit of force or moment which may be applied without causing failure due to yielding or rupture.
Column A vertical member of a structure carrying axial load and possibly moments.
Compact cross-section A cross-section which can develop the plastic moment capacity of the section but in which local buckling prevents rotation at constant moment.
Dead load All loads of constant magnitude and position that act permanently, including self-weight.
Design strength The yield strength of the material multiplied by the appropriate partial factor.
Effective length Length between points of effective restraint of a member multiplied by a factor to take account of the end conditions and loading.
Elastic design Design which assumes no redistribution of moments due to plastic rotation of a section throughout the structure.
Empirical method Simplified method of design justified by experience or testing.
Factored load Specified load multiplied by the relevant partial factor.
H-section A section with one central web and two equal flanges which has an overall depth not greater than 1·2 times the width of the flange.
I-section Section with central web and two equal flanges which has an overall depth greater than 1·2 times the width of the flange.
Imposed load Load on a structure or member other than wind load, produced by the external environment and intended occupancy or use.
Lateral restraint For a beam: restraint which prevents lateral movement of the compression flange. For a column: restraint which prevents lateral movement of the member in a particular plane.
Plastic cross-section A cross-section which can develop a plastic hinge with sufficient rotation capacity to allow redistribution of bending moments within the structure.
Plastic design Design method assuming redistribution of moments in continuous construction.
Semi-compact cross-section A cross-section in which the stress in the extreme fibres should be limited to yield because local buckling would prevent development of the plastic moment capacity in the section.
Serviceability limit states Those limit states which when exceeded can lead to the structure being unfit for its intended use.

Slender cross-section A cross-section in which yield of the extreme fibres cannot be attained because of premature local buckling.
Slenderness The effective length divided by the radius of gyration.
Strength Resistance to failure by yielding or buckling.
Strut A member of a structure carrying predominantly compressive axial load.
Ultimate limit state That state which if exceeded can cause collapse of part or the whole of the structure.

Introduction to codes

The structural design of steelwork is based on BS 5950 in the UK and countries following this code. The title of this code is given below:

BS 5950 Structural use of steelwork in building.

This section has been compiled to help designers in the UK and USA to appreciate the principal differences and similarities of applying Eurocode 3: Part 1.1 (EC3) (originally European standard ENV 1993-1-1). This code will eventually become mandatory in Europe and the UK. It will, in future, supersede BS 5950 which has the following nine parts:

Part 1 Code of practice for design in simple and continuous construction: hot-rolled sections
Part 2 Specification for materials, fabrication and erection: hot-rolled sections
Part 3 Code of practice for design in composite construction
Part 4 Code of practice for design of floors with profiled steel sheeting
Part 5 Code of practice for design in cold-formed sections
Part 6 Code of practice for design in light gauge sheeting, decking and cladding
Part 7 Specification for materials and workmanship: cold-formed sections
Part 8 Code of practice for design of the protection for structural steelwork
Part 9 Code of practice for stressed skin design

The full range of Structural Eurocodes follows:

Eurocode 1 Basis of design and actions on structures
Eurocode 2 Design of concrete structures
Eurocode 3 Design of steel structures
Eurocode 4 Design of composite steel and concrete structures
Eurocode 5 Design of timber structures
Eurocode 6 Design of masonry structures
Eurocode 7 Geotechnical design of structures
Eurocode 8 Earthquake resistance of structures
Eurocode 9 Design of aluminium structures

The codes will be issued by national standards organisations, such as BSI. The first part of EC3 to be prepared was Part 1.1 General rules for building. Other parts which are being prepared or are planned are given below:

Part 1.2 Fire resistance
Part 1.3 Cold-formed thin gauge members and sheeting
Part 2 Bridges and plated structures
Part 3 Towers, masts and chimneys
Part 4 Tanks, silos and pipelines
Part 5 Piling
Part 6 Crane structures
Part 7 Marine and maritime structures
Part 8 Agricultural structures

BS 5950 and EC3 together with the US codes on steel are classified by subject title. The designers/detailers and conventional and CAD technicians will find the classification extremely useful.

British and European Standards

BS 4:	Structural steel sections
Part 1: 1980	Specification for hot-rolled sections
BS 639: 1986	Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding
BS 2901:	Filler rods and wires for gas-shielded arc welding
Part 1: 1983	Ferritic steels
Part 2: 1990	Specification for stainless steels
Part 3: 1990	Specification for copper and copper alloys
Part 4: 1990	Specification for aluminium and aluminium alloys and magnesium alloys
Part 5: 1990	Specification for nickel and nickel alloys
BS 3692: 1967	Specification for ISO metric precision hexagon bolts, screws and nuts — metric units
BS 4105: 1990	Specification for liquid carbon dioxide, industrial
BS 4165: 1984	Specification for electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel
BS 4190: 1967	Specification for ISO metric black hexagon bolts, screws and nuts
BS 4320: 1968	Specification for metal washers for general engineering purposes — metric series
BS 4360: 1990	Specification for weldable structural steels
BS 4620: 1970	Specification for rivets for general engineering purposes
BS 4848:	Hot-rolled structural steel sections
Part 4: 1972	Equal and unequal angles
Part 5: 1980	Flats
BS 4933: 1973	Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts
BS 5135: 1984	Specification for arc welding of carbon and carbon-manganese steels
BS 5493: 1977	Code of Practice for protective coating of iron and steel structures against corrosion
BS 5531: 1988	Code of Practice for safety in erecting structural frames
BS 5950:	Structural use of steelwork in building
Part 2: 1992	Specification for materials, fabrication and erection: hot-rolled sections
Part 3:	Design in composite construction
Section 3.1: 1990	Code of Practice for design of simple and continuous composite beams
Part 4: 1982	Code of Practice for design of floors with profiled steel sheeting
Part 5: 1987	Code of Practice for design of cold-formed sections

Part 7: 1992	Specification for materials and workmanship: cold-formed sections
BS 6363: 1983	Specification for welded cold-formed steel structural hollow sections
BS 7084: 1989	Specification for carbon and carbon-manganese steel tubular cored welding electrodes
BS EN 10025: 1990	Specification for hot-rolled products of non-alloy structural steels and their technical delivery conditions
BS EN 10029: 1991	Specification for tolerances on dimensions, shape and mass for hot-rolled steel plates
BS EN 10113:	Hot-rolled products in weldable fine grain structural steels
1: 1992	General delivery conditions
2: 1992	Delivery conditions for normalised steels
3: 1992	Delivery conditions for thermo-mechanical rolled steels
BS EN 24014: 1992	Hexagon head bolts. Product grades A and B
BS EN 24016: 1992	Hexagon head bolts. Product grade C
BS EN 24017: 1992	Hexagon head screws. Product grades A and B
BS EN 24018: 1992	Hexagon head screws. Product grade C
BS EN 24032: 1992	Hexagon nuts, style 1. Product grades A and B
BS EN 24034: 1992	Hexagon nuts. Product grade C
BS 466: 1984	Specification for power-driven overhead travelling cranes, semi-goliath and goliath cranes for general use
BS 648: 1964	Schedule of weights of building materials
BS 2573:	Rules for the design of cranes
Part 1: 1983	Specification for classification, stress calculations and design criteria for structures
Part 2: 1980:	Specification for classification, stress calculations and design of mechanisms
BS 4395:	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering
Part 1: 1969	General grade
Part 2: 1969	Higher grade bolts and nuts and general grade washers
BS 4604:	Specification for the use of high-strength friction-grip bolts in structural steelwork — metric series
Part 1: 1970	General grade
Part 2: 1970	Higher grade (parallel shank)
BS 5950:	Structural use of steelwork in building
Part 1: 1990	Code of Practice for design in simple and continuous construction: hot-rolled sections
Part 8: 1990	Code of Practice for fire-resistant design
BS 6399	Loading for buildings
Part 1: 1984	Code of Practice for dead and imposed loads
Part 2: 1997	Code of Practice for wind loading
Part 3: 1988	Code of Practice for imposed roof loads
BS 8110:	Structural use of concrete
Part 1: 1985	Code of Practice for design and construction
Part 2: 1985	Code of Practice for special circumstances

BS 5950 is less definitive; it gives recommendations for the design of structural steelwork in buildings and allied structures not specifically covered in other British Standards.

Eurocode 3: Part 1.1 contains general principles which are valid for all steel structures as well as detailed application rules for ordinary buildings. The remaining parts of the Eurocode will cover bridges and plated structures, towers, masts and chimneys, tanks, silos and pipelines, piling, crane structures, marine and maritime structures, agricultural structures and fire resistance.

US codes on steel

Steel type	ASTM designation	F_y (ksi)*	F_u (ksi)*	thickness (in.)[†]	Common usage
Carbon	A36	32	58–80	Over 8	General; buildings
		36	58–80	To 8	General; buildings
	A529 Grade 42	42	60–85	To 0·5	Metal building systems
	Grade 50	50	70–100	To 1·5	Metal building systems
High-strength low-alloy	A441	40	60	4–8	Welded construction
		42	63	1·5–4	Welded construction
		46	67	0·75–1·5	Welded construction
		50	70	To 0·75	Welded construction
	A572 Grade 42	42	60	To 6	Buildings; bridges
	Grade 50	50	65	To 2	Buildings; bridges
	Grade 60	60	75	To 1·25	Buildings; bridges
	Grade 65	65	80	To 1·25	Buildings; bridges
Corrosion resistant high-strength, low-alloy	A242	42	63	1·5–4	Bridges
		46	67	0·75–1·5	Bridges
		50	70	To 0·75	Bridges
	A588	42	63	5–8	Weathering steel
		46	67	4–5	Weathering steel
		50	70	To 4	Weathering steel bridges
Quenched and tempered low-alloy	A514	90	100–130	2·5–6	Plates for welding
		100	110–130	To 2·5	Plates for welding
Quenched and tempered alloy	A852	70	110–190	To 4	Plates for welding

* ksi = kips/in.^{2}
[†] 1 inch = 25·4 mm

Cold-formed A570 Sections A to E		Buildings and bridges
Hot and cold-rolled steel	A609	Sheets, strips, coils, cut lengths
Cold-rolled sheet steel For cold-formed sections	A611 Grade A to E	Building and bridges
Hot-formed Welded and seamless tubing	A618 Grade A to E	General purpose
All above Combinations	A709 Grade 36 Grade 50 Grade 100	Buildings and bridges Welded and bolted Construction, alloy steel Plates for welded construction Bolted construction, etc.

List of comparative symbols

Parameter (common)	AISC	BS 5950	EC3
Area	A	A	A
Cross-sectional area of steel section	A, A_s	A_g	A_g
Shear area (sections)	–	A_v	A_v
Breadth of section	B	B	B, b
Outstand of flange	–	b	–
Stiff bearing length	–	b_1	–
Depth of section	h	D	d, h
Depth of web	T	d	d
Modulus of elasticity of steel	E	E	E
Eccentricity	e	e	e
Ultimate applied axial load	P	F_c	P, W
Shear force (sections)	V, F	F_v	V
Second moment of area about the major axis	I_x	I_x	I_x
Second moment of area about the minor axis	I_y	I_y	I_y
Length of span	L	L	L, l
Effective length	L_{ef}	L_E	L_e
Larger end moment	M_z	M	M
Maximum moment on the member or portion of the member under consideration	M_{max}	M_A, M_{max}	M_{max}
Buckling resistance moment (lateral torsional)	M_b	M_b	$M_{bz,Rd}$
Moment capacity of section about the major and minor axes in the absence of axial load	–	M_{cz}, M_{cy}	M_{cx}, M_{cy}
Eccentricity moment	M_e	M_e	M_e
Mid-span moment on a simply supported span equal to the unrestrained length	M_s	M_o	M_s
Ultimate moment	M_u	M_u	M_u
Maximum moment occurring between lateral restraints on a beam	M_s	M_x	M
Equivalent uniform moment	–	$\overline{M}$	–
Equivalent uniform moment factor	–	m	–
Slenderness correction factor	–	n	–
Compression resistance of column	P, F, N	P_c	N
Ultimate web bearing capacity	P_{cr}	P_{crip}	N_{cr}
Shear capacity of a section	v, s	P_v	S
Bending strength	F_b	P_c	P_c
Compressive strength	F_c	f_c	f_c
Buckling resistance of an unstiffened web	P_{wc}	P_w	P_w
Design strength of steel	F_y	P_y	P_y
Radius of gyration of a member about its major and minor axes	ν_x, ν_y	ν_x, ν_y	i_{yy}, i_{zz}
Plastic modulus about the major and minor axes	s, z	s_x, s_y	w_x, w_y
Thickness of a flange or leg	t, d	T	t, T
Thickness of a web or as otherwise defined in a clause	t	t	t
Buckling parameter of the section	–	u	–
Slenderness factor for beam	–	υ	–
Torsional index of section	–	x	–
Elastic modulus about the major and minor axes	s	z_x, z_y	w_{el}
Ratio of smaller to larger end moment	–	β	–
Overall load factor	–	γ_f	γ_f
Load variation factor: function of γ_{l1} and γ_{l2}	–	γ_l	–
Material strength factor	–	γ_m	γ_m

Parameter (common)	AISC	BS 5950	EC3
Ratio M/M_o that is the ratio of the larger end moment to the midspan moment on a simply supported span	–	γ_D	γ_D
Deflection	D, a	δ, a	δ
Constant $(275/P_y)^{1/2}$	–	ε	ε
Slenderness, that is the effective length divided by the radius of gyration	c, λ	λ	λ
Equivalent slenderness	–	λ_{LT}	λ_{LT}
Accidental action	–	–	A
Area	A	A	A
Bolt force	F_t, P	F, P	B
Capacity; fixed value; factor	–	–	C
Damage (fatigue assessment)	F_n	–	D
Modulus of elasticity	E	E	E
Effect of actions	–	–	F
Action	–	–	F
Force	F, P	F,P	G
Permanent action	–	–	G
Shear modulus	G	G	G
Total horizontal load or reaction	H	H	H
Stiffness factor (I/L)	K	K	K
Variable action	–	–	Q
Resistance; reaction internal forces and moments (with subscripts d or k)	R	R	R, S
Stiffness (shear, rotational . . . stiffness with subscripts)	K	K, S	S
Torsional moment; temperature	T, M_t	T, m_t	T
Shear force; total vertical load or reaction	S	S, V	V
Section modulus	S, Z	S	W
Value of a property of a material	–	–	X
Difference in . . . (precedes main symbol)	–	–	Δ
Distance; geometrical data	–	–	a
Throat thickness of weld	t_e, T, a	–	a
Area ratio	–	–	a
Distance; outstand	–	–	c
Diameter; depth; length of diagonal	–	–	d
Eccentricity; shift of centroidal axis	al, e	e	e
Edge distance; end distance	–	–	e
Strength (of a material)	γ, F	γ	f, γ
Gap; width of a tension field	–	–	g
Height	H, h	H, h	h
Radius of gyration; integer	r	r, i	i
Coefficient; factor	–	–	k
Ratio of normal forces or normal stresses	–	–	n
Number of ..	–	–	n
Pitch; spacing	p	p	p
Uniformly distributed force	p, w, q	w, q	q
Radius; root radius	r, R	r	r
Staggered pitch; distance	p, g	s	s
Thickness	d, t	t, d	t
Major axis	x, x	u, u	uu
Minor axis	y, y	υ, υ	υ, υ
Rectangular axes	xx, yy	xx, yy	y, y, zz
Angle; ratio; factor	–	–	α
Coefficient of linear thermal expansion	α	α	α
Angle; ratio; factor	–	β	β
Partial safety factor; ratio	–	–	ϒ
Deflection; deformation	D, Δ	δ, Δ	δ
Coefficient (in Annex E)	–	–	θ
Angle; slope	–	–	λ
Slip factor; factor	–	–	μ
Poisson's ratio	μ, υ	υ	υ
Reduction factor; unit mass	ρ	ρ	ρ

Parameter (common)	AISC	BS 5950	EC3
Normal stress	σ	σ	σ
Shear stress	υ, v	υ	ϕ, υ
Rotation; slope; ratio	–	–	χ
Reduction factor (for buckling)	–	–	ψ
Stress ratio; reduction factor	–	–	ψ
Factors defining representative values of variable actions	–	–	ψ
Cross area of bolt	A_b	A_b	A_b
Planar area of web at beam to column connection	A_{bc}	A_{bc}	A_{bc}
Area of compression flange	A_f	A_c	A_c
Area of bottom cover plate composite design	A_p	–	–
Cross-sectional area of stiffener	A_{ST}	A_{SW}	A_{SW}
Area of the girder web	A_W	A_W	A_W
Column coefficient	B	–	–
Bending factor at x–x; y–y	B_x, B_y	–	–
Bending coefficient upon moment gradient	C_b	–	–
Coefficient applied to the bending term	C_m	–	–
Ratio of critical web stress	C_υ	–	–
Euler stress	F'_c	P_{cr}	P_{cr}
Second moment area (composite)	I_{tr}	I_{comp}	I_{comp}
Coefficient used in column formula	J	–	–
Yield strength	F_y, Y	f_y, Y	F_y, y
Coefficient used in column formula	G, H	–	–
Subscripts: unbraced, dead live	U, D, L	U, D, L	U, D, L
Reduced girder, compression, flange	0, y, c, f	–	–
Larger, smaller, shear	2, 1, υ	–	–
Bearing, tensile or top; transformed	p, t, r	–	–
Concentrated transverse load or reaction	R	W	W
Statistical moment of the cover plate about neutral axis of transformed section	Q	–	–
Clear distance between transverse stiffeners	a	l	l
Amplification factor @ x–x and y–y	a_{xx}, a_{yy}	–	–
Effective width of concrete flange (composite section)	b	B, b	b
Distance from the neutral axis to the extreme fibre	c	y	y
Flange width of a beam	b_f	B_f, b_f	B_f, b_f
Total depth of steel section (composite)	d_s	h, D	h, D
Computed axial stress	f_a	–	–
Computed tensile stress	f_t	–	–
Computed bending stress	f_b	–	–
Computed shear stress	f_r	–	–
Unbraced length	l	l	l
Modular ratio	n	–	–
Allowable shear stress resistance by a connector	q	–	–
Distance from the neutral axis to the centroid	y	y	y, x, z
Distance from the neutral axis to the outermost fibre	y_b	y_b, y	y_b
Pitch	s	s, p	s, p
Permitted stress	F	P_y	P_y
Distance from the centroid to the outer of an angle	k	–	–

1. Introduction

This chapter is devoted exclusively to steel detailers/draughtsmen and their responsibilities towards engineers, architects and fabricators. Their major function is to serve as an intermediary between the planners and executor of a project. It is therefore important that they should have a clear understanding of the engineers' intent and the ability to translate it into a graphic representation. The detailers/draughtsmen must have a knowledge of the various processes involved, including:

(*a*) types of steel structures to be built and how they are built,
(*b*) a permanent record of the designers'/engineers' intent, including design, calculations and sketches,
(*c*) construction and fabrication of the steel structural components,
(*d*) conveying information on all aspects of detailing on the lines given by the engineer or an architect, by manual and computer aided means,
(*e*) clarity of presentation and accuracy of information,
(*f*) project organisation and the steel detailer's role in it.

1.1. Detail drawings

Structures are represented by means of elevations, plans and cross-sections with, where necessary, enlarged sections of special areas of the structure that require more detail for additional information. The detailers must be familiar with the instrumentation to be employed in the production of drawings. They must be familiar with the type of code and the methods which it sets out for drawings. Whether it is a building, a bridge or any other structure, the elevation and plan must be to a scale sufficient to show, by means of suitable annotations, the sizes and shapes of the members. Where support bearings and special end member connections are involved, they are to be given on an enlarged scale, in sufficient detail to enable the ironworker, the blacksmith and the carpenter to construct these components to a reasonable degree of accuracy.

With the advent of structural steel, prefabrication became essential, and this brought with it the need to supplement the arrangement drawings with detail drawings of all individual members and components. These are known as shop detail drawings and are usually prepared by the steel fabricating company in its own drawing office for use in its workshops. They are based on the layout and arrangement drawings supplied by the owner, or by the consulting engineer appointed to carry out the design. The job of the detailer is to check the information and drawings from the workshop on the fabrication of steel components based on the requirements of a typical steel code and the design drawings provided by their office. It is in the checking of these drawings that the structural steel detailers find their role and are able to play a vital part in the sequence of events that comprise the total activity of structural engineering.

The detailer should look for the following items:

(*a*) that shop drawings are correct with regard to stylised representation involving the use of standardised, abbreviated notation and special symbols,
(*b*) that the information transmitted is clearly given,
(*c*) any variations that need to be discussed with the designer,
(*d*) where a large amount of technical data given, the detailer's job involves recording and conveying it in a simple and concise manner.

1.2. Function of the steelwork detailer

The role of the steelwork draughtsman or detailer will now be examined more closely. When the contract is placed with a steelwork fabricator, and assuming that the steelwork detailer works for the fabricator, their duties can be categorised as follows.

(*a*) The consulting engineer's drawings and specifications are passed on by the company management to the drawing office, where the drawing office manager assesses the extent, complexity and time content of the job.
(*b*) The section leader confers with a senior detailer/draughtsman who constitutes a team of draughtsmen on the basis of expertise in specific areas gained from experience in previous contracts.
(*c*) The first function is to prepare a list of steel materials from the layout drawings provided by the consulting engineer, enabling the contractor to reserve the items from stock or to place orders with steel merchants or steel mills.
(*d*) The detailers proceed with the preparation of the steel work detailing drawings, providing an accurate representation of components of structures, namely, beams, girders, trusses, columns, bracings, stairways, platforms, rails, brackets, girts, purlins etc., and where other structures such as bridges, towers, tanks etc., are involved, these will follow broadly the same pattern.
(*e*) An experienced senior draughtsman or detailer must carefully supervise drawings and carefully scrutinise them as a checker. It is essential to correct the errors at this stage, as the correction of errors during fabrication in the shop or during erection on site will be infinitely more expensive. Draughtsmen should be critical of their own work, subconsciously acting as their own checker, to ensure that, to the best of their ability, their drawings are error-free.
(*f*) The detail drawings are sent to the fabrication shop, where work is put in hand, drawing the material from stock, cutting it to exact length, drilling or punching the necessary holes and assembling the various parts by means of bolting or welding to make up the components or subassemblies ready for transport to site.
(*g*) The drawing office, whether using a manual system or computer aided facilities, must now proceed with the preparation of erection drawings, showing steel framework in skeleton form (elevations, plans and cross-sections). These drawings should be checked by the senior detailer and endorsed by a qualified structural engineer. The steel erector will refer to these drawings for the assembly of the structure on site. The position of each component is identified by a distinguishing erection mark. In the fabrication shop, such erection marks are hand-marked, painted or tagged onto the steel components.

(*h*) All drawings are updated to incorporate any revisions that have occurred during the progress of the job and a complete set of prints is handed to the engineer for filing. These serve as a record of the work and are useful for future reference.

1.3. Project organisation

It is important to consider the role of the detailer in the overall management and technical organisation that is involved in the steel construction project.

(*a*) When the owner appoints the architect and engineer for the steel project, they shall carry out the following:
  (i) the architect prepares the preliminary planning and detailed planning of drawings and specifications and sends them to the structural engineer.
  (ii) The structural engineer then prepares preliminary design drawings and, with the help of quantity surveyors, indicates costs to the architects, or directly to the owners where architects are not involved.

(*b*) The detailer acts as a liaison between the engineer and the contractor, and is responsible, whether working for the engineer or steelwork contractor, for the preparation of the general arrangement (GA) drawings, shop drawings and the erection drawings.

(*c*) The detailer liaises with the steelwork contractor during erection of steelwork on site, ensuring that the engineer/designer is fully informed on day-to-day erection problems, particularly non-compliance with detailed drawings.

(*d*) The detailer is responsible for keeping the log book and other recording arrangements, including storing in an electronic or mechanical retrieval system, photocopying and recording.

2. Structural steel

2.1. Introduction

In this chapter, the material with which the steel detailer is concerned, i.e. structural steel, will be considered. It is vital that detailers should be familiar with the characteristics and properties of steel.

Steel is a man-made metal derived from iron, which is its major constituent. The remaining components are small quantities of other elements, some of which derive from the raw materials used in steel making and some of which are deliberately added to improve the quality of the steel. Steel is generally used for the basic products of the steel mill, such as plates, sections and bars, from which the structural members are fabricated; these being beams, girders, columns, struts, ties or the many other components comprising a structure. Steel is used extensively for the framework of bridges, buildings, buses, cars, conveyors, cranes, pipelines, ships, storage tanks, towers, trucks and other structures.

Although composed almost entirely of iron, steel contains small amounts of other chemical elements to produce desired physical properties such as strength, hardness, ductility, toughness and corrosion resistance. Carbon is the most important of the other elements. Increasing the carbon content produces an increase in strength and hardness, but decreases the ductility and toughness. Manganese, silicon, copper, chromium, columbium, molybdenum, nickel, phosphorus, vanadium, zirconium and aluminium are some of the other elements that may be added to structural steel. Hot-rolled structural steels may be classified as carbon steels, high-strength low-alloy steels, and alloy steels.

The concepts of strength and ductility are illustrated in Fig. 2.1. If a steel specimen is loaded in direct tension, from zero up to final rupture, and the extension of the specimen is measured, a curve can be plotted as shown. This is known as a stress–strain curve, i.e. the stress is plotted against the strain.

2.2. Steel sections

The forms in which steel is used in structures are I- and H-sections, channels, angles, flats, bars, plates, sheets, cold-formed sections and hollow sections. These descriptions apply to the cross-sectional shapes of the members, which are shown in Fig. 2.2. It will be seen that there are two main classes; hot-rolled and cold-formed. The rolled sections are produced by passing a heated billet between successive pairs of rollers that squeeze the steel, stage by stage, into the final shape. Hot-rolled plates are made in the same way, but here the rollers are flat and wide. The sections shown in Fig. 2.2 can be compounded to produce different cross-sections.

Cold-formed sections are made by passing thin steel strips (not pre-heated) through sets of rollers that form the strip into the desired section by a bending process. In the case of circular hollow sections, this is accompanied by a continuous seam-welding process, whereby the abutting edges of the rolled section are fused together. Rectangular hollow sections are formed from circular sections by a further cold-forming roller process. Therefore all cold-

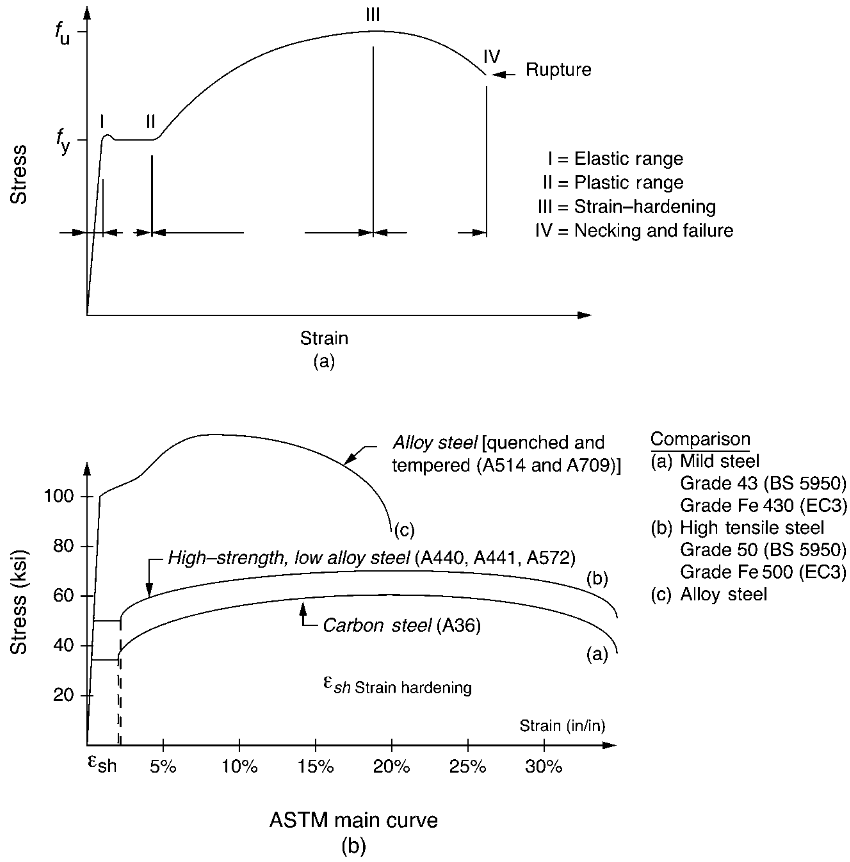


Fig. 2.1. Stress–strain curve

formed hollow sections have a longitudinal seam weld running down their full length.

2.3. Steel quality

It is necessary for steel to be produced within acceptable quality limits to ensure that it meets the requirements of a load-bearing material. These limits include minimum strength and elongation requirements, maximum content of various elements, etc. In various codes, these requirements are contained in a specification. Structural steel is produced in a number of different strength grades. Different codes also have different designation labels. For example, in EC3 grade Fe 430 represents steel with a yield strength of 43 ksi, in ASTM specifications A36 indicates carbon steel of a yield strength of 36 ksi and in BS 5950, grade 43 means carbon steel with a yield strength of 43 ksi.

2.4. Bolts and threaded fasteners and weld electrodes

2.4.1. US criteria

The following classifications apply in the USA.

- A307 (low-carbon) bolts, usually referred to as common or machine or unfinished bolts, do not have a distinct yield point (minimum yield strength of 60 ksi is taken at a strain of 0·002). Consequently, the Load and Resistance Factor Design (LRFD) Specification does not permit these bolts to be used in a slip-critical connection (see LRFD J1.11, p. 6-72, J3.1, p. 6-79, and Table J3.2, p. 6-81). However, they may be used in a bearing-type connection.

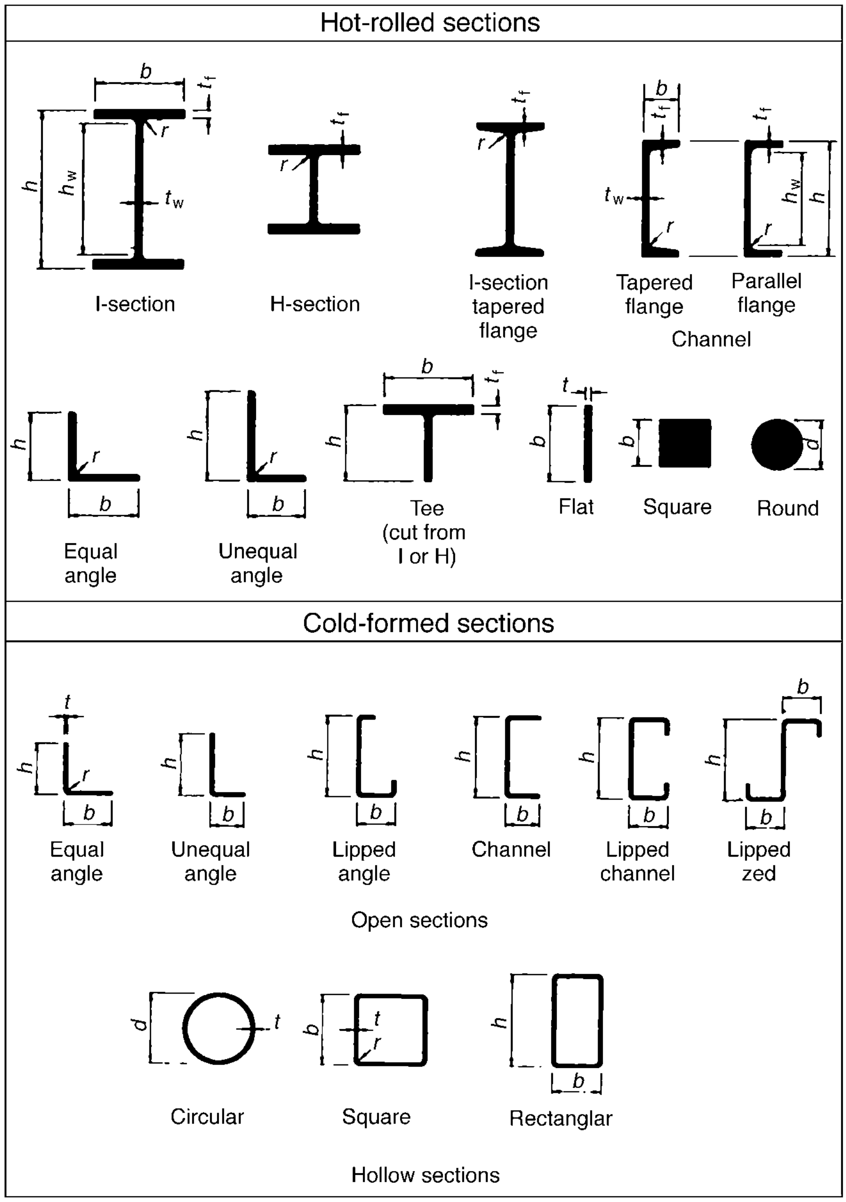


Fig. 2.2. Structural steel sections

- A325 (medium-carbon; quenched and tempered with not more than 0·30% carbon) bolts have a 0·2% offset minimum yield strength of 92 ksi (0·5–1 in. diameter bolts) and 81 ksi (1·125–1·5 in. diameter bolts) and an ultimate strength of 105–120 ksi.
- A449 bolts have tensile strengths and yield strengths similar to A325 bolts, have longer thread lengths, and are available up to 3 in. in diameter. A449 bolts and threaded rods are permitted only where a diameter greater than 1·5 in. is needed.
- A490 bolts are quenched and tempered, have alloy elements in amounts similar to A514 steels, have up to 0·53% carbon, and a 0·2% offset minimum yield strength of 115 ksi (2·5–4 in. diameter) and 130 ksi (less than 2·5 in. diameter).

Weld electrodes are classified as E60XX, E70XX, E80XX, E90XX, E100XX and E110XX where E denotes electrodes, the digits denote the tensile strength in ksi and XX represents characters indicating the usage of the electrode.

2.4.2. BS 5950 and EC3 criteria (UK version)

The classifications which apply in the UK are as follows.

- High strength friction grip (ASFG) bolts used in close tolerance holes (+0·15–0 mm). They are of different grades or types:
  - all grade 4·6 bolts — 20 mm diameter
  - all grade 8·8 bolts — 24 mm diameter.
- Black bolts grade 4·6 of mild steel based on BS 4190 (nuts and bolts) and BS 4320 (washers). They are untensioned bolts in clearance holes 2 or 3 mm larger than the bolt diameter.
- The HSFG bolts grade 8·8 are based on BS 3692 (nuts and bolts) and BS 4320 (washers).

The following provides additional performances and data:

(*a*) General grade (BS 4395, Part 1) bolts, nuts and washers with no occurrence of slip and are used in the workshop and on site.
(*b*) Higher grade (BS 4395, Part 2) bolts, nuts and washers with clearance holes and no occurrence of slip and are used in workshop and on site.
(*c*) Waisted shank (BS 4395, Part 3) bolts, nuts and washers with clearance holes and non-occurrence of slip. A prestress of approximately 70% of F_u is induced in the shank of the bolts to bring the adjoining piles into contact.

The mechanical properties of all these bolts are described in Chapter 4. Two main types of weld are recommended: butt and fillet welds. Common weld processes are given below.

(*d*) Manual metal arc (MMA) welds with a flux coating on the electrode. This process is manual and its main use is for short runs. Fillet welds larger than 6 mm are usually multi-run and uneconomical. This process can be employed both in the workshop and on site.
(*e*) Submerged arc (SUBARC) with power flux deposited over the arc. This is an automatic process and its main use is for long runs or heavy built welds. Either side of joints are welded simultaneously using twin heads. The recommended maximum weld size is 10 mm. This process can be used both in the workshop and on site.
(*f*) Metal inert gas (MIG) with carbon dioxide gas generated. This process can be automatic or semi-automatic. It replaces manual welding and is for both short and long runs. The recommended maximum weld size is 8 mm. This process is for the workshop only.

2.5. General properties

The Appendix gives properties of various steel sections based on three codes, namely BS 5950, EC3 and AISC. Some properties are given in Fig. 2.1. The following properties, shown in Table 2.1, are recommended in the absence of experimental tests for design and detailing at the tender stage.

Table 2.1 General steel properties

Steel properties	BS 5950 and EC3	AISC
Density or mass	7850 kg/m^3 (7·85 t/m^3 or 78·5 kN/m^3)	490 lb/ft^3
Young's modulus	200 GN/m^2	30×10^6 lb/ft^2
Coefficient of thermal expansion	12×10^6 per °C	0.0000065 per °F
Poisson's ratio elongation	0·3	0·3
Gauge length ASTM Grade	BS Grade	EC Grade
0·3 in./in. A36	43–20%	Fe 430
0·2 in./in. A440, A572	50–18%	Fe 50
0·1–0·15 in./in. A709	55–17%	Fe 55

2.6. Tolerances

It is not possible in the rolling process to produce sections to the exact dimensions specified. For various reasons, including roller wear, the elements of the cross-section (flanges and webs of I- and H-sections, legs of angles, etc.) may be slightly thicker than desired or may not be exactly at right angles to each other. These deviations are unavoidable and must therefore be accepted by the steel fabricator. It is important that the steelwork detailer must be aware of both the existence of these discrepancies and the tolerances applicable to each so that allowances can be made.

In addition to allowing for these rolling tolerances, allowance must also be made for inaccuracies in the shop fabrication of steel. Most structural components are large, and it would be unduly expensive to manufacture these to very close tolerances. Allowance must be made for slight variations in member length, inaccurate location of holes, out of squareness of member ends, variation in depth of welded girders and other dimensional variations.

Allowance must also be made for deviation from the required shape. This welding distortion is caused by shrinkage of the molten weld metal during cooling. Where site welding is involved, the workshop drawings should include an allowance for weld shrinkage at site by detailing the components with extra length.

Steel sections are supplied by the mills in standard length, usually ranging from 9 m to 13 m for hot-rolled sections and from 6 m to 9 m for cold-formed sections. The standard lengths are nominal; the actual lengths supplied may vary from the nominal standard length within specified tolerances.

A check-list should be clearly drawn up showing types of variation of the following:

(*a*) rolled section
(*b*) member length
(*c*) camber variation
(*d*) bolted connections, pilot holes in large complex joints reamed out to full size during erection
(*e*) line and level of bolts and inaccuracy in setting foundations, provision for grouted spaces under base plates and extra length bolts with excess threads
(*f*) column fabrication or beam fabrication.

For compression members or beams (other than purlins or girts) of length L between points that are laterally restrained the acceptable tolerance is: greater of 3 mm or $L/1000$; for other members of length L: lesser of 25 mm or $L/500$.

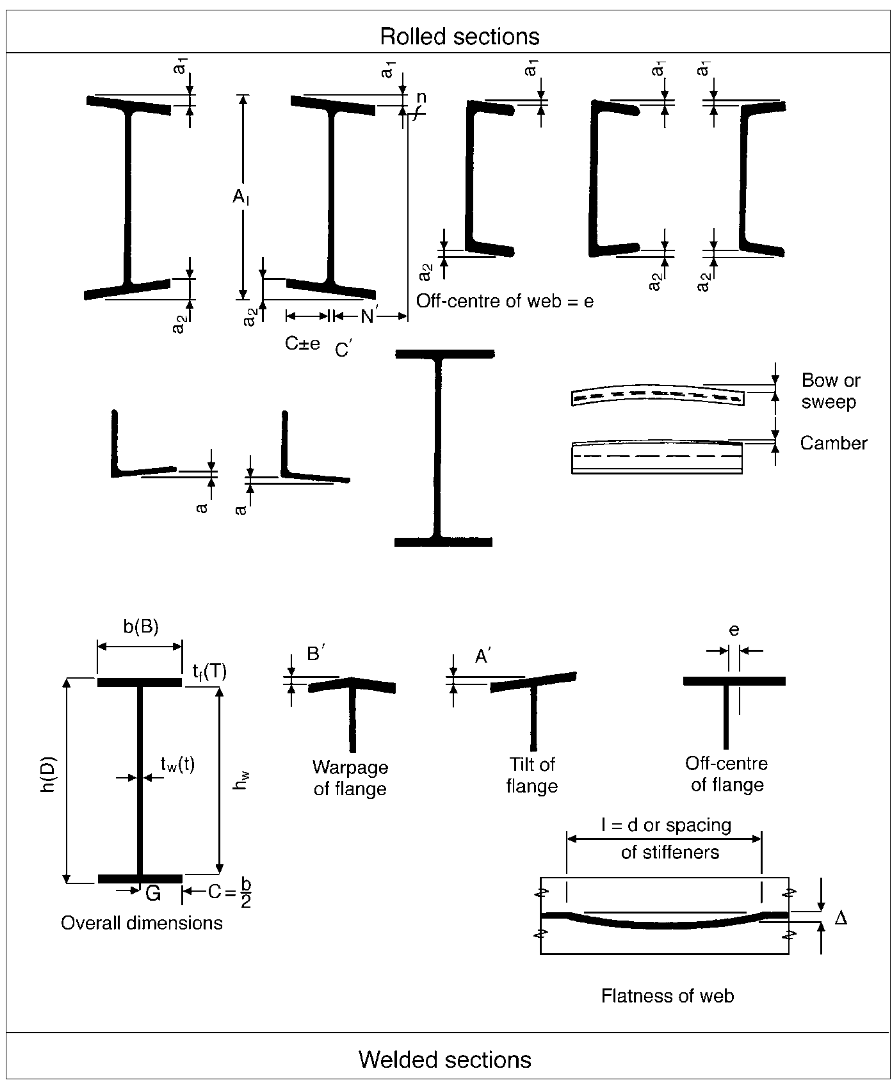
Figure 2.3 summarises some of the important rolling and fabrication inaccuracies that can occur in practice. For clarity, the distortions are greatly exaggerated. Since Eurocode EC3 is new, few details are currently available in this area. A careful search has been made of the German and French practices and these, together with the British and American practices are reviewed in the following sections, providing a comparison of the tolerances adopted or recommended by various Codes. Fig. 2.3 shows the best possible compromise offered to the detailer.

2.6.1. Tolerances (European practice)

All dimensions in mm (EC3).

Width of flange	$b \leqslant 400$, tolerance $= \pm 4$	
	$b > 400$, tolerance $= \pm 6$	
Overall depth	$h \leqslant 1000$, tolerance $= \pm 3$	
	$h > 1000$, tolerance $= \pm 5$	
Flatness of web	$t_w < h_w/150$	$\Delta = d/120$, but $\leqslant 8$

Tolerances



BS5950 and EC3

Fig. 2.3. Tolerances: BS 5950 notation given within brackets; EC3 notation given without brackets

$t_w \geqslant h_w/150$ $\Delta = d/150$, but $\leqslant 8$
$e = 6$, $A' = b/200$, $B' = b/200$

Fabrication tolerances
The straightness tolerances specified in Table 7.2 of EC3 have been assumed in the derivation of the design rules for the relevant type of member. Where the curvature exceeds these values, the additional curvature shall be allowed in the design calculations. The straightness has a permitted deviation between $\pm 0.001L$ and $\pm 0.002L$.

2.6.2. Tolerances (British practice)

All dimensions in accordance with BS 5950 and BS 4.
Referring to Fig. 2.3, the rolled sections, their tolerances and effects in detailing are summarised as follows.

Beams, channels and columns
h at the centre line of the web from top flange.

Tolerances ±3·2; h up to 305 +3·2 − 0·8
>305 up to 406 +4·0 − 1·6
>406 +4·8 − 1·6
Flange width b + 6·4 − 4·8 from the centre line of web

Off-centre 'e' of the web and dimension A_1

h = 102 up to 305	e = 3·2	$A_1 = h + 4{\cdot}8$
h > 305	e = 4·8	$A_1 = h + 6{\cdot}4$
	$c' = t_w/2 + 2$ mm	
	$N' = c - c' + 6$ mm	
	$N = (h - d)/2$	

Out of squareness	$(\overline{K} = a_1 + a_2)$	$\overline{K}$
	b = up to 102	1·6
	b = 102 up to 203	3·2
	b = 203 up to 305	4·8
	b > 305	6·4

Specified weight
(Channel) based on BS 4

Flats and plates — EC3 (BS 5950)
Overall end plates from the centre line of cross-section to top flange:

Thickness	Width of flats/thick	Width of plates	Length of end plates
Up to 10	$0{\cdot}4/t_0$ 35 → 0·5	0·5	+0, –3
>40	$0{\cdot}8/t_0$ 150 → 1·5	1·0 width 2% > 5 mm	±4 lapped only
>80	1·0	1·3	

Additional items:

Cross-section	Camber	b/150	$\Delta = d/150$;	L/1000
	Bow			
	Straightness	L/100 ≮ 3 mm		
A_1 with b = 450	+6			
>450	+9			

The erection tolerances specified in Table 7.1 of EC3 apply to the following reference points:

- for a column, the actual centre point of the column at each floor level and at the base, excluding any base-plate or cap-plate

- for a beam, the actual centre point of the top surface at each end of the beam, excluding any end-plate.

Table 2.2. Normal tolerances after erection

Criterion	Permitted deviation
Deviation of distance between adjacent columns	±5 mm
Inclination of a column in a multi-storey building between adjacent floor levels	0·002h Where h is the storey height
Deviation of a column's location in a multi-storey building at any floor level, from a vertical line through the intended location of the column base	$0{\cdot}0035\Sigma h/n^{0{\cdot}5}$ Where Σh is the total height from the base to the floor level concerned And n is the number of storeys from the base to the floor level concerned
Inclination of a column in a single storey building, (not supporting a crane gantry) other than a portal frame	0·0035h Where h is the height of the column
Inclination of the column of a portal frame (not supporting a crane gantry)	Mean: 0·002h Individual: 0·010h

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Position of holding down bolts

(*a*) Tolerances shall be specified for the positional deviations of the holding down bolts which will enable the tolerance limits for erection of steelwork to be satisfied.

(*b*) Tolerances shall be specified for the levels of the holding down bolts which enable the specified tolerances to be satisfied for the following criteria:
- the level of the base plate
- the thickness of the bedding material under the base plate
- the protrusion of the bolt through the nut
- the number of threads clear below the nut.

(*c*) The deviations of the spacing between individual bolts within the group of holding down bolts for each member shall not exceed the following:
- for bolts rigidly cast in, between centres of bolts: ±5 mm
- for bolts set in sleeves, between centres of sleeves: ±10 mm

2.6.3. Tolerances based on US code (American Institute of Steel Construction — AISC)

Table 2.3. Comparative symbols

BS 5950	EC3	AISC
A′	A′	C
B	b	B
B/2	c	B/2
D	h	–
B/2 ± e	c ± e	B/2 ± E
a_2	a_2	T
a_1	a_1	T′

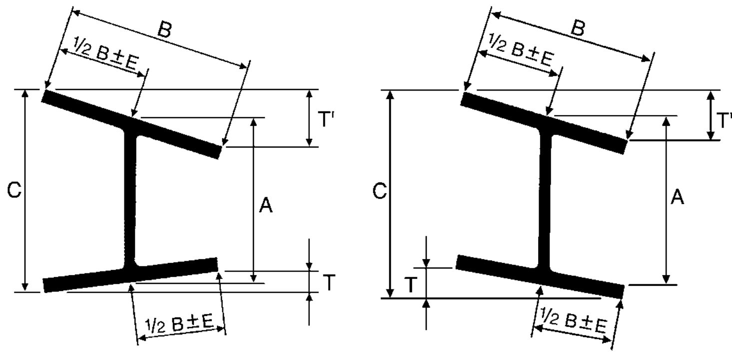


Fig. 2.4. Tolerances and parameters (AISC code)

Table 2.4. Rolling tolerances

Section nominal size: in.	A, Depth: in. Over theoretical	A, Depth: in. Under theoretical	B, Fig. width: in. Over theoretical	B, Fig. width: in. Under theoretical	T+T′, Flanges, out of square, max: in.	E* web off centre, max: in.	C, max. depth at any cross-section over theoretical depth: in.
To 12, incl.	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{4}$
Over 12	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{1}{4}$

* Variation of $\frac{5}{16}$ in. max. for sections over 426 lb/ft

Table 2.5. Cutting tolerances

W shapes	Variations from specified length for lengths given: in.			
	30 ft and under		Over 30 ft	
	Over	Under	Over	Under
Beams 24 in. and under in nominal depth	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{3}{8}$
Beams over 24 in. nom. depth; all columns	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{1}{2}$

2.6.4. Other tolerances

Area and weight variation: 2·5% theoretical or specified amount.
Ends out-of-square: 1/64 in. per in. depth, or of flange width if it is greater than the depth.

2.6.5. Cambering of rolled beams

All beams are straightened after rolling to meet sweep and camber tolerances listed hereinafter for W shapes and S shapes. The following data refers to the subsequent cold cambering of beams to produce a predetermined dimension.

The maximum lengths that can be cambered depend on the length to which a given section can be rolled, with a maximum of 100 ft. The following table outlines the maximum and minimum induced camber of W shapes and S shapes.

Table 2.6. Camber and sweep

Sizes	Length	Permissible variation: in. Camber	Sweep
Sizes with flange width equal to or greater than 6 in.	All	$\frac{1}{8}$ in. $\times \frac{\text{(total length: ft)}}{10}$	
Sizes with flange width less than 6 in.	All	$\frac{1}{8}$ in. $\times \frac{\text{(total length: ft)}}{10}$	$\frac{1}{8}$ in. $\times \frac{\text{(total length: ft)}}{5}$
* Certain sections with a flange width approx. equal to depth and specified on order as columns	45 ft and under	$\frac{1}{8}$ in. $\times \frac{\text{(total length: ft)}}{10}$ with $\frac{3}{8}$ in. max.	
	Over 45 ft	$\frac{3}{8}$ in. $+ \left[\frac{1}{8} \times \frac{\text{(total length: ft} - 45)}{10}\right]$	

* Applies only to: W8 x 31 and heavier. W12 x 65 and heavier, W10 x 49 and heavier, W14 x 90 and heavier. If other sections are specified on the order as columns, the tolerance will be subject to negotiation with the manufacturer.

Table 2.7. Maximum and minimum induced camber

Sections nominal depth: in:	Specified length of beam: ft Over 30 to 42 incl.	Over 42 to 52 incl.	Over 52 to 65 incl.	Over 65 to 85 incl.	Over 85 to 100 incl.
	Max. and min. camber acceptable: in.				
W shapes 24 and over	1–2 incl.	1–3 incl.	2–4 incl.	3–5 incl.	3–6 incl.
W shapes 14 to 21, incl. and S shapes 12 in. and over	$\frac{3}{4}$–$2\frac{1}{2}$ incl.	1–3 incl.	2–4 incl.	$2\frac{1}{2}$–5 incl.	Inquire

Consult the producer for specific camber and/or lengths outside the above listed available lengths and sections.

Mill camber in beams of less depth than tabulated should not be specified. A single minimum value for camber, within the ranges shown above for the length ordered, should be specified. Camber is measured at the mill and will not necessarily be present in the same amount in the section of beam as received due to release of stress induced during the cambering operation. In general, 75% of the specified camber is likely to remain. Camber will approximate a simple regular curve nearly the full length of the beam, or between any two points specified. Camber is ordinarily specified by the ordinate at the mid-length of the portion of the beam to be curved. Ordinates at other points should not be specified.

Although mill cambering to achieve reverse or other compound curves is not considered practical, fabricating shop facilities for cambering by heat can accomplish such results as well as forming regular curves in excess of the limits tabulated above.

Table 2.8. Camber ordinate tolerances

Lengths	Plus tolerance	Minus tolerance
50 ft and less	$\frac{1}{2}$ in.	0
Over 50 ft	$\frac{1}{2}$ in. plus $\frac{1}{8}$ in. for each 10 ft or fraction thereof in excess of 50 ft	0

2.6.6. Tees split from W, M and S shapes and angles split from channels

Dimension A on Fig. 2.5 may be approximately $\frac{1}{2}$ beam or channel depth, or any dimension resulting from off-center splitting on two lines as specified on the order.

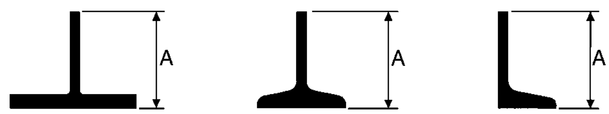


Fig. 2.5. Depth tolerances

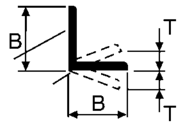
Table 2.9. Depth of beam split versus variation A

Depth of beam from which tees or angles are split	Variations in depth A over and under	
	Tees	Angles
To 6 in. excl.	$\frac{1}{8}$	$\frac{1}{8}$
6 to 16 excl.	$\frac{3}{16}$	$\frac{3}{16}$
16 to 20 excl.	$\frac{1}{4}$	$\frac{1}{4}$
20 to 24 excl.	$\frac{5}{16}$	–
24 and over	$\frac{3}{8}$	–

The above tolerances for depths of tees or angles include the allowable tolerances in depth for the beams and channels before splitting.

2.6.7. Other tolerances

Other rolling tolerances as well as cutting tolerances, area and weight variation, and ends out-of-square will correspond to those of the beam or channel before splitting, except



$$\text{camber} = \tfrac{1}{8}\ \text{in.} \times \frac{\text{total length: ft}}{5}$$

* Angles, bar size

Table 2.10. Rolling tolerances

*Specified length of leg: in.	Variations from thickness for thicknesses given over, and under: in.			B Length of leg, over and under: in.	T, out of square per in. of B: in.
	$\frac{3}{16}$ and under	Over $\frac{3}{16}$ to $\frac{3}{8}$ in.	Over $\frac{3}{8}$		
1 and under	0·008	0·010		$\frac{1}{32}$	†$\frac{3}{128}$
Over 1 to 2 incl.	0·010	0·010	0·012	$\frac{3}{64}$	†$\frac{3}{128}$
Over 2 to 3 excl.	0·012	0·015	0·015	$\frac{1}{16}$	†$\frac{3}{128}$

* The longer leg of an unequal angle determines the size for permissible variations.
† $\frac{3}{128}$ in. per in. = $1\frac{1}{2}$ degrees.

Table 2.11. Cutting tolerances

Section	Variations over specified length for lengths given no variation under				
	5 to 10 ft excl.	10 to 20 ft excl.	20 to 30 ft excl.	30 to 40 ft excl.	40 to 65 ft incl.
All sizes of bar-size angles	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$

Camber: $\frac{1}{4}$ in. in any 5 ft, or $\frac{1}{4}$ in. × total length, ft/5
Sweep: not applicable; see camber tolerance.
Straightness: because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation has been performed.
Ends out-of-square: $\frac{3}{128}$ in. per in. of leg length or $1\frac{1}{2}$ degrees. Tolerance based on longer leg of an unequal angle.
A member is 'bar size' when its greatest cross-sectional dimension is less than 3 in.

2.6.8. Rectangular sheared plates and universal mill plates — width and tolerance for sheared plates

(1 1/2 in. and under in thickness)

Table 2.12. Length tolerance only for universal mill plates

Specified dimensions: in.		Variations over specified width and length for thicknesses: in., and equivalent weights: lb. per sq. ft given							
		To 3/8 excl.		3/8 to 5/8 excl.		5/8 to 1 excl.		1 to 2 incl.*	
Length	Width	To 15·3 excl.		15·3 to 25·5 excl.		25·5 to 40·8 excl.		40·8 to 81·7 incl.	
		Width	Length	Width	Length	Width	Length	Width	Length
To 120 excl.	To 60 excl.	3/8	1/2	7/16	5/8	1/2	3/4	5/8	1
	60 to 84 excl.	7/16	5/8	1/2	11/16	5/8	7/8	3/4	1
	84 to 108 excl.	1/2	3/4	5/8	7/8	3/4	1	1	1 1/8
	108 and over	5/8	7/8	3/4	1	7/8	1 1/8	1 1/8	1 1/4
120 to 240 excl.	To 60 excl.	3/8	3/4	1/2	7/8	5/8	1	3/4	1 1/8
	60 to 84 excl.	1/2	3/4	5/8	7/8	3/4	1	7/8	1 1/4
	84 to 108 excl.	9/16	7/8	11/16	15/16	13/16	1 1/8	1	1 3/8
	108 and over	5/8	1	3/4	1 1/8	7/8	1 1/4	1 1/8	1 3/8
240 to 360 excl.	To 60 excl.	3/8	1	1/2	1 1/8	5/8	1 1/4	3/4	1 1/2
	60 to 84 excl.	1/2	1	5/8	1 1/8	3/4	1 1/4	7/8	1 1/2
	84 to 108 excl.	9/16	1	11/16	1 1/8	7/8	1 3/8	1	1 2/2
	108 and over	11/16	1 1/8	7/8	1 1/4	1	1 3/8	1 1/4	1 3/4
360 to 480 excl.	To 60 excl.	7/16	1 1/8	1/2	1 1/4	5/8	1 3/8	3/4	1 5/8
	60 to 84 excl.	1/2	1 1/4	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8
	84 to 108 excl.	9/16	1 1/4	3/4	1 3/8	7/8	1 1/2	1	1 7/8
	108 and over	3/4	1 3/8	7/8	1 1/2	1	1 5/8	1 1/4	1 7/8
480 to 600 excl.	To 60 excl.	7/16	1 1/4	1/2	1 1/2	5/8	1 5/8	3/4	1 7/8
	60 to 84 excl.	1/2	1 3/8	5/8	1 1/2	3/4	1 5/8	7/8	1 7/8
	84 to 108 excl.	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8	1	1 7/8
	108 and over	3/4	1 1/2	7/8	1 5/8	1	1 3/4	1 1/4	1 7/8
600 to 720 excl.	To 60 excl.	1/2	1 3/4	5/8	1 7/8	3/4	1 7/8	7/8	2 1/4
	60 to 84 excl.	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1	2 1/4
	84 to 108 excl.	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1 1/8	2 1/4
	108 and over	7/8	1 3/4	1	2	1 1/8	2 1/4	1 1/4	2 1/2
720 and over	To 60 excl.	9/16	2	3/4	2 1/8	7/8	2 1/4	1	2 3/4
	60 to 84 excl.	3/4	2	7/8	2 1/8	1	2 1/4	1 1/8	2 3/4
	84 to 108 excl.	3/4	2	7/8	2 1/8	1	2 1/4	1 1/4	2 3/4
	108 and over	1	2	1 1/8	2 3/8	1 1/4	2 1/2	1 3/8	3

* Permissible variations in length apply also to universal mill plates up to 12 in. in width for thicknesses over 2 to 2 1/2 in. incl. except for alloy steels up to 1 3/4 in. thick.

Notes: permissible variations under specified width and length—1/4 in. Table applies to all steels listed in ASTM A6.

Table 2.13. Flatness tolerances (carbon steel only)

Specified thickness: in.	Flatness tolerances for specified widths: in.							
	To 36 excl.	36 to 48 excl.	48 to 60 excl.	60 to 72 excl.	72 to 84 excl.	84 to 96 excl.	96 to 108 excl.	108 to 120 excl.
To $\frac{1}{4}$ excl.	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$
$\frac{1}{4}$ to $\frac{3}{8}$ excl.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
$\frac{3}{8}$ to $\frac{1}{2}$ excl.	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$ excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	1	1
$\frac{3}{4}$ to 1 excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
1 to 2 excl.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$
2 to 4 excl.	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$
4 to 6 excl.	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$
6 to 8 excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$

Notes:
1. The longer dimension specified is considered the length and permissible variations in flatness along the length should not exceed the tabular amount for the specified width in plates up to 12 ft. in length.
2. The flatness variations across the width should not exceed the tabular amount for the specified width.
3. When the longer dimension is under 36 in. the permissible variation should not exceed $\frac{1}{4}$ in. When the longer dimension is from 36 to 72 in. incl., the permissible variation should not exceed 75% of the tabular amount for the specified width, but should in no case be less than $\frac{1}{4}$ in.
4. These variations apply to plates which have a specified minimum tensile strength of not more than 6000 psi or compatible chemistry or hardness. The limits in the table are increased by 50% for plates specified to a higher minimum tensile strength or compatible chemistry or hardness.

Table 2.14. Flatness tolerances (high-strength low-alloy and alloy steel, hot-rolled or thermally treated)

Specified thickness: in.	Flatness tolerances for specified widths: in.							
	To 36 excl.	36 to 48 excl.	48 to 60 excl.	60 to 72 excl.	72 to 84 excl.	84 to 96 excl.	96 to 108 excl.	108 to 120 excl.
To $\frac{1}{4}$ excl.	$\frac{13}{16}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{5}{8}$
$\frac{1}{4}$ to $\frac{3}{8}$ excl.	$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$ excl.	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{5}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$ excl.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
$\frac{3}{4}$ to 1 excl.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{5}{16}$
1 to 2 excl.	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	1
2 to 4 excl.	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$
4 to 6 excl.	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{1}{8}$
6 to 8 excl.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$

Notes:
1. The longer dimension specified is considered the length and variations from a flat surface along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length.
2. The flatness variation across the width should not exceed the tabular amount for the specified width.
3. When the longer dimension is under 36 in., the variation should not exceed $\frac{3}{8}$ in. When the large dimension is from 36 to 72 in. incl., the variation should not exceed 75% of the tabular amount for the specified width.

3. Drafting practice for detailers

3.1. Introduction to the fundamentals of drafting

This chapter covers the fundamentals of the art of drafting. The primary requirement is drafting equipment, but various techniques are also needed for the practical execution of different kinds of work, lettering, dimensions, symbols, line thickness, breaking lines, provision of match lines, scaling details, indication of bolts and bolt lines, indication of welding, orthographic projections, elevation and section arrows and finally abbreviations. These elements are discussed here.

3.2. Equipment

All workshop detail drawings are made in pencil on tracing paper or on plastic drafting film. These materials are transparent to enable copies or prints to be made from the drawings by a dye-line printing process. In special cases, drawings are prepared in ink on drafting film, for durability. The equipment required by the structural steelwork detailer is as follows:

(*a*) drawing board, furnished with a separate T-square, or a more elaborate drafting system
(*b*) drawing paper or film (see Table 3.1 for drawing paper sizes)
(*c*) pencils
(*d*) pencil sharpener
(*e*) pens, supplied in point diameters (corresponding to the line thickness required of 0.25 mm, 0.35 mm, 0.50 mm, 0.70 mm with each diameter being $\sqrt{2}$ times greater than the previous size
(*f*) set squares—three set squares are sufficient for all drafting needs, viz. 45° and 30°/60° fixed squares and an adjustable square giving angles of 0° to 90°
(*g*) scales—two scales are usually required, one having 1:20, 1:25, 1:50 and 1:100 reductions and the other 1:15, 1:30, 1:40 and 1:75 reductions (EC3). In general, the following scales should be used: 1:5, 1:10, 1:20, 1:25, 1:50, 1:100, 1:200
(*h*) protractor
(*i*) compasses
(*j*) circle template
(*k*) eraser and shield
(*l*) french curves
(*m*) calculator—a scientific electronic calculator is a necessary aid in the summing of dimensions, the computation of bevel dimensions and bracing end clearances, and the calculation of steelwork masses on quantity lists
(*n*) computers—an increasing number of fabricators are using various computer-aided drawing (CAD) programs to assist in the preparation of

layout and detail drawings. This is a highly specialised technique, but results in significant time savings on larger contracts (see Fig. 3.1 for a typical CAD-based drawing office).

Table 3.1. Drawing sizes

Designation	Size (mm) UK and Europe	Size (in.) USA
A0*	1189 × 841	48 × 34
A1*	841 × 594	34 × 24
A2	594 × 420	24 × 16
A3*	420 × 297	16 × 12
A4*	297 × 210	12 × 8
B1	1000 × 707	40 × 28

* Widely used.

3.3. Lettering, lines and dimensions/marks

No particular style of lettering is recommended but a number of practices have indicated distinct uniform letters and figures that will produce decent copy prints. Stencils are used for viewing drawing titles. The computer-aided techniques can produce a number of different lettering schemes and symbols. In all cases, the clarity and uniformity of all symbols are the main requirements. Letters can either be upright or sloping at about 15°. Lower case lettering is used for general notations and upper case for headings, titles, sections and elevation arrows, etc. The minimum size of lettering in the UK and the USA is 2·5 mm and 3 mm respectively. All notes, letters, dimensions and arrow heads used on plans, elevations, sketches and erection drawings are either free hand or computer generated. See Figs 3.2 and 3.3 for typical examples of lettering.

Fig. 3.1. CAD-based drawing office (with compliments of G.I.K. Institute of Engineering Sciences and Technology, TOPI N.W.F.P., Pakistan)

Fig. 3.2. Lettering and symbols and lettering styles (adapted from AISC practice)

It is sometimes a requirement that drawings be microfilmed for storage purposes. This process involves reproducing the drawing photographically at a much smaller size onto transparent film. When copies of the drawing are required, the transparency is enlarged to its original (or as appropriate) size and a print is taken.

When the drawing is enlarged it may not necessarily be to the original size, in which case the scale of the original is lost. It is therefore necessary to provide a scale at the bottom edge of the original drawing. The scale should be 100 mm long and marked off in 10 mm divisions.

Arrow heads are sharply pointed and touch the lines. Dimension lines should be dark, thin but unbroken lines. Fig. 3.3 demonstrates the convention adopted for border lines, visible or invisible (hidden) lines, centre-lines, break away lines, etc. The density of these lines is a true representation for each case. Fig. 3.3 also gives a sample dimensional detail of a typical steel girder elevation and section which shows various arrow heads and dimensional lines.

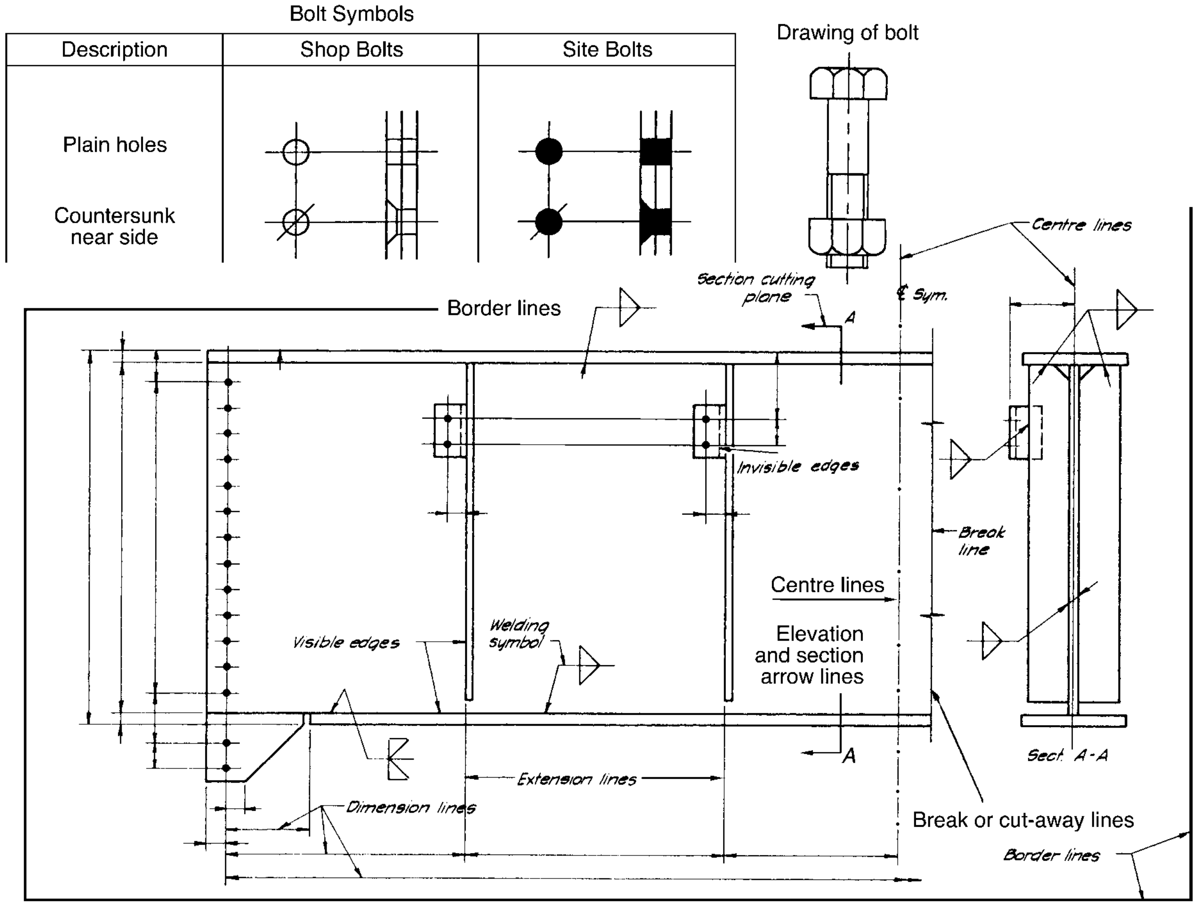


Fig. 3.3. Drafting conventions for structural detailing (based on BS 5950 and EC3)

When only part of an object is to be shown, it is necessary to use break lines. These denote an imaginary cut through the object and imply that anything beyond the cut line is not of importance in that particular view.

In structural work, break lines are used primarily to close the ends of members which are only partially shown on the drawing. Fig. 3.3 illustrates break lines as used on girder work. Break lines should not be used to indicate foreshortening of the length of beam or column, nor should they be used to show reduction of the width or depth of any structural member. However, since machine drawing practice sanctions break symbols to show reduction in length of such parts as pipe and shafting, this custom may be retained where machinery is involved on structural details. Break lines should not be used to indicate out of scale drawings.

Centre lines are used to indicate the centres of webs on beams and girders, as shown in the top flange view and in section A–A of Fig. 3.3. Centre lines are also frequently used on girders when there is an axis of symmetry about the mid-point of the girder's length. This means that all dimensions and details on the right side of the centre line are in the same relative position as on the left side.

Although beams are shown in their full length, even if symmetrical about the mid-point, common practice in the case of symmetrical girders is to draw only one-half of the length. Leader lines and arrows are used to relate a note to the object to which it refers. Examples are shown in Fig. 3.3. The arrow head should normally point to the outline of the object, as shown in the detail. In the case of flat plates and groups of holes, the arrow should preferably point to the view showing the surface of the plate and the main view of the holes, and not to the plate edge.

On long members, particularly bridge girders, where the detail requires more than one sheet, it is customary to draw as much of the drawing as is convenient on the first sheet of the series and continue the drawing on successive sheets until the member is complete. The several sections of such a member are related to one another by match lines. Match lines are usually established at a readily identifiable point, such as a stiffener gauge line or, for welded work, the face of a bar stiffener. Match lines are tied by dimensions to the closest dimensioned feature of all the views they cross. The ends of each pair of match lines carry identical letters or numbers, such as X–X, Y–Y, 1–1, 2–2, etc.

Bolts and bolt holes are shown in accordance with the symbols indicated in Fig. 3.3. The diameters should be drawn to scale. Where bolts are of the high-strength friction-grip type, this should be clearly indicated by the note 'HSFG'. It will be seen that a distinction is made between shop bolts, which are installed during assembly in the shop, and site bolts, which are used to connect the components together during erection. In large scale details, where it is desirable to show the bolts for a particular reason, they may be depicted.

Welding is indicated according to the standard symbols as shown in Fig. 3.3. This is the most commonly used symbol. The welds are not usually shown on the drawing as the symbols are self-explanatory. Chapters 4 and 5 are devoted to bolts and welding, including specification details.

Erection marks are needed for each separate or loose item that comes out of the workshop so that the item can be identified on site and erected in the right position. It is the detailer/draughtman's responsibility to allocate these marks as the detailing proceeds. On beams, the mark should be located on the top flange. On columns, the mark should be located on the lower end of the shaft on the flange.

Erection marks usually consist of prefix letters followed by the numbers (in consecutive order) of the components. Standard prefixes are as follows:

B	beams and girders	KB	kneebraces
BK	brackets	P	purlins
C	column	R	rafters
CG	crane girders	RB	rafter bracing members
FR	false rafters	RG	roof girders
G	girts	T	trusses
GG	gantry girder	VB	vertical bracing members

In buildings with several floors, the beams may be further identified according to the floor they are to be on. For example, B/3/30 or B-3-30 would indicate beam no. 30 on the third floor and C/5/39 or C-5-39 column no. 39 on the fifth floor.

Another convention sometimes used is to allocate even numbers to beams running in, say, a north–south direction and odd numbers to beams running east–west. This is of considerable assistance to the erector, who can readily identify the location of each beam in the floor.

3.4. Specified codes, specifications and detailing of drawings

3.4.1. Composition of a typical structure

The detailer must be briefed on the structure, its design under a specific code and be given a comprehensive guide regarding its composition when drawing elevations, plans and cross-sections. The drawing should show the structure as it will appear when erected on site. The detailer will be required to draw each component separately with descriptive notation.

3.4.2. Design loading and methods of analysis

It is necessary for the detailer to have a basic understanding of how the design loading on a structure is derived and specified, to enable him to interpret correctly the loads and forces given on engineers' drawings and to use them in designing connections. Loading such as self-weight, imposed loading, wind loading, etc. that the structure must be capable of sustaining are termed nominal loading.

The modern method of structural design is called limit-state design, which means that the structure is designed to resist the applied loading under two limiting conditions or states. These are the ultimate and the serviceability limit states.

(*a*) Ultimate limit state — this is the state at which the structure or any part of it is just at the point of collapse or failure when subjected to a combination of applied loads; these loads being the nominal loads multiplied by appropriate factors.

(*b*) Serviceability limit state — this is the state beyond which the structure or any part of it no longer performs acceptably under the applicable combination of nominal (not ultimate) loading, i.e. in its normal use or function.

3.4.3. Information provided by the engineer

It is at this stage that the steelwork detailer receives all the data required to proceed with the task of preparing the workshop drawings. The information is usually provided by the design engineer in the form of general arrangement drawings and a brief specification. The drawings will include a layout of the structure and typical connection details.

It is essential that the information provided is complete and explicit. The preparation of shop drawings is an activity lying on the critical path, which means that any delay in the execution of this task will contribute to an extension of the time required to complete the entire steelwork project. The following information would be required by the detailer/draughtsman from the design engineer.

(*a*) General arrangement (i.e. layout) drawings, preferably to scale, including elevations, sections and plans, giving a complete representation of the entire building. These drawings should give floor levels, the orientation of the building (by means of a north arrow), location on the site, relationship to other structures (if any), etc.

(*b*) The section sizes of all members in the building, e.g. columns, beams, all truss and lattice girder members, rafters, purlins, girts, bracings, crane beams and stairs, etc.

(*c*) Sketches of any connections, components or details in the structure that lie outside the scope of generally accepted or standard structural practice.

(*d*) The type of flooring for each suspended floor, e.g. reinforced concrete slab, composite slab, precast planks and topping, cellular steel deck and concrete, open grating, Vastrap plate, etc.

(*e*) A column base layout, giving the ultimate loads on the foundations, the levels of the bases and the holding down bolt details.

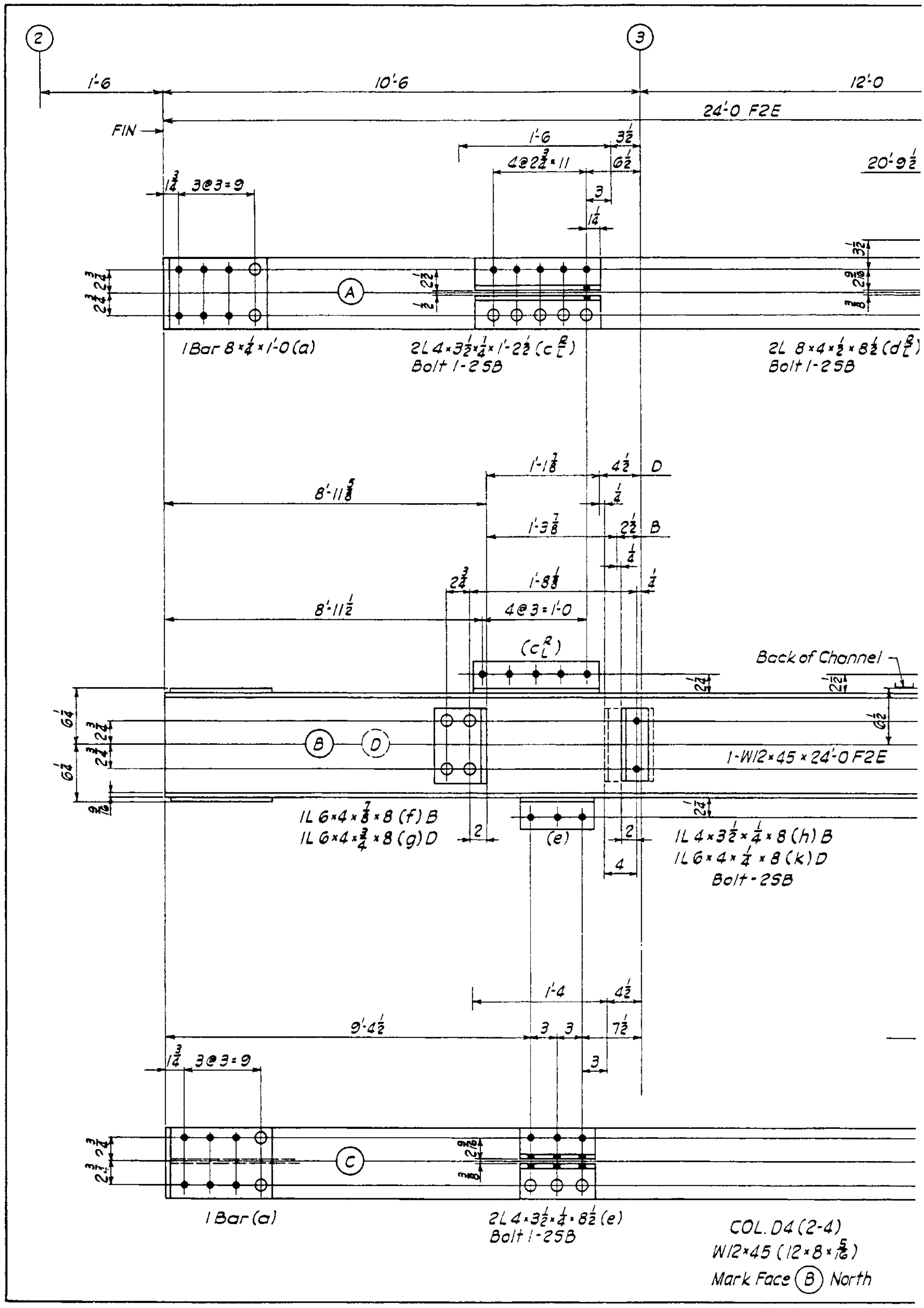
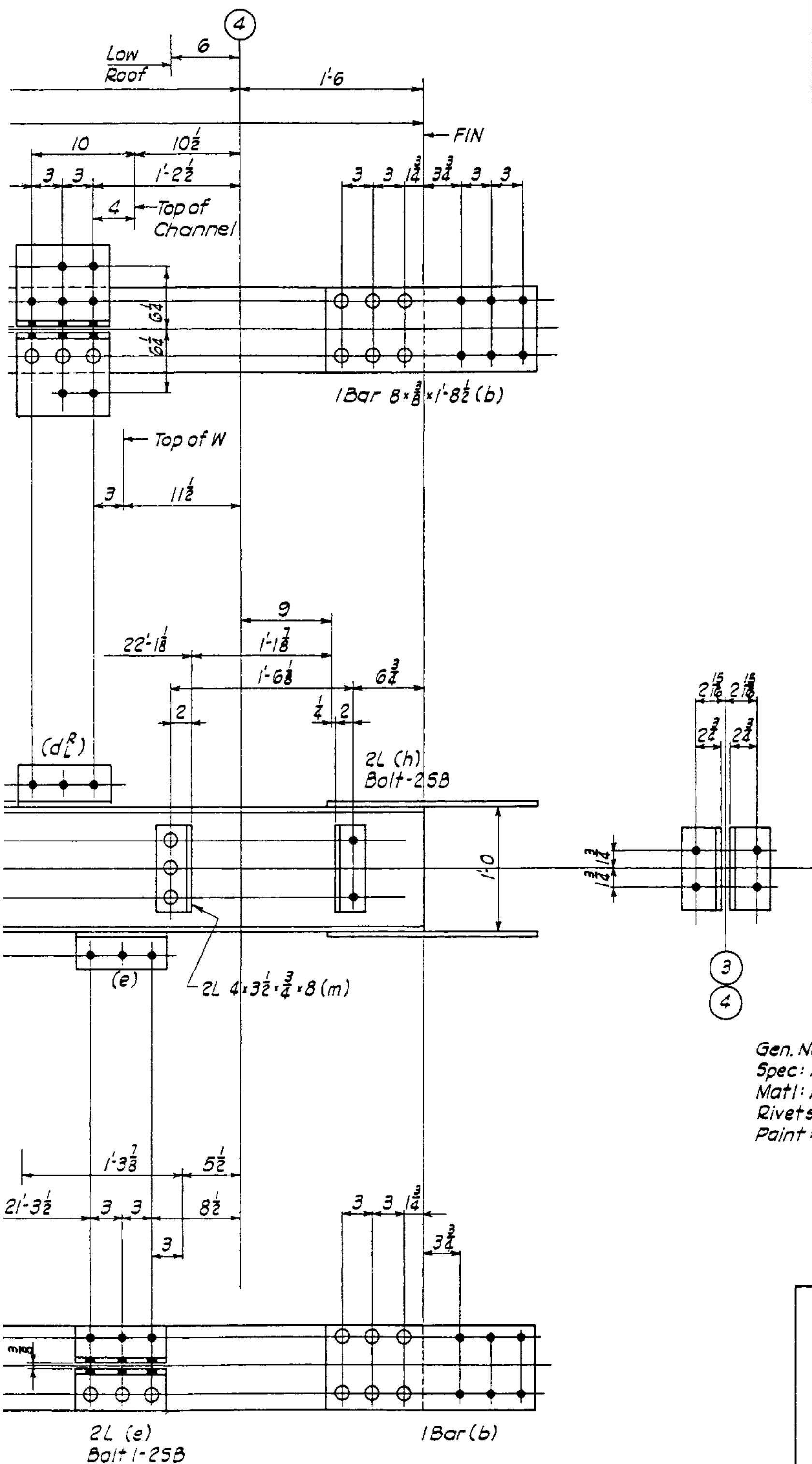


Fig. 3.4. Detail drawing of girders (AISC practice) Copyright: American Institute of Steel Construction, Inc. Reprinted with permission. All rights reserved.

REQUIRED		
No.	DESC.	MARK
ONE	COLUMN	D4(2-4)



Gen. Notes:
Spec: AISC - latest edition
Matl: ASTM A36
Rivets: 7/8"φ ASTM A501-1; Open holes 15/16" diam.
Paint: One coat SSPC Paint 13-64 (Brown) except shop contact surfaces, no paint. Open holes are for high strength structural bolts. No paint within 5" of holes for high strength structural bolts.

TITLE BLOCK

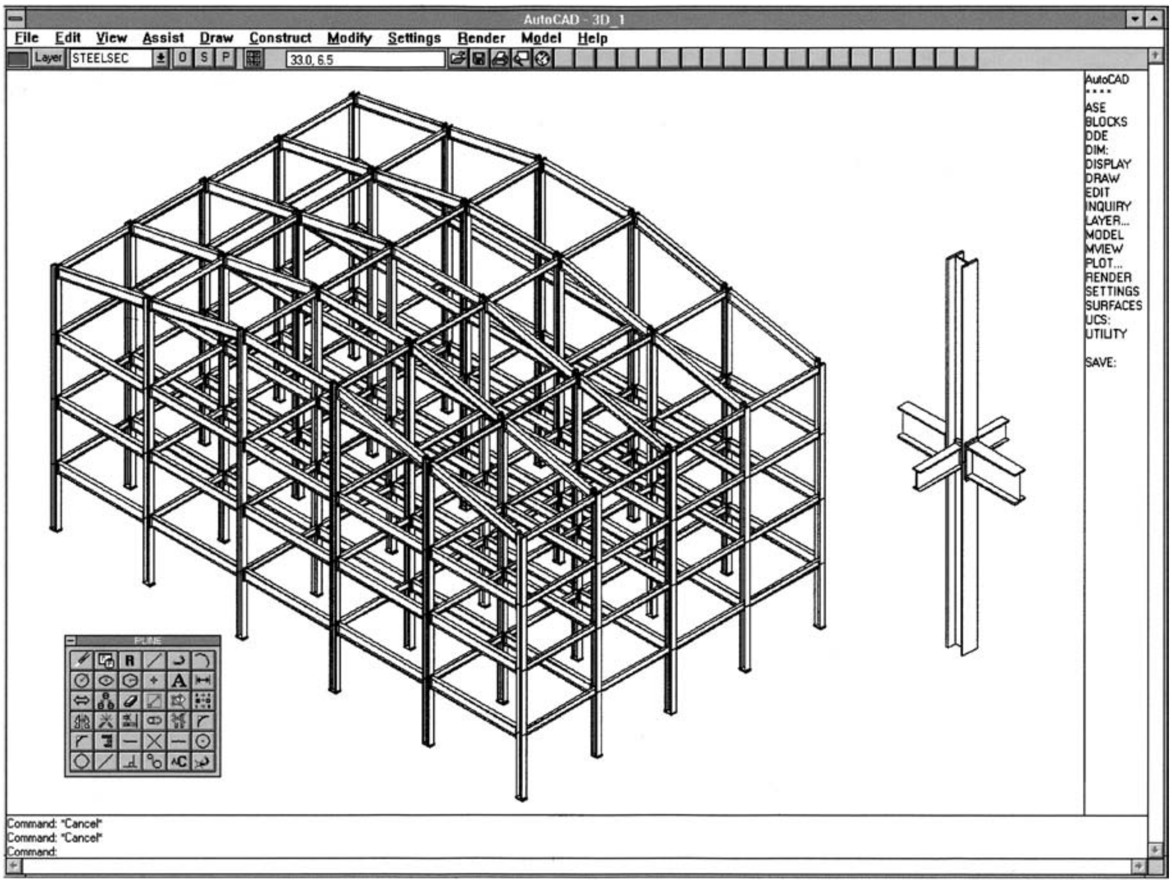


Fig. 3.5. CAD detailing of the skeleton of a steel building (BS 5950 practice – MasterSeries)

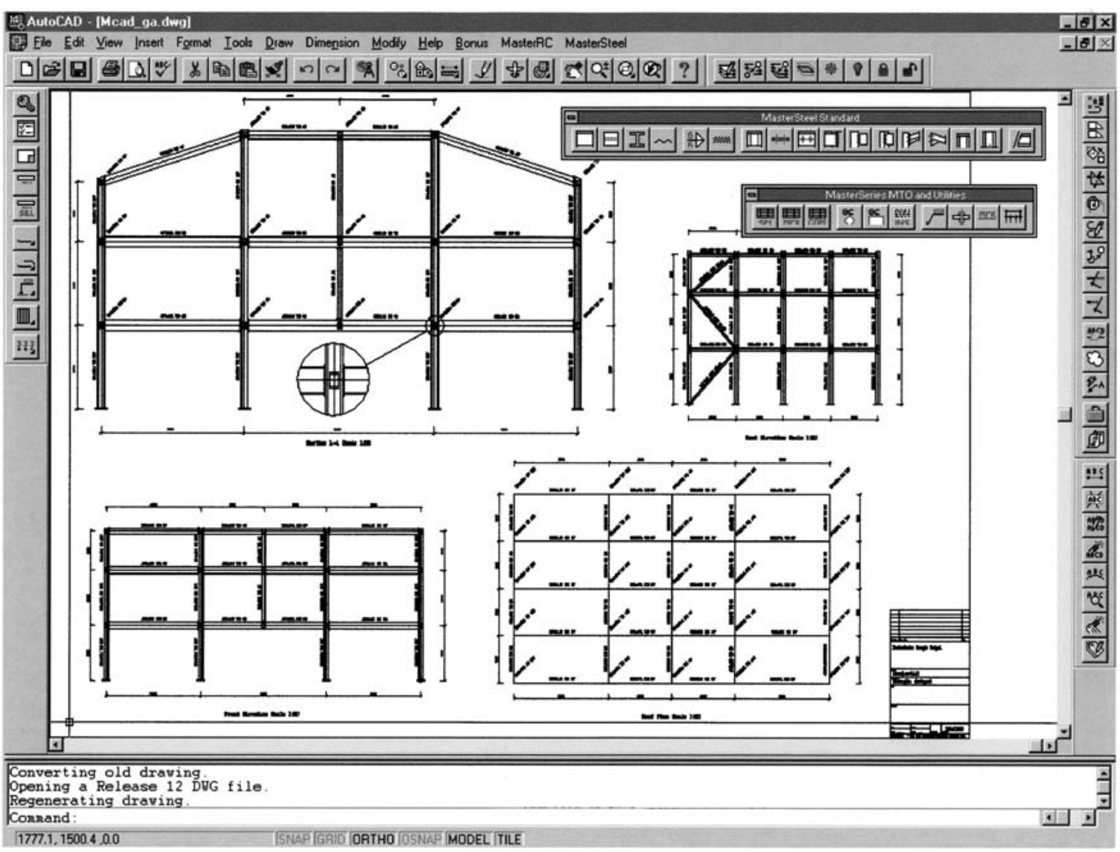


Fig. 3.6. CAD detailing of steel components (BS 5950 practice – MasterSeries)

Table 3.2. Standard abbreviations

American Standard	AS	horizontal	horiz, HORIZ
approximate	approx	including	incl
arrangement	arrgt	inside or internal	diameter ID
as other end	AOE	intermediate	interm
assembly	assy	kilonewton	kN
back mark	BM	kilonewton-metre	kN.m
beam	bm, Bm	kilopascal	kPa
bearing	brg, BRG	left hand	LH
bending moment	BM	length, overall length	len, O ALL
between	betwn	level	lev
bevel	bev	long	lg
bottom	btm	long leg outstanding	llos
building	bldg	machined (surface)	m/c
centre, centres	cr, crs	bridge	brdg
British Standard	BS	mark	mk, MK
centre line	cl ℄	marked	mkd
centre to centre	c/c	material	matl
circular hollow section	CHS	maximum	max
cleat	clt, CLEAT	megapascal	MPa
column	col	metre	m
continuous	cont	millimetre	mm
cross centres	c/c	minimum	min
countersunk	csk, CSK	miscellaneous	misc
cylinder, cylindrical	cyl	near side	ns
detail	dtl	Newton	N
diameter	dia, DIA	nominal	nom, NOM
diagonal	diag	not to scale	NTS
dimension	dim, DIM	number	No
distance	dist	opposite	opp
ditto	-do-, ditto	outside diameter	OD
drawing	drg	outstanding leg	osl
excluding	excl	overall	oa
extension	extn	pitch circle diameter	PCD
far side	fs	plate	pl, PLT
figure	fig	plate girder	PG
fillet weld	fw	radius	RAD, rad
finish floor level	FFL	rectangular hollow section	RHS
flange	flg, FLG	reinforced concrete	rc, RC
flat bar	fl	required	reqd, REQD
floor level	FL	revised	revd
foundation	found	revision	rev
galvanised	galv	right hand	RH
general arrangement	GA	setting out point	SOP
girder	gdr, Gdr, GDR	short leg outstanding	slos
grade (of steel or bolt)	Gr	sketch	sk
gusset	guss, GUSSET	specification	spec
hexagon	hex	square	sq
high-strength friction-grip	HSFG	square hollow section	SHS
holding down (bolt)	HD	standard	std
hole, holes	hl, hls	top of steel	TOS
steelwork	stwk	typical	typ, TYP
stiffener	stiff	underside	u/s
symmetrical	sym	unless otherwise noted	uon
thick	thk	vertical	vert, VERT
tolerance	tol	volume	vol
top of concrete	TOC	full penetration weld	FPBW
top of foundation	TOF	(butt type)	

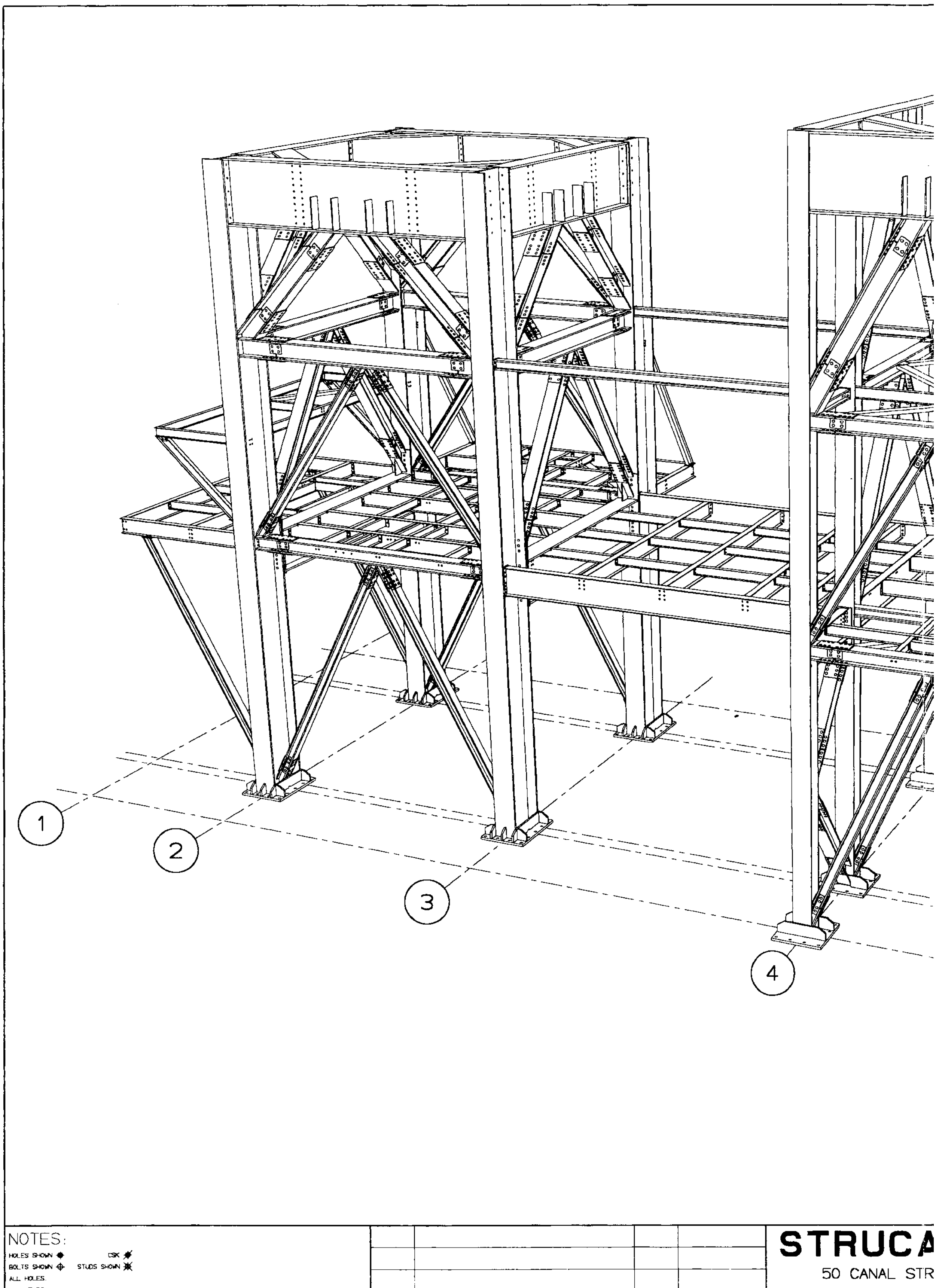
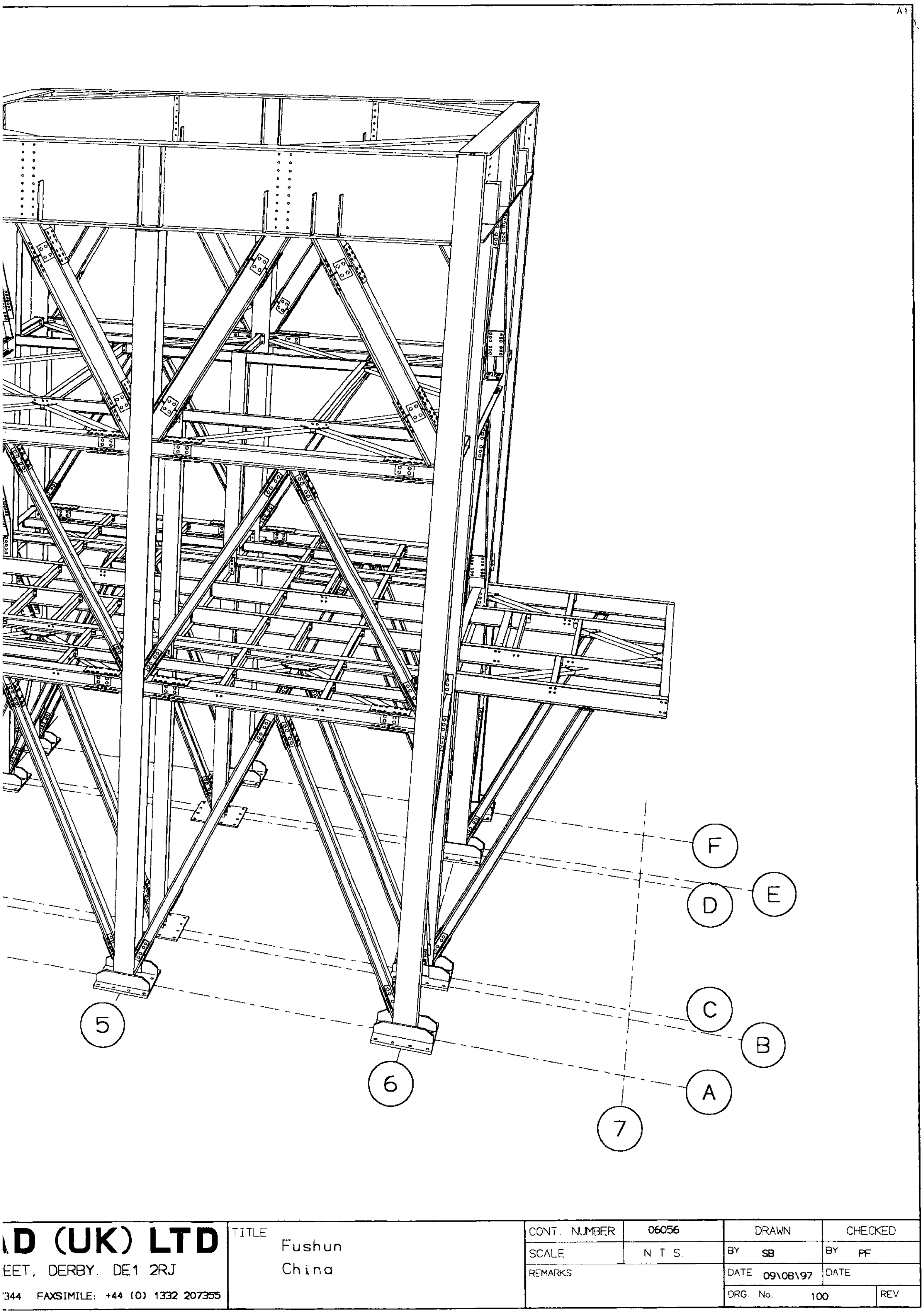


Fig. 3.7. CAD detailing (BS 5950 practice)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(*f*) The code of practice to which the building was designed, so that the design of connections and other details can be carried out to the same code.
(*g*) The specifications to which the steelwork is to be fabricated, welded and erected.
(*h*) The grade of steel to be used for the various parts of the building, e.g. Grade Fe 430 (EC3) steel for hot-rolled sections.
(*i*) The bolt grades to be used for the shop and site connections. Details of friction-grip type connections must be provided by the engineer.
(*j*) Cambers, if required, for long-span plate girders, lattice girders or trusses need to be provided.

3.4.4. General arrangement and detail drawings

The general arrangement drawings are similar to those provided by the engineer. However, they usually do not include member loads and forces, but do include member erection marks.

The orientation of the building is shown by means of a north arrow. Where true north is not parallel to one of the sides of the building (in plan), the ‘grid north’ convention is used for convenience, this being the direction (parallel to one side) nearest to true north.

Detail drawings depict every individual structure member and component in the job and include detailed notes on their fabrication. This information includes the section size and overall lengths of members, the positions and diameters of all holes, the positions, types and sizes of all welds, dimensions of notches, cut-outs and snipes where necessary, details of attachments such as cleats, brackets, base plates, stiffeners, bearing plates, etc., and many other details depending on the type of structure.

Beams, trusses, purlins, girts and girders are drawn in the horizontal position, i.e. parallel to the lower edge of the sheet. Short columns are drawn in the vertical position, but long columns are placed horizontally, with their bases to the right. Inclined girders, such as sloping conveyor gantries, may be drawn at their true slope or horizontally.

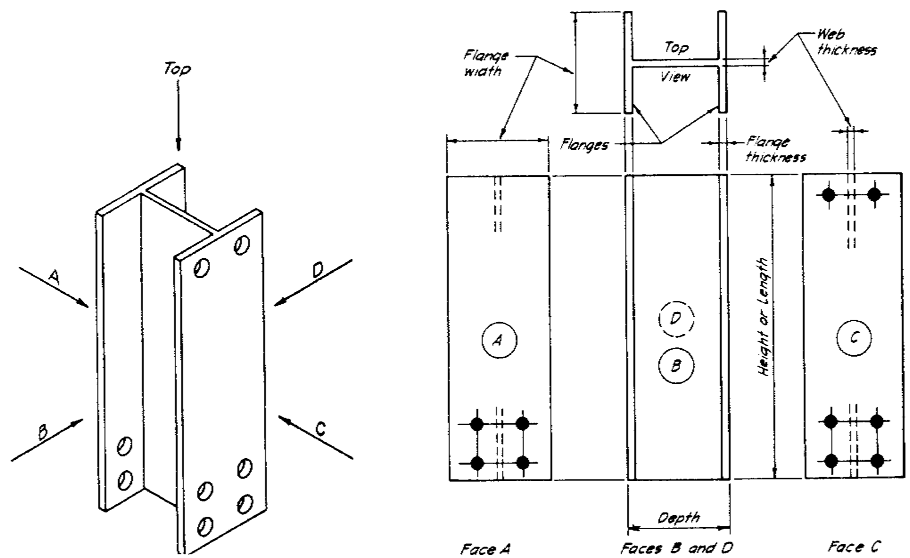
The most commonly used scale for detail drawings is 1:15, but in the case of more complex members a larger scale, say 1 : 10 would be used.

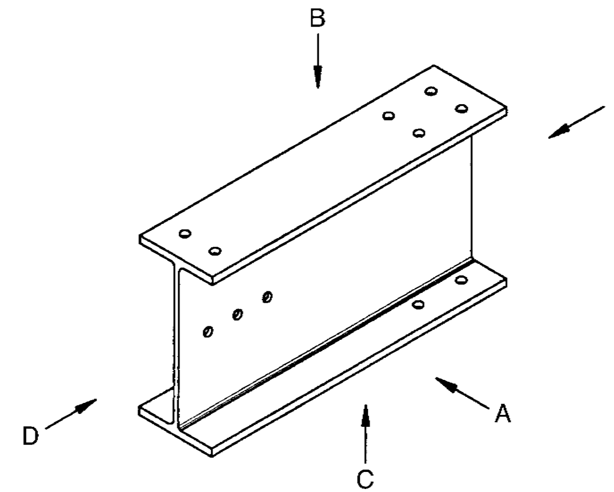
Detail drawings should be provided with a list of general notes, stating the grade of steel, the sizes and types of bolts to be used, the diameters of the bolt holes and whether the holes should be drilled or punched, the type of welding electrodes and what painting is required. Fig. 3.4 gives a layout based on these suggestions. Ideally, the drawing should also contain a small scale key plan in one corner showing the location of the detailed item in relation to the structure. Figs 3.5 to 3.8 show examples of computer aided detailing.

3.4.5. Abbreviations

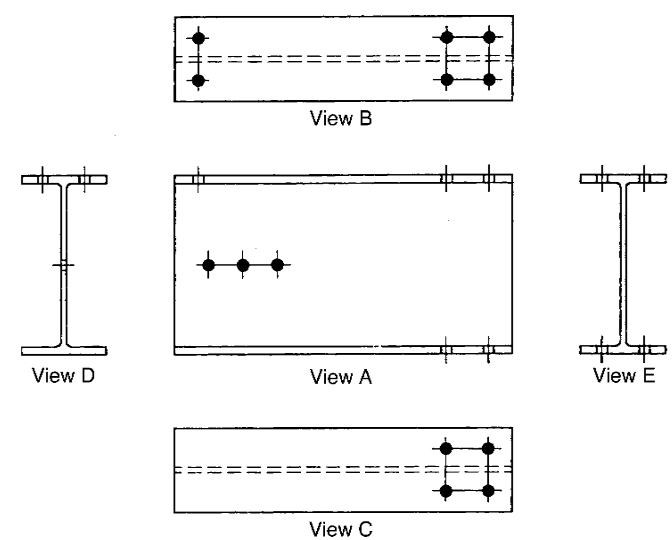
A large number of words and phrases are used repetitively on drawings. Their substitution by abbreviations saves the draughtsman's time and results in a less cluttered drawing. It is important, however, that only recognised, standard abbreviations are used and that their use is consistent. A list of the more common abbreviations is given in Table 3.2.

Third-angle orthographic projection

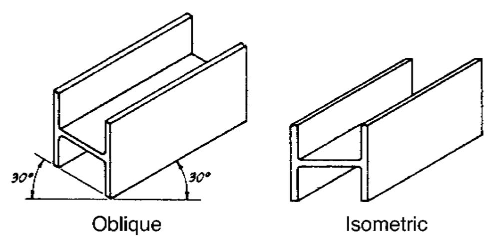




I-section beam



Detail of column



3.4.6. Orthographic projection

Although pictorial drawing has some application in developing and communicating ideas, it does not lend itself readily to making structural shop drawings. As a consequence, a multiview system known as orthographic projection is used for shop details throughout the industry. The basis of this method is to show the characteristics of an object by using as many dimensioned views as necessary to describe it fully.

The objects depicted on a design drawing are three-dimensional or solid, but on paper it is actually only possible to represent them in two dimensions. The method used by artists to create a realistic three-dimensional impression is called perspective drawing, where the building appears exactly as it would in a photograph. A simpler representation is shown in Fig. 3.9, called isometric drawing, along with a third representation in which three or more views are shown, the viewing axis being normal (perpendicular) to the surface of the part depicted. Fig. 3.10 indicates beam and column details in third-angle orthographic projection showing various views drawn along A–D directions.

4. Bolts and bolted joints

4.1. Introduction

The most common method of joining one component to another in structural steelwork is bolting. Bolting may be carried out either in the shop or on site and has the advantage that the components can be separated easily should this become necessary for any reason. Most fabricators prefer to use welding for shop connections, but where workshops are equipped with automated punching and drilling machines, shop bolting is generally found to be quicker and cheaper. For site connections, however, bolting is virtually the universal medium of connection. The main function of the bolt is to transmit a force from one member to another.

In all bolted connections a transfer of force is involved and in nearly all cases the transfer is by one or more of the following modes:

(*a*) shear in the bolt shank,
(*b*) bearing of the bolt shank against the holes in the two components,
(*c*) friction between the parts when the bolt is tightened to clamp the parts firmly together, and
(*d*) tension, when the load is applied in the axial direction of the bolt.

All these cases are shown in Fig. 4.1.

It is necessary for the steelwork detailer to have a clear understanding of how bolts work and to be able to select a suitable group of bolts to transmit the forces specified on the engineer’s drawings.

In the following section, the recommendations given by the British, European and American codes are discussed.

4.2. Types of bolt

Bolts have hexagonal heads and nuts, parallel shanks and threads cut or rolled into the shanks. They come in standard shank diameters of 12 mm, 16 mm, 20 mm and 24 mm in a large range of lengths and in various grades of strength. Fig. 4.1 illustrates a typical structural bolt, nut and washer assembly and gives the associated terminology. Bolts are designated by size, i.e. the nominal diameter of the shank and thread, and by length, i.e. the total length of the shank (including thread) up to the underside of the head. The bolt sizes mentioned above are designated M12, M16, M20 and M24 (M means metric).

Here the British and the European Codes have common designations. The American designations are as follows:

- ASTM A307 — Grade A and B (unfinished bolts) $\frac{1}{4}$ in. to 4 in. (6·4 mm to 100 mm)
- ASTM A502 — Ribbed type grades
- ASTM A325 — Bearing type, same as ASTM A307 for sizes including 16 mm

- ASTM A325, A490 — High-strength bolts 5/8 in. to 1 in. (16 mm to 25·4 mm)

Table 4.1 gives a summary of the ASTM versions of various bolt types.

4.2.1. ASTM specifications

A variety of bolt designations exists. Bolts are employed for a number of different purposes. The following list details some well known designated bolts.

(*a*) ASTM A307 (unfinished) bolts — Grade A and Grade B with a minimum tensile strength of 55 ksi for all sizes, $\frac{1}{4}$ in. to 4 in. inclusive. They are tightened securely by using long handled manual wrenches and are widely used for relatively light members. The nuts are easily loosened and hence require special locking features.
(*b*) Turned bolts (replaced by high-strength bolts).
(*c*) Ribbed bolts — these are interference type fasteners made from carbon steel ⩾A502 Grade 1 rivet.
(*d*) Bearing bolts — the bearing bolt incorporates the advantages of the ribbed bolt and the knurled pattern, and a heavy nut with or without a washer. Bolt ribs are designed with a small taper to facilitate progress through the hole. It is claimed that, while driving, the interrupted ribs will not peel, pack under the head or break off; they will cut grooves into the sides of the hole into the process of filling it. In this manner full bearing is created along the entire grip length. This body-bound fit affords not only a fully effective cross-sectional bolt area but also a rigid joint with an inherent resistance to slippage. Therefore, the bolt will transmit load primarily by shear and bearing and the initial tensioning normally required for other high-strength bolts may be considered unnecessary.
(*e*) High-strength tension control and tension set bolts — these bolts, commonly known as TC and TS bolts, are similar in performance. Fasteners equivalent to ASTM A325 and A490 bolts in sizes ranging from diameters of $\frac{5}{8}$–12 in. can be supplied. Each bolt has a round head with a torque control notch at its tip. Bolts are installed with an electric wrench which engages both the bolt and the nut in the outer and the inner sleeves of the wrench until the notch of the bolt shears off. The bolt does not rotate during fastening. The notch is designed to shear off when the fastener is loaded to a predetermined tension. The advantage of these bolts is that the completion of bolt fastening can be confirmed by the shear-off of the notch, thus eliminating the use of an inspection wrench. Data for various bolts are given in tabulated form, together with individual specifications beginning with the high-strength bolts.

High-strength bolts

High-strength bolts produce large and predictable tensions when tightened. Initially, tensioning of high-strength bolts also results in more rigid joints, more satisfactory stress distributions, and greater assurance against nut loosening.

The A325 bolt is available in the following three types:

- Type 1 — bolts of medium-carbon steel, in sizes $\frac{1}{2}$ to $1\frac{1}{2}$ in. diameter, inclusive
- Type 2 — bolts of low-carbon martensite steel, in sizes $\frac{1}{2}$ to 1 in. diameter, inclusive (not to be hot galvanised)
- Type 3 — bolts having atmospheric corrosion resistance and weathering characteristics comparable with those of A588 and A242 steels in sizes $\frac{1}{2}$ to $1\frac{1}{2}$ in. diameter, inclusive.

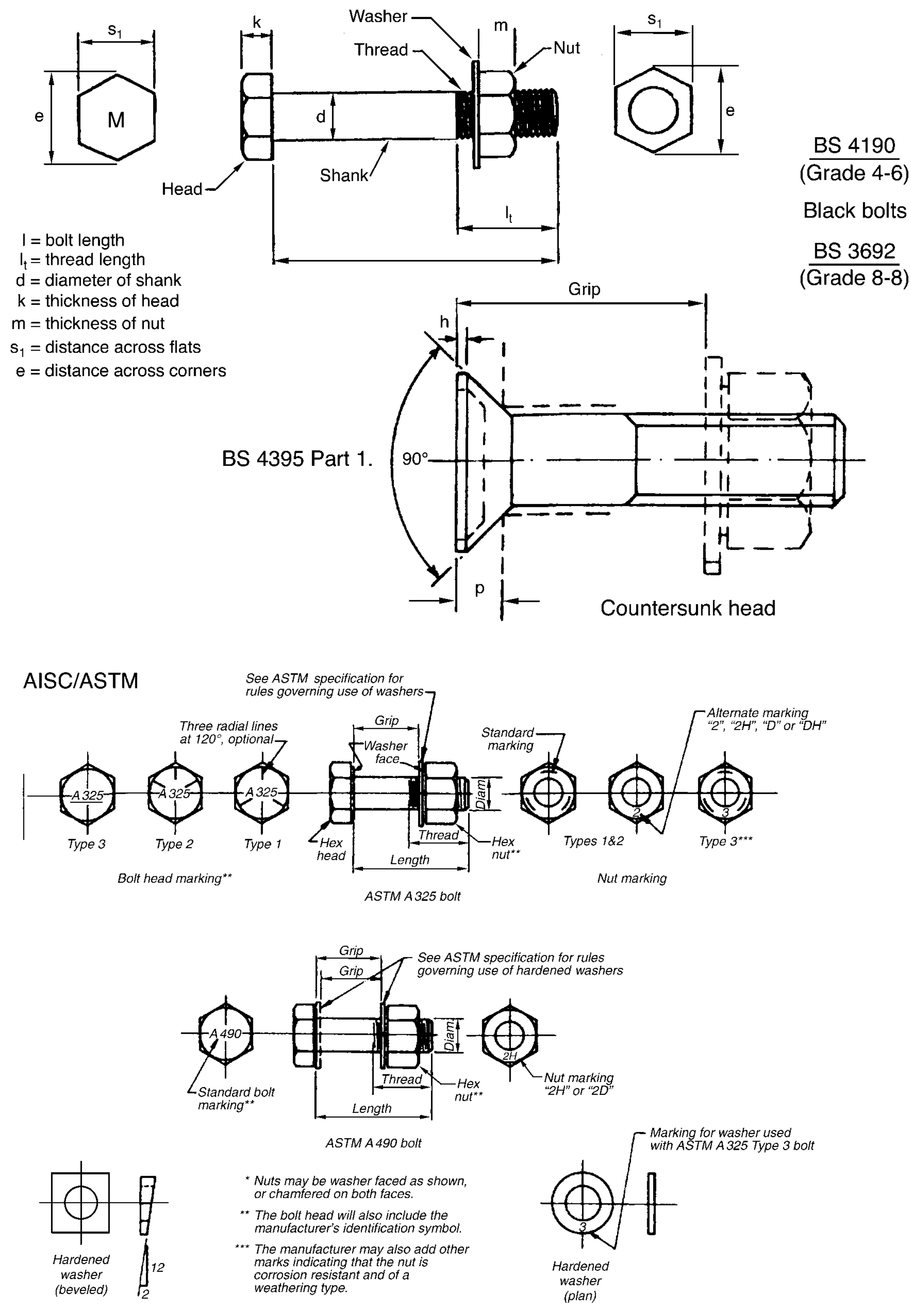
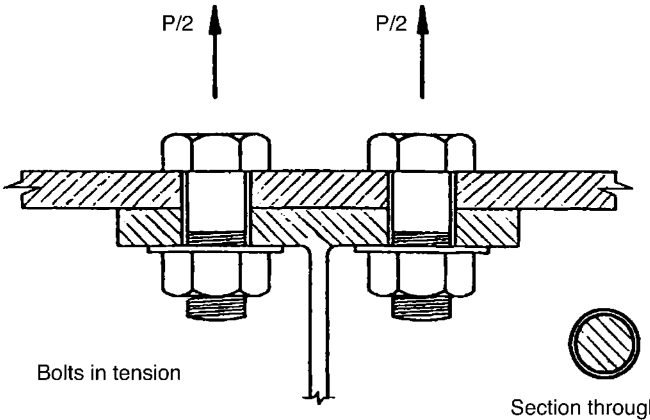
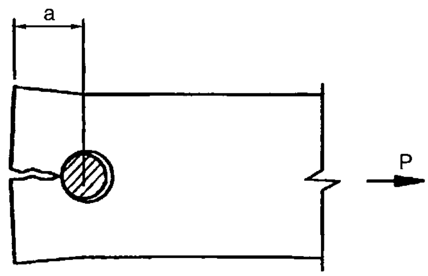


Fig. 4.1. Data on bolts

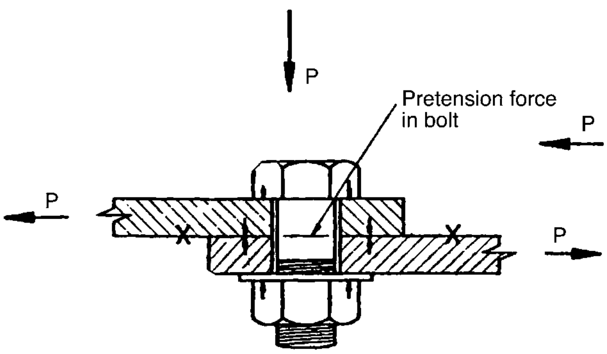


Bolts in tension

Section through bolt

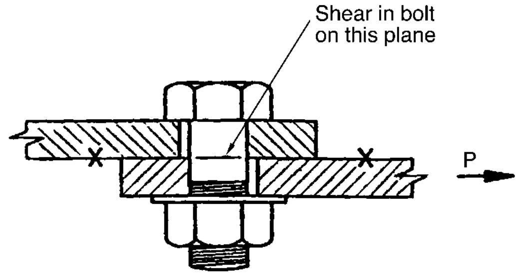


Bolt end distance

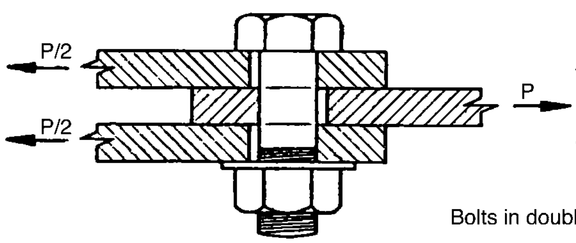


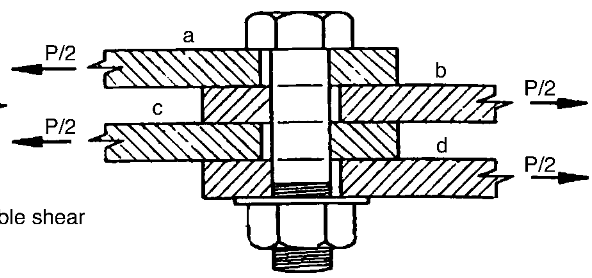
X – X = friction plane

HSFG bolt



Bolt in single shear





Bolts in double shear

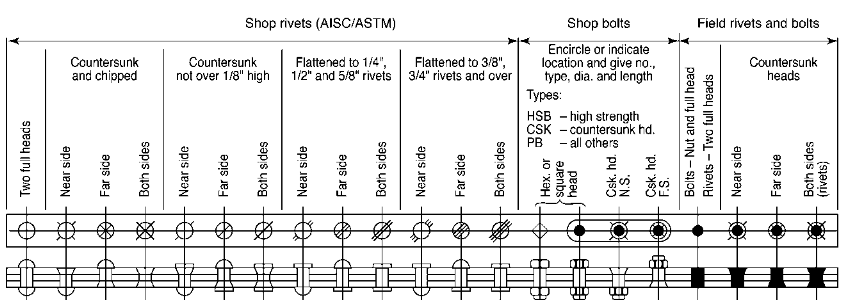


Table 4.1. Properties of high-strength structural bolts

ASTM designation	Type name	Bolt diameter: in.	Tensile strength on stress area: ksi[a]	Proof load on stress area: ksi[b]
A32-88a	High-strength bolts For structural steel joints	$\frac{1}{2}$–1	120	85
		$1\frac{1}{8}$–$1\frac{1}{2}$	105	74
A490-88a	High-strength alloy steel bolts for structural steel joints	$\frac{1}{2}$–$1\frac{1}{2}$	150–170[c]	120[c]

[a] Stress area = 0·785 (D − 0·9743/n)^2; D = nominal bolt size, n = threads per in.
[b] Ratio of proof load tensile strength is roughly 0·70 for A325 and A490 bolts.
[c] Same as A354-BD bolts.

Type 1 is used if the type is not specified.

Dimensional requirements for the A325 and the A490 bolt are identical and must conform to the ANSI Standard B18.2 for heavy hexagonal structural bolts, which have shorter thread lengths than other standard bolts.

Required bolt length may be determined in the following manner: add the grip (total thickness of connection material) and the stock length adjustment and the washer thickness (5/32 in. for a flat hardened washer and 5/16 in. for a bevel washer), if any. These bolt lengths should be rounded up to the next $\frac{1}{4}$ in.

Different grades of high-strength bolts are combined with various nuts which guarantee failure by bolt yielding rather than by stripping of the nut threads. Heavy semi-finished hexagonal nuts, with dimensions conforming to the requirements of the ANSI Standard B18.2, are used with both the A325 and the A490 bolts.

Table 4.1 gives a summary of high-strength bolts, material properties, loads and stress. Fig. 4.1 gives the bolt assembly specified by ASTM.

Installation and inspection of high-strength bolts

The procedure for installing high-strength bolts depends on whether the joint is slip-critical or not. For slip-critical joints, the installation procedures used in tightening A325 and A490 bolts are essentially the same. Although pneumatic powered impact wrenches are preferred, long-handled manual torque wrenches or electrical wrenches may be used.

The diameter of round bolt holes (‘standard’ holes) must not be more than 1/16 in. larger than the nominal diameter of the bolt. Holes may be punched in material not thicker than the nominal bolt diameter plus 1/8 in. Holes must be either drilled or subpunched and reamed in thicker material. Oversize, short-slotted, and long-slotted holes may be used if approved by the designer. Table 4.5 summarises the sizes and other important features of oversize and slotted holes permitted by the AISC. Hardened washers are required for bolts in oversize and slotted holes.

The inspection procedures for high-strength bolts must be sufficiently outlined in the contract documents agreed among the architects, engineers, contractors and the inspection agencies. The inspection document must be referred to prior to the inspection. Table 4.6 gives one area of inspection for the nut rotation from snug-tight conditions. A typical beam detailing is shown in Fig. 4.2.

Table 4.2. Bolt proof loads

Bolt size	Min. bolt tension: kips[a]	
	A325 bolts	A490 bolts
$\frac{1}{2}$	12	15
$\frac{5}{8}$	19	24
$\frac{3}{4}$	28	35
$\frac{7}{8}$	39	49
1	51	64
$1\frac{1}{8}$	56	80
$1\frac{1}{4}$	71	102
$1\frac{3}{8}$	85	121
$1\frac{1}{2}$	103	148

[a] Equal to 70% of specified tensile strength.

Table 4.3. Combined tension and shear on bolts

Bolt type	Threads in shear plane		No threads in shear plane	
A325	$\sqrt{(44^2 - 4{\cdot}39 f_v^2)}$	$\begin{pmatrix} 117 - 1{\cdot}9\, f_v \leqslant 90 \\ 147 - 1{\cdot}9\, f_v \leqslant 113 \end{pmatrix}$	$\sqrt{(44^2 - 2{\cdot}15 f_v^2)}$	$\begin{pmatrix} 117 - 1{\cdot}5\, f_v \leqslant 90 \\ 147 - 1{\cdot}5\, f_v \leqslant 113 \end{pmatrix}$
A490	$\sqrt{(44^2 - 4{\cdot}39 f_v^2)}$		$\sqrt{(54^2 - 1{\cdot}82 f_v^2)}$	
A307		$\begin{pmatrix} 59 - 1{\cdot}9\, f_v \leqslant 45 \\ 26 - 1{\cdot}8\, f_v \leqslant 20 \end{pmatrix}$		

The AISC-ASD allowable bolt tension in ksi is given by the following: ($\phi F_t A_b$) where, $\phi = 0{\cdot}75$; F_t = nominal tension stress. Equations in brackets show AISC-LRFD specification.

4.2.2. British and European codes and specifications

The three most commonly used types of bolt are the following:

(*a*) grade 4·8 ordinary bolts — these are used for the great majority of connections, especially where force transfer is by shear and bearing,
(*b*) grade 8·8 precision bolts — having a much higher strength grading and manufactured to closer dimensional tolerances than ordinary bolts,
(*c*) high-strength friction-grip bolts — the grade generally used is 8·8S but a higher grade 10·9S is also available. These bolts are used for force transfer by friction between the connected parts.

For other grades refer to Figs 4.3 and 4.4.

The strength gradings have the following significance. The first number, multiplied by 100 is the minimum tensile strength (approximately) of the bolt material in MPa. The second number, divided by 10, is the ratio (approximately) of the yield stress or stress at a permanent set of 0·2% to the minimum tensile strength. Therefore, a grade 8·8 bolt has a tensile strength of 800 MPa and yield stress of $0{\cdot}8 \times 800 = 640$ MPa. A grade 4·8 bolt has a tensile strength of 420 MPa and yield stress of 340 MPa. The lengths in which each size of bolt is available (i.e. the size/length combinations) are given in Table 4.8.

4.3. Bolt holes

The holes for the bolts will usually be punched or drilled and will have a diameter 2 mm larger than the bolt shank diameter for bolt sizes up to 24 mm diameter and 3 mm larger for bolts of greater diameter. Such holes are called clearance holes; they facilitate assembly of components by making allowance for slight inaccuracies in fabrication of the steelwork. Reference should be made to specific codes where variations exist.

4.4. Strength or resistance of bolts

The different modes by which bolts are able to transmit a force are described in Table 4.7. The ability of a bolt to transfer an applied force, i.e. its ability to withstand this force, is called its resistance. The resistance is dependent on three main components:

(*a*) the area over which the force is applied,
(*b*) the strength of the bolt material and

Table 4.4. AISC allowable stresses and nominal strengths for high-strength bolts

		AISC-ASD[a] allowable stress: ksi		AISC-LRFD nominal strength: ksi		
Load condition	Hole type	A325	A490	A325	A490	ϕ
Tension	Standard, oversize, or slotted	44	54	90	113	0·75
Shear: slip-critical connection[b]	Standard	17·0[c]	21	17	21	1
	Oversize, short-slot	15·0[c]	18	15	18	1
	Long-slot	12·0[c]	15	12	15	0·85[d]
Shear: bearing connection[e,f]						
Threads in shear plane	Standard or slot	21	28	48	60	0·75
No threads in shear plane	Standard or slot	30	40	60	75	0·75
Bearing	Standard or short-slot	$1{\cdot}2F_u$[g]	$1.2F_u$[g]	$2{\cdot}4F_u$[i]	$2{\cdot}4F_u$	0·75
	Long-slot perpendicular to load	$1{\cdot}0F_u$[g,h]	$1{\cdot}0F_u$[g,h]	$2{\cdot}4F_u$[j]	$2{\cdot}4F_u$[j]	0·75

[a] Values given are those of the AISC-ASD specification. For slip-critical connections, AISC prescribes the same shear values as for LRFD and more conservative bearing values.
[b] Class A surfaces (clean mill scale and blast-cleaned surfaces with Class A coatings slip coefficient = 0·33). For other surfaces see Ref. 13, Appendix A1.
[c] Service-load shears must be less than these values multiplied by the applicable values of ϕ. allowable shear per bolt = $2\phi A_v F_v$ allowable bearing per bolt = $2{\cdot}4\phi dtF_u$
[d] Use $\phi = 0{\cdot}85$ if the load is in the direction of the slot.
[e] Tabulated values shall be reduced by 20% for connections transmitting axial force if the distance parallel to the force, between extreme fasteners exceeds 50 in.
[f] Static loading only. For fatigue loading, see AISC-LRFD specification Appendix K4 and AISC-ASD specification Appendix K4.
[g] Minimum spacing and edge distances apply.
[h] If deformation around the hole is not a design consideration and adequate spacing and edge distances are provided, the allowable stress may be increased to $1{\cdot}5F_u$.
[i] Applies to connections with two or more bolts in the line of force and distance from centre of hole or centre of the end of a slotted hole, to edge of connected part not less than 1·5d, and centre of holes not less than 3d apart.
[j] If deformation around the hole is not a design consideration, the allowable stress for the bolt nearest the edge may be increased to $3{\cdot}0F_u$.

Table 4.5. Oversize and slotted holes

Type of hole	Nominal bolt size: in.	Overall dimension of hole: in.	Hardened washer	Remarks
Oversize	$\frac{3}{8}-\frac{7}{8}$	Nominal size + $\frac{3}{16}$	One in outer ply	May be used in slip-critical connection
	1	$1\frac{1}{4}$		
	$1\frac{1}{8}$	$1\frac{7}{16}$		
	$1\frac{1}{4}$	$1\frac{9}{16}$		
	$1\frac{3}{8}$	$1\frac{11}{16}$		
	$1\frac{1}{2}$	$1\frac{13}{16}$		
Short-slotted	$\frac{3}{8}$	$\frac{11}{16}\times\frac{7}{8}$	One in outer ply	May be used in slip-critical or bearing-type connections. Slot must be normal to direction of loading in bearing-type connection
	$\frac{3}{4}$	$\frac{13}{16}\times 1$		
	$\frac{7}{8}$	$\frac{15}{16}\times 1\frac{1}{8}$		
	1	$1\frac{1}{16}\times 1\frac{3}{16}$		
	$1\frac{1}{8}$	$1\frac{3}{16}\times 1\frac{1}{8}$		
	$1\frac{1}{4}$	$1\frac{5}{16}\times 1\frac{3}{8}$		
	$1\frac{3}{8}$	$1\frac{7}{16}\times 1\frac{3}{4}$		
	$1\frac{1}{2}$	$1\frac{9}{16}\times 1\frac{7}{8}$		
Long-slotted	$\frac{3}{8}-1\frac{1}{2}$	Width: nominal diameter plus $\frac{1}{16}$. Length: not to exceed $2\frac{1}{2}$ times bolt diameter	$\frac{5}{16}$ in. plate washer with standard hole, and hardened washers if required	May be used in only one of the connected parts of either slip-critical or bearing-type connection. Slot must be normal to the direction of loading in bearing-type connection

*Table 4.6. Nut rotation from snug-tight condition**

Bolt length (as measured from underside of head to extreme end of point)	Disposition of outer faces of bolted parts: Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	$\frac{1}{3}$ turn	$\frac{1}{2}$ turn	$\frac{2}{3}$ turn
Over 4 diameters but not exceeding 8 diameters	$\frac{1}{2}$ turn	$\frac{2}{3}$ turn	$\frac{5}{6}$ turn
Over 8 diameters but not exceeding 12 diameters†	$\frac{2}{3}$ turn	$\frac{5}{6}$ turn	1 turn

* Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by $\frac{1}{2}$ turn and less, the tolerance should be ±45°. Required rotation must be determined by tests in a tension device simulating the actual conditions.

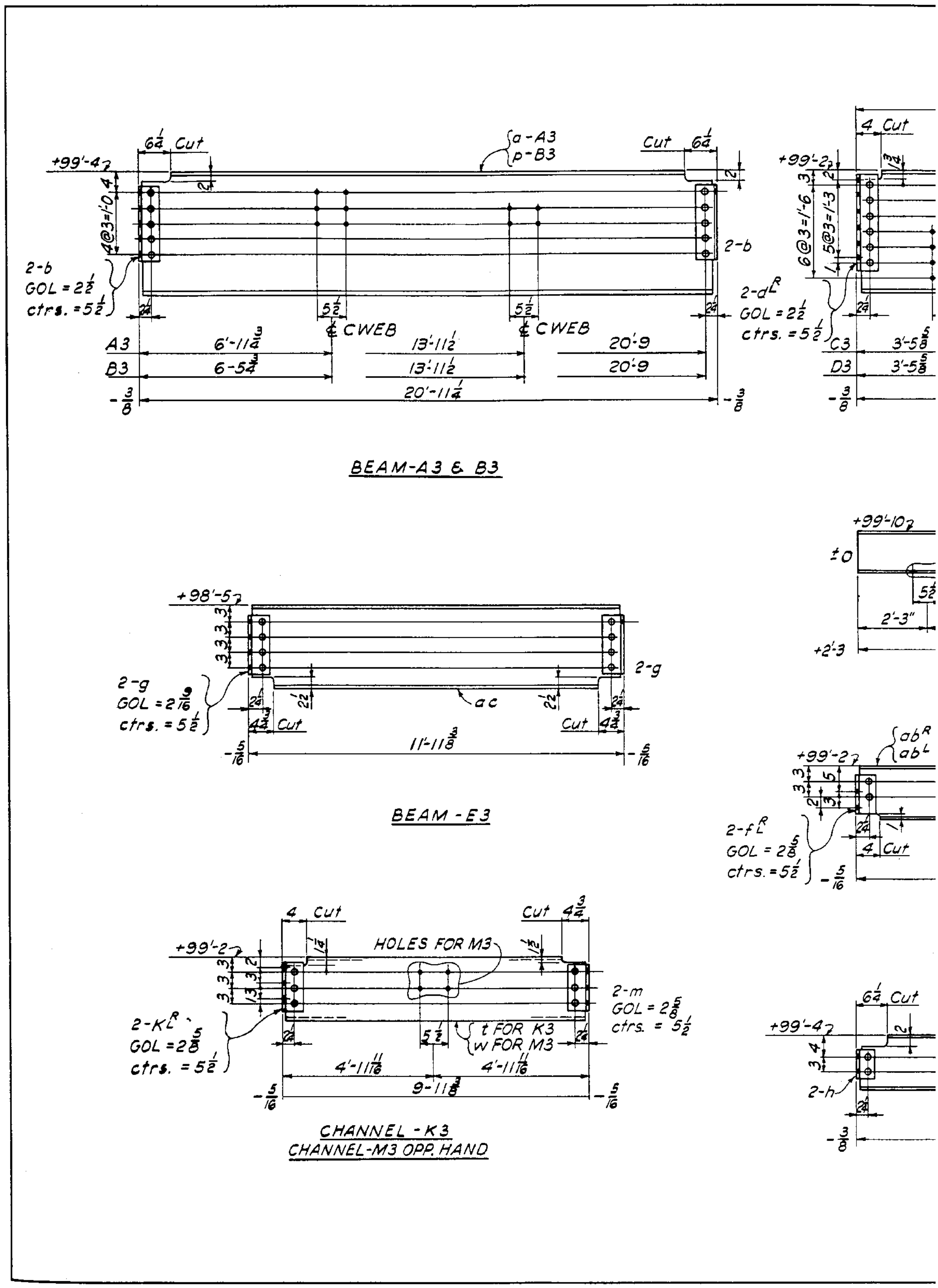
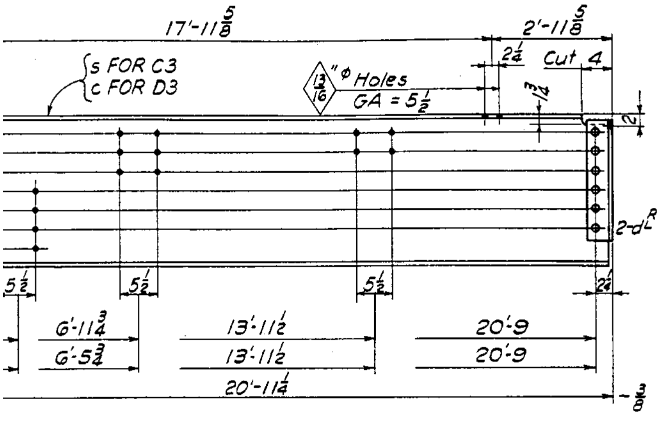
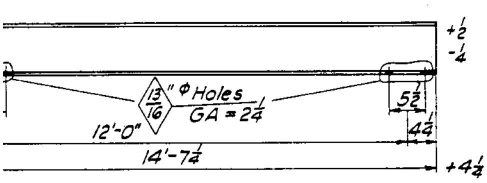


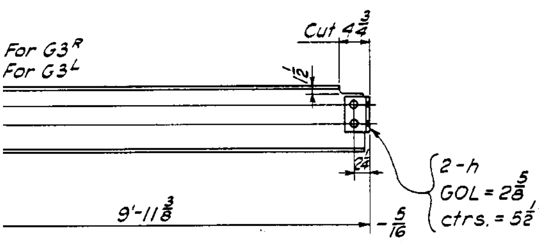
Fig. 4.2. Typical fabrication details for a beam (AISC practice)



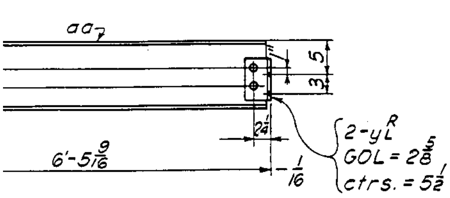
BEAM - C3 & D3



BEAM - F3



CHANNEL - G3 R
CHANNEL - G3 L



BEAM - N3

BILL OF MATERIALS												
	SHOP BILL						Weight	MILL ORDER				
Line	No.	Shape	Ft.	In.	Ass'bly Mark	Remarks		No.	Shape	Length Ft.	Length In.	Item
1	2	BEAMS: 1-A3 & 1-B3										
2	1	W 24 × 76	20	10½	a	A3	1586					73
3	1	W 24 × 76	20	10½	p	B3	1586					73
4	8	L 4 3½ 3/8	1	2½	b		88			22	0	110
5	20	Riv. 7/8 φ					20					
6							3280					
7	2	BEAMS: 1-C3 & 1-D3										
8	1	W 24 × 94	20	10½	s	C3	1962					62
9	1	W 24 × 94	20	10½	c	D3	1962					62
10	4/4	L 4 3½ 3/8	1	6½	d R/L		112					110
11	24	Riv. 7/8 φ					24					
12							4060					
13	ONE BEAM - E3											
14	1	W 16 × 40	11	10½	ac		475					86
15	4	L 4 3½ 3/8		11½	g		36					s
16	8	Riv. 7/8 φ					8					
17							519					
18	ONE BEAM - F3											
19	1	S 8 × 18.4	14	7¼			269					
20												
21	2	CHANNELS 1-G3 R & 1-G3 L										
22	1/1	C 10 × 15.3	9	10½	ab R/L		302			10	4½	118
23	2/2	L 4 3½ 3/8		7½	f R/L		23					s
24	4	L 4 3½ 3/8		5½	h		16					s
25	8	Riv. 7/8 φ					8					
26							349					
27	2	CHANNELS 1-K3 & 1-M3										
28	1	C 12 × 20.7	9	10½	t	K3	205			19	10	81
29	1	C 12 × 20.7	9	10½	w	M3	205					81
30	4	L 4 3½ 3/8		8½	m		26					s
31	2/2	L 4 3½ 3/8		9½	K R/L		28					s
32	12	Riv. 7/8 φ					12					
33							476					
34	ONE BEAM - N3											
35	1	W 10 × 15	6	4¾	aa		96					85
36	2				h		8					s
37	1/1	L 4 3½ 3/8		6½	y R/L		10					s
38	4	Riv. 7/8 φ					4					
39							118					
40												

Gen. Notes:
Spec: AISC latest edition
Matl: ASTM A 36
Rivets 7/8" φ
Holes 15/16" φ unless noted
Paint: As per Spec.

TITLE BLOCK

(*c*) a factor, called a resistance factor, which allows for variability of material properties and workmanship.

When these three components are multiplied together they give the factored resistance of the particular bolt under consideration. Thus, in general terms,

$$\text{Factored resistance} = \phi A f_u$$

where ϕ is the resistance factor, A the relevant area and f_u a unit stress dependent on the minimum tensile strength of the bolt material. Again, the value of ϕ has to be judged against a specific code.

The factored shear resistance of a bolt is dependent on its material grade and its cross-sectional area on the shear plane, whereas the factored bearing resistance is dependent on the diameter of the bolt, the grade of the plate material and the thickness of the plate.

Bolts may be in tension (see Fig. 4.1). In this type of loading, the force in each bolt is P divided by the number of bolts in the connection (in this case,

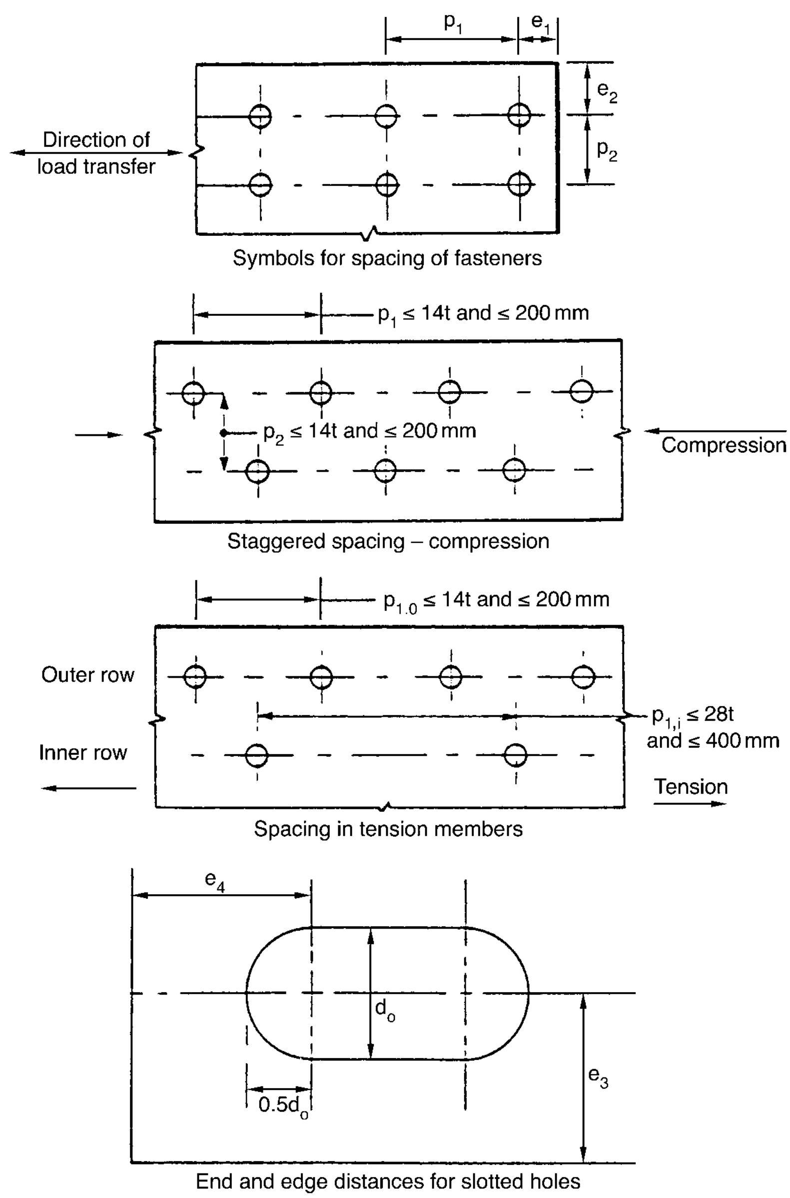


Fig. 4.3. Bolted connections (based on EC3). The extracts from DD ENV 1993 Part 1.1 are reproduced with the permission of BSI under licence number 2000SK/0364

two); the force acts axially in each bolt. There is no slip in the connection, so the bolts do not act in shear or bearing.

High-strength friction-grip bolts (or HSFG bolts) are used where a slip-resistant connection is required under shear loading, i.e. loading in the plane of the connected parts and at right angles to the bolt axes.

Table 4.7. Bolts, nuts and washers **ENV 1993-1-1: 1992**

Nominal values of yield strength f_{yb} and ultimate tensile strength f_{ub} for bolts

Bolt grade	4·6	4·8	5·6	5·8	6·8	8·8	10·9
f_{yb} (N/mm^2)	240	320	300	400	480	640	900
f_{ub} (N.mm^2)	400	400	500	500	600	800	1000

Bolts of grades lower than 4·6 or higher than 10·9 shall not be used unless test results prove their acceptability in a particular application.

Maximum spacing in compression members
The spacing p_1 of the fasteners in each row and the spacing p_2 between rows of fasteners, should not exceed the lesser of 14t or 200 mm. Adjacent rows of fasteners may be symmetrically staggered. The centre-to-centre spacing of fasteners should also not exceed the maximum width which satisfies local buckling requirements for an internal element.

Maximum spacing in tension members
In tension members the centre-to-centre spacing $p_{1,i}$ of fasteners in inner rows may be twice that for compression members, provided that the spacing $p_{1,0}$ in the outer row along each edge does not exceed that given in Fig. 4.3.

Slotted holes
The minimum distance e_3 from the axis of a slotted hole to the adjacent end or edge of any part (see Fig. 4.3) should not be less than $1{\cdot}5d_o$.

The minimum distance e_4 from the centre of the end radius of a slotted hole to the adjacent end or edge of any part (see Fig. 4.3) should not be less than $1{\cdot}5d_o$.

Both of these values may be multiplied by 1·5 in members not exposed to the weather or other corrosive influences.

Maximum end and edge distances
Where the members are exposed to the weather or other corrosive influences, the maximum end or edge distance should not exceed 40 mm + 4t, where t is the thickness of the thinner outer connected part.

In other cases the end or edge distance should not exceed 12t or 150 mm, whichever is the larger.

Minimum end distance
The end distance e_1 from the centre of a fastener hole to the adjacent end of any part, measured in the direction of load transfer (see Fig. 4.3) should be not less than $1{\cdot}2d_0$, where d_0 is the hole diameter.

The end distance should be increased if necessary to provide adequate bearing resistance.

Minimum spacing
The spacing p_1 between centres of fasteners in the direction of load transfer (see Fig. 4.3), should be not less than $2{\cdot}2d_o$. This spacing should be increased if necessary to provide adequate bearing resistance.

The spacing p_2 between rows of fasteners, measured perpendicular to the direction of laod transfer (see Fig. 4.3), should normally be not less than $3{\cdot}0d_o$. This spacing may be reduced to $2{\cdot}4d_o$ provided that the design bearing resistance is reduced accordingly.

Table 4.7. (continued). (Based on British Standards)

Washers (to BS 4320)				
Nominal Size	Diameter			Thickness (Nom)
	Inside (Nom)	Outside (max) d2		
d	d1	Normal	Large	s
(M12)	14	24	28	3
M16	18	30	34	3
M20	22	37	39	3
(M22)	24	39	44	3
M24	26	44	50	4
(M27)	30	50	56	4
M30	33	56	60	4
(M33)	36	60	66	5
M36	39	66	76	5

Bolts

Type	BS No
Black bolts, grade 4.6 (mild steel)	BS 4190 (nuts and bolts) BS 4320 (washers)
High tensile bolts, grade 8.8	BS 3692 (nuts and bolts) BS 4320 (washers)
HSFG bolts, general grade	BS 4395 Pt 1 (bolts, nuts and washers)
Higher grade	BS 4395 Pt 2 (bolts, nuts and washers)
Waisted shank	BS 4395 Pt 3 (bolts, nuts and washers)

The means of force transfer is by friction between the piles; no slipping takes place, so the bolts are not acting in shear or bearing. It is necessary, however to ensure an adequate frictional resistance between the contact surfaces of the connected parts. The frictional resistance is therefore dependent on

(*a*) the pretension force in the bolt and
(*b*) the coefficient of friction of the contact surfaces.

The means of load transfer illustrated in Fig. 4.1 is the only viable one.

After installation, all HSFG bolts have to be checked to ensure that sufficient torque has been applied to the nut to produce the required pretension in the shank. Washers should be used under the head and/or nut of bolts only in the following circumstances:

- bearing bolts with washers passing through holes with greater than normal clearance
- ordinary flat washers — bearing bolts where threads must be excluded from shear plane; use sufficient washers to prevent threads from being within thickness of connected parts that are required to develop bearing resistance

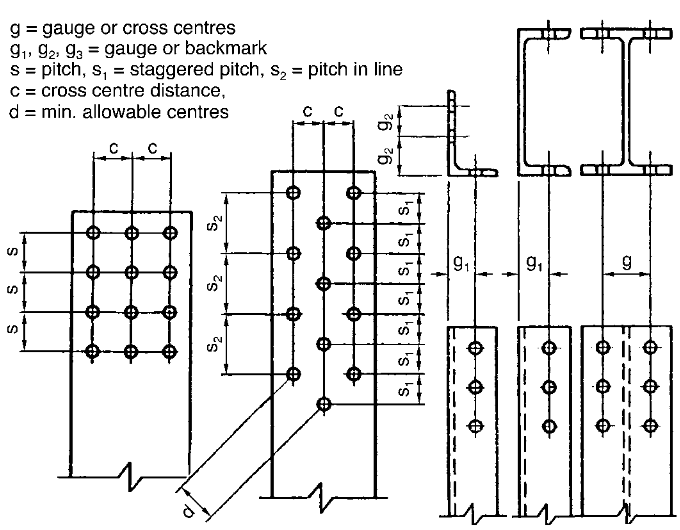


Fig. 4.4. Additional data on fastenings (based on British practice)

Table 4.8. Additional data on bolted connections (based on EC3)

HSFG Bolts	Washers						Add to Grip for Length
	Round				Tapered		
	Diameter		Thickness (nom)	Clip	Overall Size	Inside Diameter (nom)	
Nominal Size	Inside (nom)	Outside (max)					
d	d1	d2	s	w	c	d3	–
(M12)	14	30	3	12	–	–	22
M16	18	37	3	14	38	18	26
M20	21	44	4	18	38	21	30
(M22)	23	50	4	19	45	23	34
M24	26	56	4	21	57	26	36
(M27)	29	60	4	23	57	29	39
M30	33	66	4	26	57	33	42
(M33)	36	75	5	29	57	36	45
M36	–	–	–	–	–	–	48

Resistances of Grade 8.8 Friction-Grip Bolts

Size	Pre-Tension (kN)	Factored Tension Resistance (T_r)	Slip resistances, *Vs*, per interface per bolt, at serviceability load (kN)		
			Class of contact surface		
			A	B	C
(M12)	49	47.2	13.5	22.1	17.9
M16	91	83.9	23.9	39.4	31.8
M20	142	131	37.4	61.5	49.8
(M22)	176	159	45.2	74.4	60.2
M24	205	189	53.9	88.6	71.6
M30	326	295	84.1	138	112
M36	475	425	121	199	161

Contact surfaces:
A = Clean mill scale
B = Blasted clean
C = Galvanised and wire-brushed

Sizes in brackets are non-preferred

HSFG Bolts							Bolts and Nuts					Bolts				Nuts
Mechanical Properties to BS 4395: Parts 1&2							Pitch of Thread	Width Across Flats (max)	Width Across Girders (max)	Washer Face		Hex Head Depth (max)	Countersunk Headed			Depth (max)
	General Grade Part 1			Higher Grade Part 2						Diameter (max)	Depth		Diameter	Flash	Min Ply	
Tensile Stress Area	Proof Load	Yield Load	Ultimate Load	Proof Load	Yield Load	Ultimate Load										
mm²	kN	kN	kN	kN	kN	kN	–	s1	e	g	b	k	j	h	p	m
84.3	49.4	53.3	69.6	–	–	–	1.75	22	25	22	0.4	9	24	2	9	12
157	92.1	99.7	130	122.2	138.7	154.1	2.0	27	31	27	0.4	11	32	2	9	16
245	144	155	203	190.4	216	240	2.5	32	37	32	0.4	14	40	3	12	19
303	177	192	250	235.5	266	269.5	2.5	36	42	36	0.4	15	44	3	13	20
358	207	225	292	274.6	312	345	3.0	41	47	41	0.5	16	48	4	15	23
459	234	259	333	356	406	450	3.0	46	53	46	0.5	18	54	4	16	25
561	286	313	406	435	495	550	3.5	50	58	50	0.5	20	60	5	19	27
694	–	–	–	540	612	680	3.5	55	64	55	0.5	22	66	5	20	30
817	418	445	591	–	–	–	4.0	60	69	60	0.5	24	72	5	22	32

Table 4.8. (Continued)

Black Bolts									Dimensions to BS 4190 (nearest mm)					
		Mechanical Properties				Pitch of Thread	Width Across Flats (max)	Width Across Corners (max)	Depth of Head (max)	Bolts			Nuts	
		Grade 4.6 (BS 4190)		Grade 8.8 (BS 3692)						Standard Length of Thread			Depth m (max)	
Nominal Size	Tensile Stress Area	Ultimate Load	Proof Load	Ultimate Load	Proof Load					l				
d	mm²	kN	kN	kN	kN		s1	e	k	≤ 125	≤ 200	> 200	Standard	Thin
(M12)	84.3	33.1	18.7	66.2	48.1	1.74	19	22	9	30	36	49	11	7
M16	157	61.6	34.8	123	89.6	2.0	24	28	11	38	44	57	14	9
M20	245	96.1	54.3	192	140	2.5	30	35	14	46	52	65	17	9
(M22)	303	118.8	67.3	238	173	2.5	32	37	15	50	56	69	19	10
M24	353	138	78.2	277	201	3.0	36	42	16	54	60	73	20	10
(M27)	459	180	102	360	262	3.0	41	47	18	60	66	79	23	12
M30	561	220	124	439	321	3.5	46	53	20	66	72	85	25	12
(M33)	694	272	154	544	396	3.5	50	58	22	72	78	91	27	14
M36	817	321	181	641	466	4.0	55	64	24	78	84	97	30	14

Recommended Bolt and Nut Combinations										
Grade of Bolt	4.6	4.8	5.6	5.8	6.6	6.8	8.8	10.9	12.9	14.9
Recommended Grade of Nut	4	4	5	5	6	6	8	12	12	14

- ordinary flat washers — HSFG bolts where the torque-control method of tightening is used
- flat through-hardened washers — bolts passing through tapered flanges of I-sections or channels, or other tapered elements.

4.5. Layout of bolts

The arrangement of the bolt holes usually follows a rectangular pattern, i.e. the holes are in rows and the holes in one row are opposite those in other rows, as shown in Fig. 4.3. This provides for easier setting out and a neat appearance. The spacing between bolts in the longitudinal direction of member is called pitch and the spacing at right angles to this is called cross-centre distance. The minimum pitches and cross-centres that are allowable from a design point of view are laid down in various codes. When the bolts in alternate rows are offset from those in intermediate rows they are said to be in staggered pattern (see Fig. 4.3). This pattern is used when a large number of bolts are to be fitted into a limited width, since the zig-zag arrangement allows the bolts to be more closely nestled while still maintaining the required minimum centre-to-centre distance, d. However, the length of the bolt group is increased.

Holes in the flanges of I- and H-sections and channels and the legs of angles are usually placed on lines at a set distance from the web centres of the I- and H-sections (gauge lines or cross-centre lines) or from the backs of channels or angles.

4.5.1. ENV 1993-1-1: 1992 (EC3) requirements

Figure 4.4 gives specifications for bolts and other parameters for bolts in special circumstances including spacings and edge distances. The clearances in standard holes for fasteners (except for fitted bolts) are given by EC3 as follows:

- 1 mm for M12 and M14 bolts
- 2 mm for M16 and M24 bolts
- 3 mm for M27 and larger bolts

Holes with smaller clearances than standard holes may be specified. Holes with 2 mm nominal clearance may also be specified for M12 and M14 bolts, provided that the design meets the requirements. Oversize and slotted holes may be used for slip-resistance connections only where specified. The nominal clearance in oversize holes for slip-resistant connections shall be:

- 3 mm for M12 bolts
- 4 mm for M14 to M22 bolts
- 6 mm for M24 bolts
- 8 mm for M27 and larger bolts.

Oversize holes in the outer ply of a slip-resistant connection shall be covered by hardened washers. Holes for holding down bolts may be oversize holes with clearance as specified in the project specification, provided that these holes are covered by cover plates of appropriate dimensions and thickness. The holes in the cover plates shall not be larger than standard. The nominal sizes of short slotted holes for slip resistant connections shall be not greater than:

- $(d+1)$ mm by $(d+4)$ mm for M12 and M14 bolts
- $(d+2)$ mm by $(d+6)$ mm for M16 to M22 bolts
- $(d+2)$ mm by $(d+8)$ mm for M24 bolts
- $(d+3)$ mm by $(d+10)$ mm for M27 and larger bolts

where d is the nominal bolt diameter in mm.

The nominal sizes of long slotted holes for slip-resistant connections shall be not greater than:

- (d + 1) mm by 2·5d for M12 and M14 bolts
- (d + 1) mm by 2·5d for M16 and M24 bolts
- (d + 1) mm by 2·5d for M27 and larger bolts

Slots in an outer ply shall be covered by cover plates of appropriate dimensions and thickness. The holes in the cover plates shall not be longer than standard holes. The sizes required for long slotted holes for movement joints shall be specified.

Bolts

Where design is based on bolts with unthreaded shanks in the shear plane, appropriate measures shall be specified to ensure that, after allowing for tolerances, neither the threads nor the thread run-out will be in the shear plane.

Bolts with threads up to the head may be used except where prohibited by the project specification. The length of non-preloaded bolts shall be such that, after allowing for tolerances:

- the threaded shank will protrude beyond the nut after tightening, and
- at least one full thread (in addition to the thread run-out) will remain clear between the nut and the unthreaded part of the shank.

The length of a preloaded bolt shall be such that, after allowing for tolerances:

- the threaded shank will protrude beyond the nut after tightening, and
- at least four full threads (in addition to the thread run-out) will remain clear between the nut and the unthreaded part of the shank.

Nuts

For structures subject to vibration, measures shall be taken to avoid any loosening of the nuts. If non-preloaded bolts are used in structures subject to vibrations, the nuts should be secured by locking devices or other mechanical means. The nuts of preloaded bolts may be assumed to be sufficiently secured by the normal tightening procedure. Steel packing plates shall be provided where necessary to ensure that the remaining step does not exceed the specified limit. Unless a greater value is specified, the minimum thickness of a steel packing plate should be:

- 2 mm in indoor conditions, if exposed to corrosive influences
- 4 mm in outdoor conditions or if exposed to corrosive influences.

5. Welding

5.1. Introduction

Welding is the fusing together of two pieces of steel by means of heat to form a single piece. The heat is produced by the passage of an electric current through an electrode, causing the surfaces of the two pieces and the metal from the electrode to melt and fuse into one on cooling.

There are two main types of weld: butt welds and fillet welds. A butt weld (or groove weld) is defined as one in which the metal lies substantially within the planes of the surfaces of the joined components. A full penetration butt weld is normally expected to develop full strength. A partial penetration weld achieves a specified depth of penetration only. The most commonly used welding processes are manual metal arc welding (as described below), automatic welding with a continuous coated electrode feeding automatically off a drum, gas shielded welding, where a bare electrode is used, and submerged arc welding, which utilises an arc entirely submerged in a granular flux that is fed progressively onto the molten weld pool as welding proceeds. A fillet weld is approximately triangular in section, formed within a reentrant corner of a joint. Its strength is achieved through shear capacity of the weld metal across the throat, the weld size being specified as the leg length.

The results of a comparative study of the three main codes AISC (American Institute of Steel Construction), British and European, are given below. Differences in the methodology and specifications have been highlighted, supported by self-explanatory diagrams and tables.

5.2. Welded connections, joints and weld types

There are some 40 jointing processes, which may be categorised into 9 major groups: brazing, flow, forge, induction, thermit, gas, resistance electroslag, electrogas and arc welding. Arc welding can be more precisely categorised as shielded metal-arc welding (‘stick’ welding) flux-cored arc welding and submerged arc welding. Welds may be classified in terms of the position of the weld during welding, the type of weld, type of joint or the magnitude and type of forces to be transmitted. Only a combination of these categories will define a weldment adequately. It is necessary to understand the difference between the terms ‘joint types’ and ‘weld types’. ‘Joint types’ describes the configuration of the steel parts relative to each other, while ‘weld types’ refers to the type of weld employed to hold the parts together. Fig. 5.1 depicts some basic types of joint used in structural engineering in the USA. Fig. 5.2 gives the recommendations made by Eurocode 3. Almost all the welds used to make the above joints are of two basic types: groove welds and fillet welds. Groove welds can be subdivided into square, bevel, V, J and U types depending on the shape to which the plate edge is prepared or grooved to accommodate the weld.

5.2.1. Reinforcement and backing

Where a complete joint penetration weld is required and the weld has a single bevel, V or U groove, the small weld opposite the main weld may be laid-

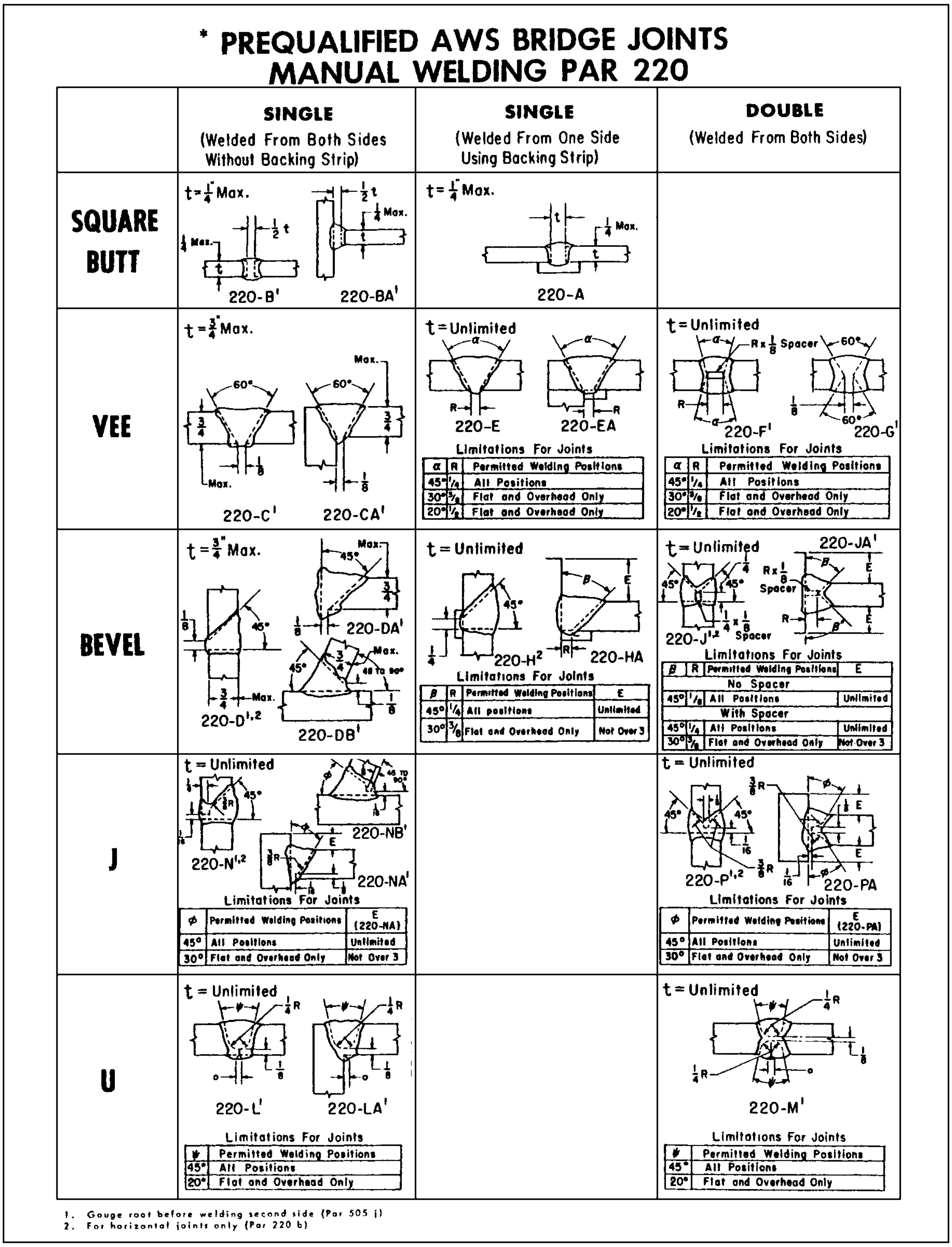


Fig. 5.1. American Welding Society (AWS) — manual and automatic welding

either before or after the main weld; in the former case the small weld is called a backing weld and in the latter a back weld.

When access is available on only one side of a joint but full joint penetration is required, a steel backing strip may be used. The bar is tack-welded to one or both of the plates and when the first run of the main weld is laid it fuses onto the strip to provide full penetration.

5.2.2. Welding positions

The term 'position' when used in connection with a welded joint refers to the position in which the bead is laid, i.e. whether flat, horizontal, vertical, overhead, etc. The welding position is of great importance since the quality of the weld is directly affected by the manner in which the weld metal is deposited. Not all electrodes are suitable for all positions; many electrodes are specified for use in a particular position and should be used only in that position to obtain good results.

5.2.3. Distortion

Once a molten weld bead has been deposited and begins to cool, it will solidify and attempt to contract, both along and across its axis. This will induce residual tensile stresses because of the restraint imposed by the surrounding structure, as well as distortions due to the lack of complete rigidity in the surrounding structure.

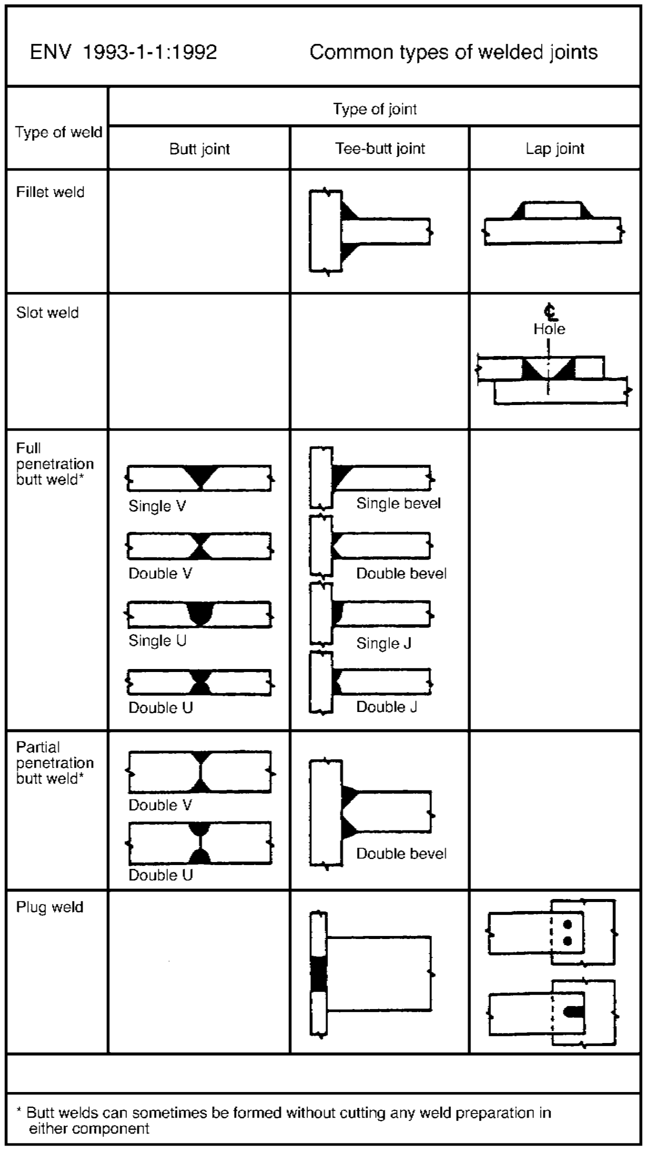
Longitudinal shrinkage of a built-up welded member can cause slender webs and outstands to buckle and if the weld or welds are eccentric to the centroid of the member cross-section will cause overall bowing of the member. Transverse shrinkage is likely to cause both angular and out-of-plane distortions.

5.2.4. Electrodes

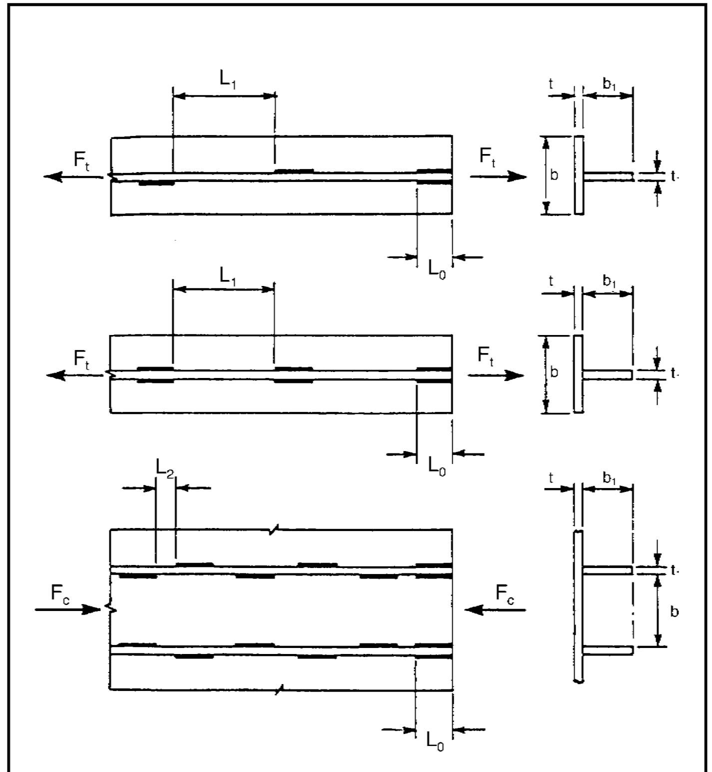
Each combination of weldable steel, welding condition and welding position requires the use of specific electrodes, classified on the basis of the mechanical properties of the deposited weld metal, the welding position of the electrode, the type of coating or covering and the type of current required. Each electrode is identified by a code number EXXXXX, where E stands for electrode and each X represents a number. The first two (or three) numbers indicate the minimum tensile strength, in ksi, of the deposited metal in the as-welded condition. The next number refers to the position in which the electrode is capable of making satisfactory welds; 1 means all positions (flat, vertical, overhead and horizontal), 2 means flat and horizontal fillet welds, and 3 means flat only. The last X represents a digit which indicates the current to be used and the type of coating or covering on the electrode, e.g. (1) high-cellulose sodium coating for use with direct-current reverse polarity (electrode positive) only; or (2) iron powder/titania coating for use with direct current, either polarity or alternating current. Hence, E6018 implies a mild-steel arc-welding electrode with a minimum tensile strength of 60 ksi. Similar values are given in SI units.

Electrodes for shielded metal-arc welding are manufactured in sizes ranging in diameter from 1/16 to 3/8 in. and in length from 9 to 18 in. Coatings serve as mediums for incorporating alloying elements which affect the tensile strength, hardness, corrosion resistance and other physical properties of the weld metal.

In submerged-arc welding, appropriate combinations of bare electrodes and granular fusible fluxes are selected to produce the specified properties in the deposited weld metal. Choices are governed by the welding procedure, the type of joint and the composition of the base metal. The designations are Grade SAW-1 and Grade SAW-2 which imply weld metal yield points of 45 and 50 ksi respectively.



Intermittent fillet welds



$L_0 \geq 0.75b$ or $0.75b_1$ – whichever is smaller
$L_1 \leq 16t$ or $16t_1$ or 200 mm – whichever is smallest
$L_2 \leq 12t$ or $12t_1$ or $0.25b$ or 200 mm – whichever is smallest

Fillet welds may be used for connecting parts where faces form an angle of between 60° and 120°.

Smaller angles than 60° are also permitted. However, in such cases the weld shall be considered to be a partial penetration butt weld.

For angles over 120°, fillet welds shall not be relied upon to transmit forces.

End returns should be indicated on the drawings.

Fillet welds may be continuous or intermittent.

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Welded connections

Weldable structural steels

Welding by an arc welding processes* as follows:

111 – metal-arc welding with covered electrodes
114 – flux-cored arc welding (without gas shield)
12 – submerged-arc welding
131 – MIG (metal inert gas) welding
135 – MAG (metal active gas) welding
136 – flux-cored wire metal-arc welding
141 – TIG (tungsten inert gas) welding

Fig. 5.2. Welded connections (based on EC3). The extracts from DD ENV 1993 Part 1.1 are reproduced with the permission of BSI under licence number 2000SK/0364

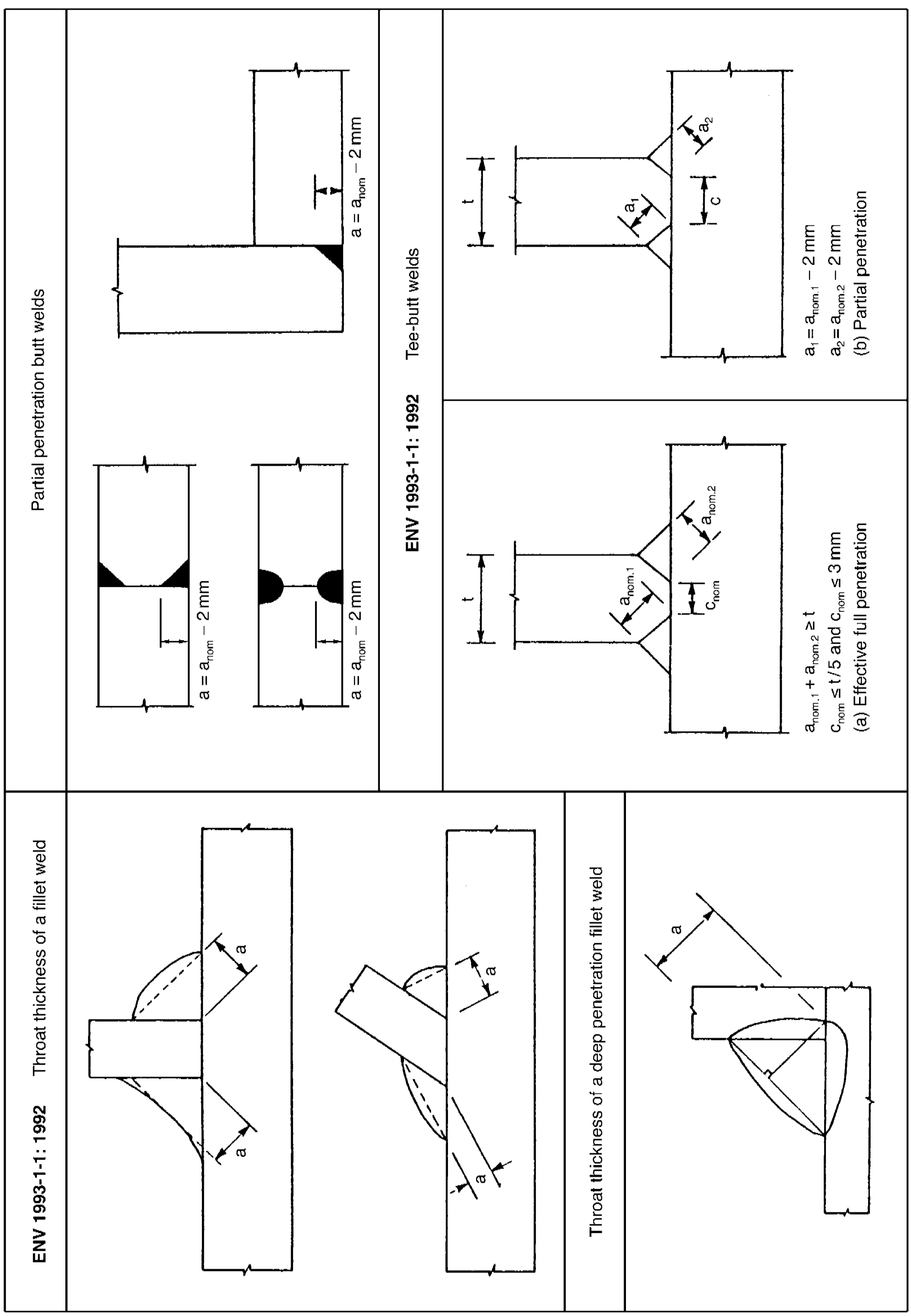


Fig. 5.2. Continued

Two levels of weld-metal yield points are specified for the gas metal-arc welding process, Grade GMAW-1 (55 ksi) and Grade GMAW-2 (60 ksi). An appropriate combination of electrode and shielding which satisfies the mechanical property requirements for Grade GMAW-1 or GMAW-2 may be used respectively in lieu of submerged arc welding Grade SAW-1 or SAW-2.

5.2.5. Resistance per unit length based on EC3

The design resistance per unit length of fillet weld shall be determined using either the method given below, or else the alternative method given. The resistance of a fillet weld may be assumed to be adequate if, at every point in its length, the result of all the forces per unit length transmitted by the weld does not exceed its design resistance $F_{w.Rd}$.

Independent of the orientation of the weld, the design resistance per unit length $F_{w.Rd}$ shall be determined from:

$$F_{w.Rd} = f_{vw.d}a \tag{5.1}$$

where, $f_{vw.d}$ is the design shear strength of the weld.

The design shear strength $f_{vw.d}$ of the weld shall be determined from:

$$f_{vw.d} = \frac{f_u/\sqrt{3}}{\beta_w \sqrt{m_w}} \tag{5.2}$$

where f_u is the nominal ultimate tensile strength of the weaker part joined and β_w is the appropriate correlation factor.

The value of the correlation factor β_w should be taken from Table 5.1.

Table 5.1. Correlation factor versus ultimate strength

	Ultimate tensile strength f_u	Correlation factor β_w
EN 10025		
Fe 360	360 N/mm^2	0·8
Fe 430	430 N/mm^2	0·85
Fe 510	510 N/mm^2	0·9
PrEN 10113		
Fe E 275	390 N/mm^2	0·8
Fe E 355	490 N/mm^2	0·9

For intermediate values of f_u the value of β_w may be determined by linear interpolation.

Design resistance of butt welds

The design resistance of a full penetration butt weld shall be taken as equal to the design resistance of the weaker of the parts joined, provided that the weld is made with a suitable electrode (or other welding consumable) which will produce all-weld tensile specimens having both a minimum yield strength and a minimum tensile strength not less than those specified for the parent metal.

The resistances which such welds use in common for steel grade Fe 430 are given in Table 5.2.

Table 5.2. Weld resistance for steel grade Fe 430

Thickness: mm	Shear: kN/mm	Tension or compression: kN/mm
6	0·86	1·50
8	1·15	2·00
10	1·44	2·50
12	1·73	3·00

5.2.6. Strength resistance based on grade E43 electrodes to BS 639

Weld capacities of the fillet and/or butt weld are summarised in Tables 5.3 and 5.4 for grade 43 and 50 steel. Equations (5.1) and (5.2) are still applicable for strength resistance.

5.2.7. Welded joints based on American specifications

Figure 5.1 gives the detailed practice adopted by the American Welding Society (AWS). Refer to section 5.2.4 for the electrodes and their symbols and welding specification by AISC.

Table 5.3. Fillet welds—capacities with grade E43 electrodes to BS 639 grade of steel 43 and 50

Leg length: mm	Throat thickness: mm	Capacity at 215 N/mm^2: kN/m	Leg length: mm	Throat thickness: mm	Capacity at 215 N/mm^2: kN/m
3·0	2·12	456	12·0	8·49	1824
4·0	2·83	608	15·0	10·61	2280
5·0	3·54	760	18·0	12·73	2737
6·0	4·24	912	20·0	14·14	3041
8·0	5·66	1216	22·0	15·56	3345
10·0	7·07	1520	25·0	17·68	3801

Table 5.4. Strength of full penetration butt welds

Thickness: mm	Shear at $0{\cdot}6 \times P_y$: kN/m	Tension or compression at P_y: kN/m	Thickness: mm	Shear at $0{\cdot}6 \times P_y$: kN/m	Tension or compression at P_y: kN/m
Grade of steel 50					
6·0	1278	2130	22·0	4554	7590
8·0	1704	2840	25·0	5175	8625
10·0	2130	3550	28·0	5796	9660
12·0	2556	4260	30·0	6210	10350
15·0	3195	5325	35·0	7245	12075
18·0	3726	6210	40·0	8280	13800
20·0	4140	6900	45·0	9180	15300
Grade of steel 43					
6·0	990	1650	22·0	3498	5830
8·0	1320	2200	25·0	3975	6625
10·0	1650	2750	28·0	4452	7420
12·0	1980	3300	30·0	4770	7950
15·0	2475	4125	35·0	5565	9275
18·0	2862	4770	40·0	6360	10600
20·0	3180	5300	45·0	6885	11475

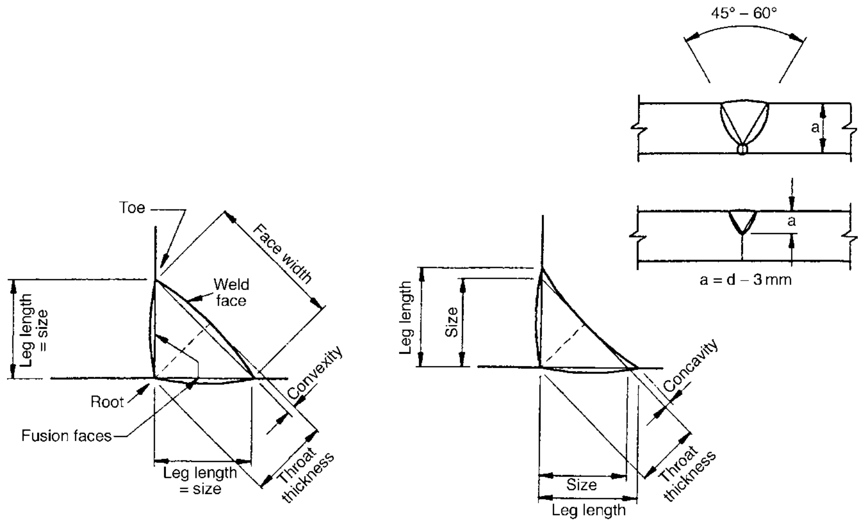


Fig. 5.3. Fillet and groove welds—weld profile terminology

(a) Fillet-welded joints

The fillet weld is the weld most commonly used to connect lapping and intersecting parts. Its cross-section forms a 45° isosceles triangle with the connecting parts (Fig. 5.3). To obtain a satisfactory fillet weld, the electrode should bisect the angle between the intersecting surfaces to be welded and should lean approximately 20° in the direction of travel. Fillet weld dimensions are influenced by the joining parts and the clearance provided for the welding operation. The AWS code specifies the minimum size of fillet welds to avoid cracked welds (see Table 5.5).

(b) Groove welded joints (butt weld joints)

To obtain joints with a predictable degree of weld penetration, the AWS standards recommend values for the groove angle and the root opening. Complete joint penetration means that the filler metal and the base metal are fused throughout the depth of the joint.

Most of the structural steel welded joints outlined by the AWS and the AISC are considered to be prequalified, provided the welding is done in accordance with the requirements. The term ‘prequalified’ implies that a joint may be used without performing welding procedure qualification tests. If a joint differs from those covered in the specifications, its adequacy must be verified by tests such as those prescribed in the AWS Standard Qualification Procedure.

Table 5.5. Minimum weld sizes

Thickness of thicker part joined: in.	Minimum leg size of fillet weld: in.	Minimum effective throat of partial-penetration groove weld: in.
To $\frac{1}{4}$ incl.	$\frac{1}{8}$	$\frac{1}{8}$
Over $\frac{1}{4}$ to $\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{16}$
Over $\frac{1}{2}$ to $\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
Over $\frac{3}{4}$	$\frac{5}{16}$	–
Over $\frac{3}{4}$ to $1\frac{1}{2}$		$\frac{5}{16}$
Over $1\frac{1}{2}$ to $2\frac{1}{4}$		$\frac{3}{8}$
Over $2\frac{1}{4}$ to 6		$\frac{1}{2}$
Over 6		$\frac{5}{8}$

The system of groove weld classification is not to be confused with the ideographic weld identification system adopted by the AWS which uses the following notation.

(1) Joint type: B = butt, C = corner, T = tee
(2) Material thickness and efficiency:
L = limited thickness with complete penetration
U = unlimited thickness with complete penetration
P = partial penetration
(3) Groove type:

1 — square	4 — single-bevel	7 — double-U
2 — single-V	5 — double-bevel	8 — single-J
3 — double-V	6 — single-U	9 — double-J

(4) Welding process:
S = submerged arc
No symbol indicates manual shielded metal arc.

For example, the designation TC – U4 means (1) the joint may be used for either a tee or a corner, (2) it may be used on an unlimited range of material thicknesses, (3) the groove is a single-bevel, and (4) the welding will be performed by the manual shielded metal arc process.

The groove welded strength is given in Table 5.4.

5.3. Welding symbols

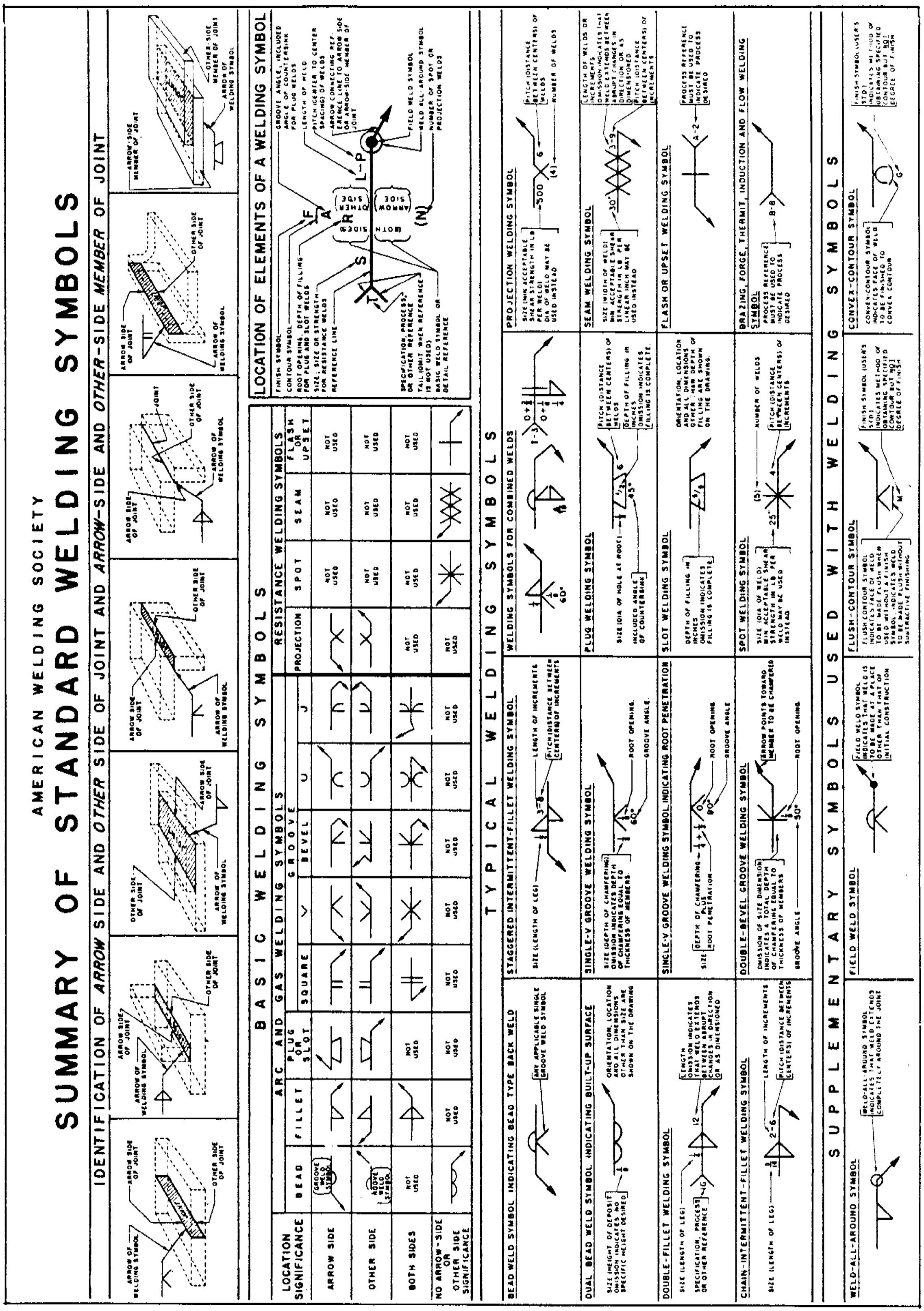
Standardised symbols are used to denote the type and size of welds on structural detail drawings. The following points should be noted in connection with the construction and use of welding symbols.

(*a*) The reference line is drawn in either the horizontal or the vertical direction, i.e. parallel to the horizontal or vertical axis of drawing. If placed vertically, the information on it should be able to be read when the drawing is viewed from the right.
(*b*) The arrow points to the weld(s) or welded joint being described.
(*c*) The fillet weld symbol is a small isosceles triangle based on the reference line and having its vertical side to the left.
(*d*) The single-bevel weld symbol is a 45° V with its apex to the reference line and its vertical leg to the left.
(*e*) The double-bevel and double-V weld symbols have their legs at 60° to each other.
(*f*) Symbols and notations referring to the arrow side of the joint are placed below the reference line; those referring to the other side of the joint are placed above it.

Figure 5.4 shows a summary of standard welding symbols recommended by the American Welding Society (AWS) which have been universally adopted. For clarity, the application of these symbols is explained by a series of tabulated examples in Fig. 5.4. These have been used in the UK and countries covered by the Eurocodes.

5.4. Practical notes for guidance

Figure 5.5 summarises practical guidance for detailers prior to the preparation of GA drawings and structural details for welded steel structures. Where



Courtesy of American Welding Society

Note—the word "Butt" weld used in this manual comes under the heading of "Groove" weld principally as "Square" - "V" or "Bevel"

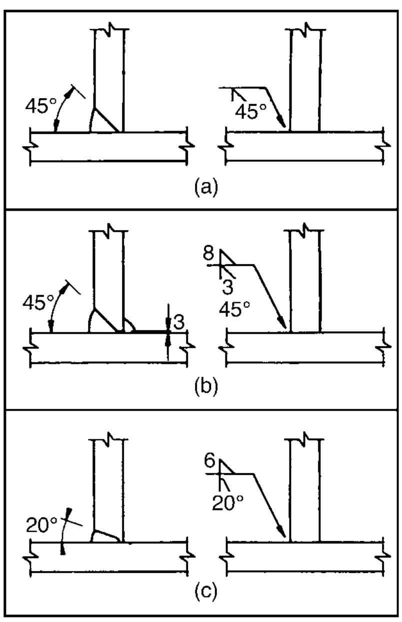
Fig. 5.4. Summary of standard welding symbols (American practice—courtesy of the American Welding Society)

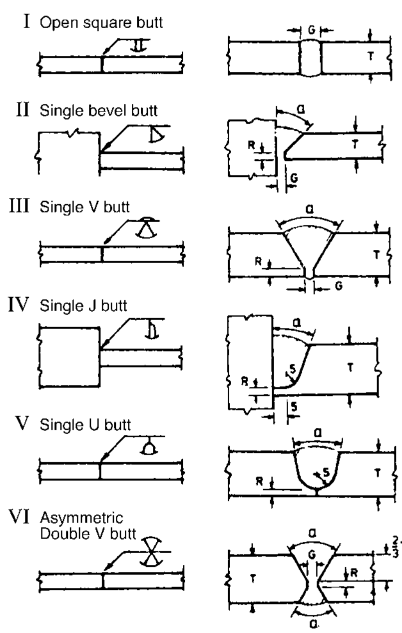
groove (butt) welds are involved, the edges trends of the steel components arc usually prepared by flame cutting, arc-air gouging or edge planning to provide square, bevel, V-, U-, or J-shaped grooves which are straight and true to dimension. Relatively thin material may be groove welded with square cut edges.

A complete penetration weld is one which achieves fusion of weld and base metal throughout the depth of the joint. It is made by welding from both sides of the joint, or from one side to a backing bar or backing weld. Except where backing bars are employed, specifications require that for full penetration groove welds made by the manual shielded metal-arc process, the weld roots must be chipped or gouged to sound metal before making the second weld.

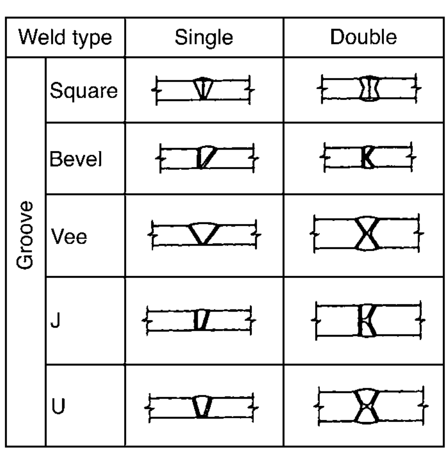
Partial penetration groove welds are employed when stresses to be transferred do not require full penetration, or when welding must be done from one side of a joint only and it is not possible to use backing bars or to gouge weld roots for backing welds. The application of partial penetration groove welds is governed by specifications which may limit the effective throat thickness or the thickness of the material on which they are to be used.

Edge preparation of base material for partial penetration welds is similar to that for full penetration groove welds, but it usually covers less than the full joint thickness. The effective throat thickness and hence the weld strength of





	Thickness T	Gap G	Angle a	Root R
	mm	mm		mm
I	0 – 3 3 – 5	0 – 3 3	– –	– –
II	5 – 12 > 12	3 3	45° 45°	1 2
III	> 10	5 10	45° 20°	0 0
IV	> 20	–	20°	5
V	> 20	–	20°	5
VI	> 12	3	60°	2



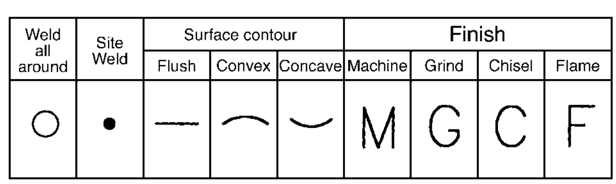


Fig. 5.5. Practical guidelines on welding (British practice)

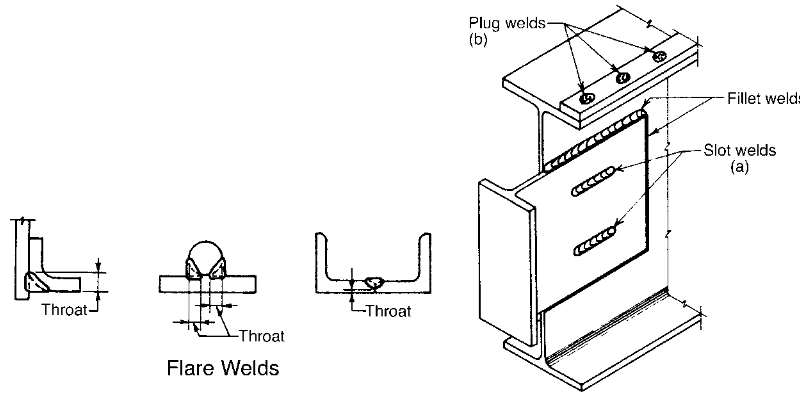


Fig. 5.6. Examples of flare welds and other welds in operation

partial penetration groove welds is normally limited to less than the full joint thickness.

The use of partial penetration welds is subject to British, European and AWS codes and specification provisions. These are more restrictive in bridge specifications than in building codes.

Flare welds are special cases of groove welds in which the groove surface of one or both parts of a joint is convex. This convexity may be the result of edge preparation, but more often one or both joint components consists of round rods or a shape with a rounded corner or bend. Fig. 5.6 illustrates several types of flare welded joint. The effective throat dimension is used in design calculations. Complete penetration in a flare weld is usually difficult to achieve and design values should be applied conservatively.

Plug and slot welds are used in lap joints, to transmit shear loads, prevent the buckling of lapped parts or to join component parts of built-up members. Round holes or slots are punched or otherwise formed in one component of the joint before assembly. With the parts in position, weld metal is deposited in the openings, which may be partially or completely filled depending on the thickness of the punched material. Fig. 5.6 shows slot welds and plug welds. Slot welds are used in conjunction with fillet welds to stitch a wide area of a T-beam to a beam web. Fig. 5.6 also shows plug welds being used to attach a guide strip to the top of a beam flange.

5.4.1. Joint prequalification

Welded joints which conform to all codes and specification provisions for design, materials and workmanship are designated as prequalified joints. These include specific fillet, groove, plug and slot welded joints of sufficient variety to cover most requirements of structural work. These joints have been thoroughly tested and are recommended for general use in the fabrication of buildings and bridges.

The types of groove weld to be used for various joint arrangements, thickness of materials, welding processes and welding positions are usually specified on the engineer's design sheets or drawings. Therefore, the draughtsman seldom selects the type of groove weld. However, should it be necessary to verify design information or to select an appropriate groove weld to detail a shop splice, reference should be made either to the fabricator's standard welds or to the codes and specifications published by various authorities.

5.4.2. Welding positions

The position of a joint when the welding is performed has a definite structural and economic significance. It affects the ease of making the weld, the size of electrode, the current required and the thickness of each weld layer deposited in multi-pass welds.

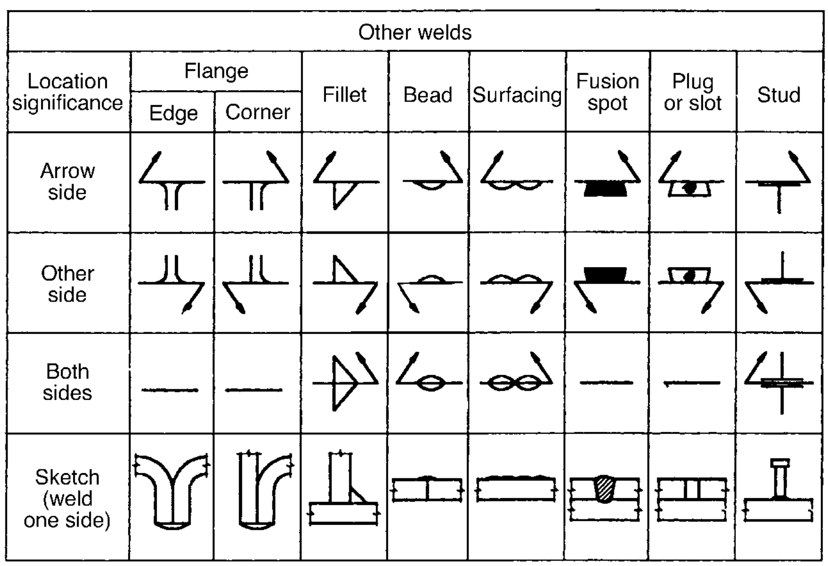
The basic weld positions are

(*a*) flat: the face of the weld is approximately horizontal and welding is performed from above the joint
(*b*) horizontal: the axis of the weld is horizontal. For groove welds the face of the weld is approximately vertical; for fillet welds the face is usually at 45° to the horizontal and vertical surfaces
(*c*) vertical: the axis of the weld is approximately vertical
(*d*) overhead: welding is performed from the underside of the joint.

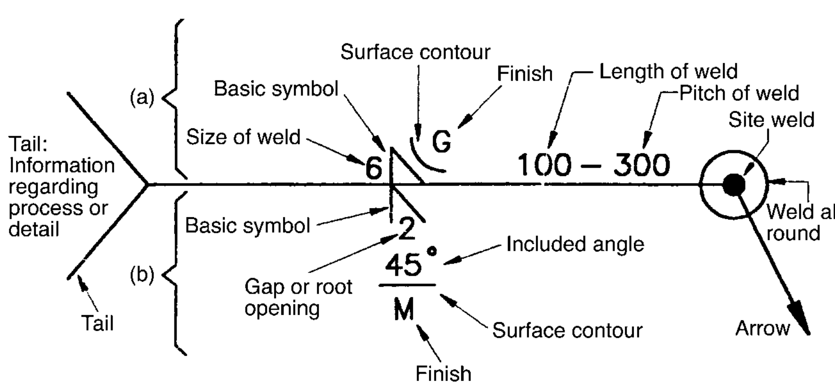
5.4.3. Welding symbols

Shop details and erection plans for welded construction must provide specific instructions for the type, size and length of welds and their locations on the assembled piece. This information is usually given by means of welding symbols. Most structural fabricators have adopted the basic method described in the American Welding Society booklet Standard Welding Symbols, AWS A2.0. The symbols in this system, commonly used in structural work are shown in Fig. 5.4.

Three basic parts are needed to form a welding symbol: an arrow pointing to the joint, a reference line upon which dimensional data is placed and a basic weld symbol device indicating the weld type required. A fourth part of the welding symbol, the tail, is used only when it is necessary to supply additional



Note: Arrow side means side of joint to which arrow points



(a) Information regarding ‘other side’ of joint
(b) Information regarding ‘arrow-side’ of joint

Fig. 5.7. Construction of a welding symbol

data such as specification, process or detail references. See Fig. 5.7 for the construction of a welding symbol.

An indication of specification references in the tail is necessary only when two or more electrode classes are required for the welding on a particular drawing. Normally, this information is carried in the general notes or on a job data sheet. The same is true for process references. However, since specification references usually determine the process, process references will be needed only for electrogas, stud or other kinds of welding where the electrode specification does not describe the process or method. When references are not needed to supplement the welding symbol, the tail is omitted.

The symbol for welds should be made large enough to be easily recognised and understood. Some fabricators supply welding symbol templates to their

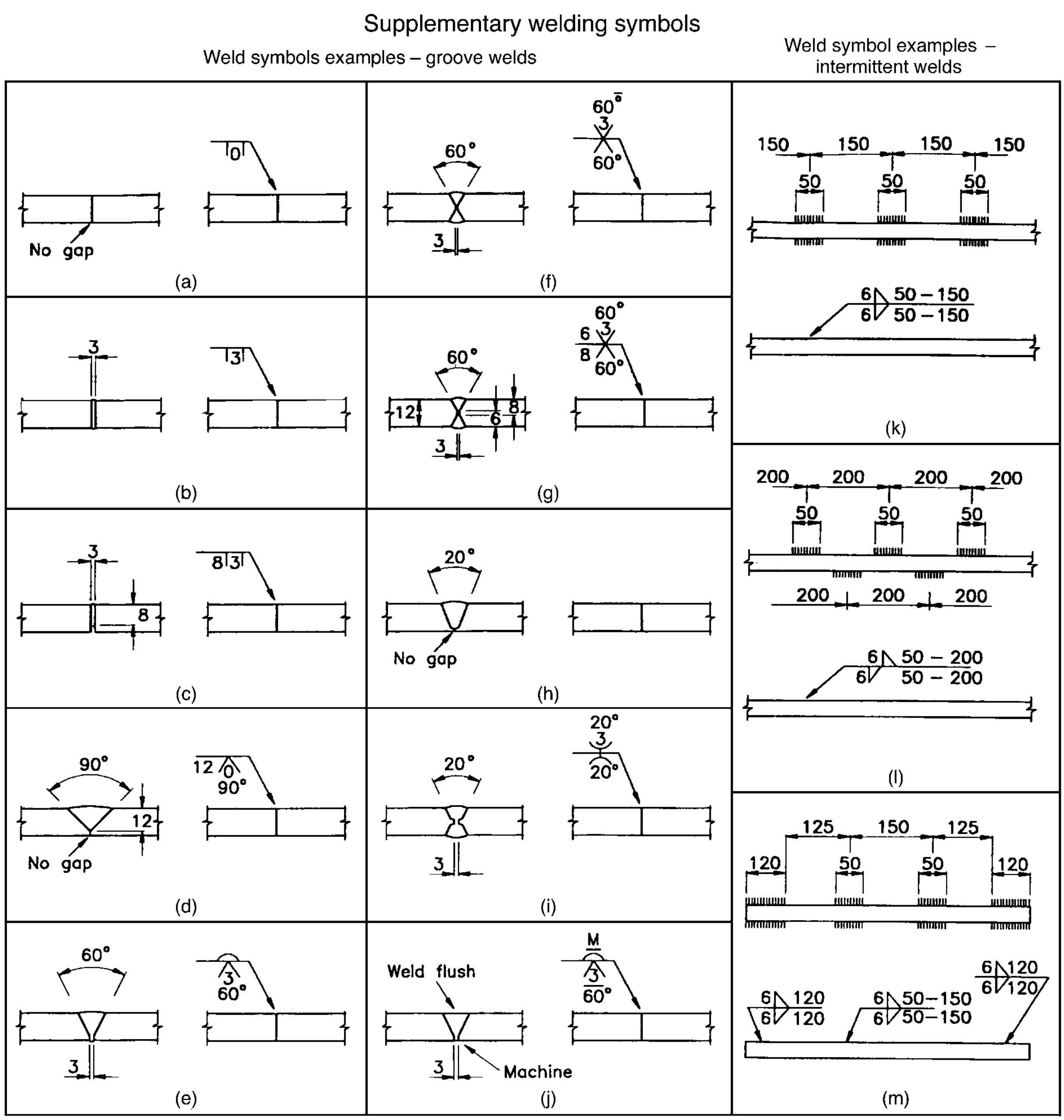
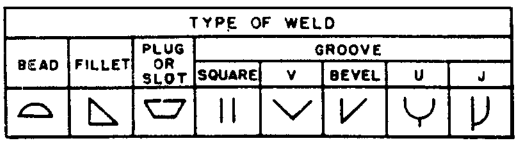


Fig. 5.8. Basic welding symbols for groove and intermittent welds (based on EC3). The extracts from DD ENV 1993 Part 1.1 are reproduced with the permission of BSI under licence number 2000SK/0364

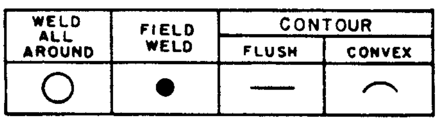
draughtsmen. These may also be purchased from suppliers of drafting equipment.

The construction and application of welding symbols for groove welds are basically similar to those for fillet welds. However, whereas fillet welds are represented by a single basic symbol (the triangle), groove welds involve seven basic symbols. These may be combined with each other or compounded with supplementary weld symbols to cover a wide variety of weld profiles and edge preparations. The shapes of the basic weld symbols for groove and intermittent welds are shown in Fig. 5.8.

Reference lines and any information placed on them are arranged to read like other notes on a drawing: from left to right if the reference line is horizontal and from bottom to top if it is placed vertically on the sheet. Reference lines are usually placed in horizontal or vertical positions.



Basic Arc and Gas Weld Symbols



Supplementary Symbols

NOTE—"BUTT" WELD IS A GROOVE WELD GENERALLY SHOWN AS "SQUARE" "V" or "BEVEL" IN ILLUSTRATIONS ABOVE AND BELOW.

SAFE ALLOWABLE LOADS FOR FILLET WELDS (In Shear)

For dynamic or vibrational loads it may be desirable to reduce unit stress, depending on severity of load.

Size of Fillet Weld	Shear Value: Pounds per Lineal Inch	Bevel Butt Welds and Fillet Weld: Size of Weld	Electrode Weight Lbs. Per Lin. Ft.
1/8"	1200	1/8"	.08
3/16"	1800	3/16"	.15
1/4"	2400	1/4"	.25
5/16"	3000	5/16"	.36
3/8"	3600	3/8"	.50
1/2"	4800	1/2"	.83
5/8"	6000	5/8"	1.25
3/4"	7200	3/4"	1.75
		7/8"	2.40
		1"	3.00
"Fusion Code" (Structural) A.W.S.		These weights based on approx. clearance of 3/16" between parts.	

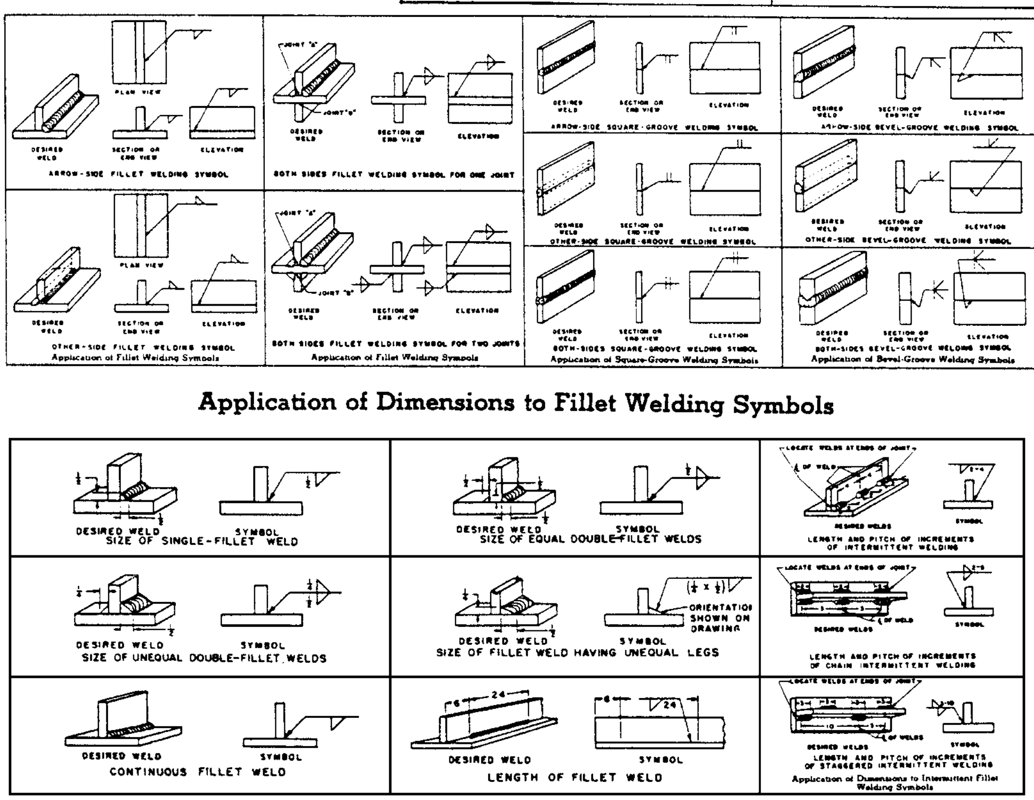


Fig. 5.9. Welding symbols—additional data (American practice—courtesy of Lincoln Electric Co.)

The arrow may be located at the right or left end of the reference line and may point upward or downward from it. The arrow is drawn at an angle of about 45° to the reference line, except when some other arrangement is necessary to avoid crowding a portion of the drawing. The arrow head should never be placed on the reference line or on a continuous extension of the reference line. Some angular break should always be employed.

Weld dimensions are placed on the welding symbol with the weld size to the left of the basic weld symbol or device and the weld length to the right.

Weld dimensions are placed on the same side of the reference line as the device. When a device is required on both sides of the reference line and the weld size and length are identical for the arrow and other side of the joint, it is unnecessary to repeat dimensional data above and below the reference line.

Additional data on welding symbols, as used specifically by Lincoln Electric Co., USA, is given in Fig. 5.9.

6. Design detailing of major steel components

This chapter gives a comparative study of detailing practices for major steel components such as beams, girders, columns, trusses, and various fastenings. Three major codes are considered and they are based on British, European and American practices. Both bolted and welded connections or fastenings are given as practised under the BS 5950, EC3 and AISC and LRFD Codes.

6.1. Beams and girders

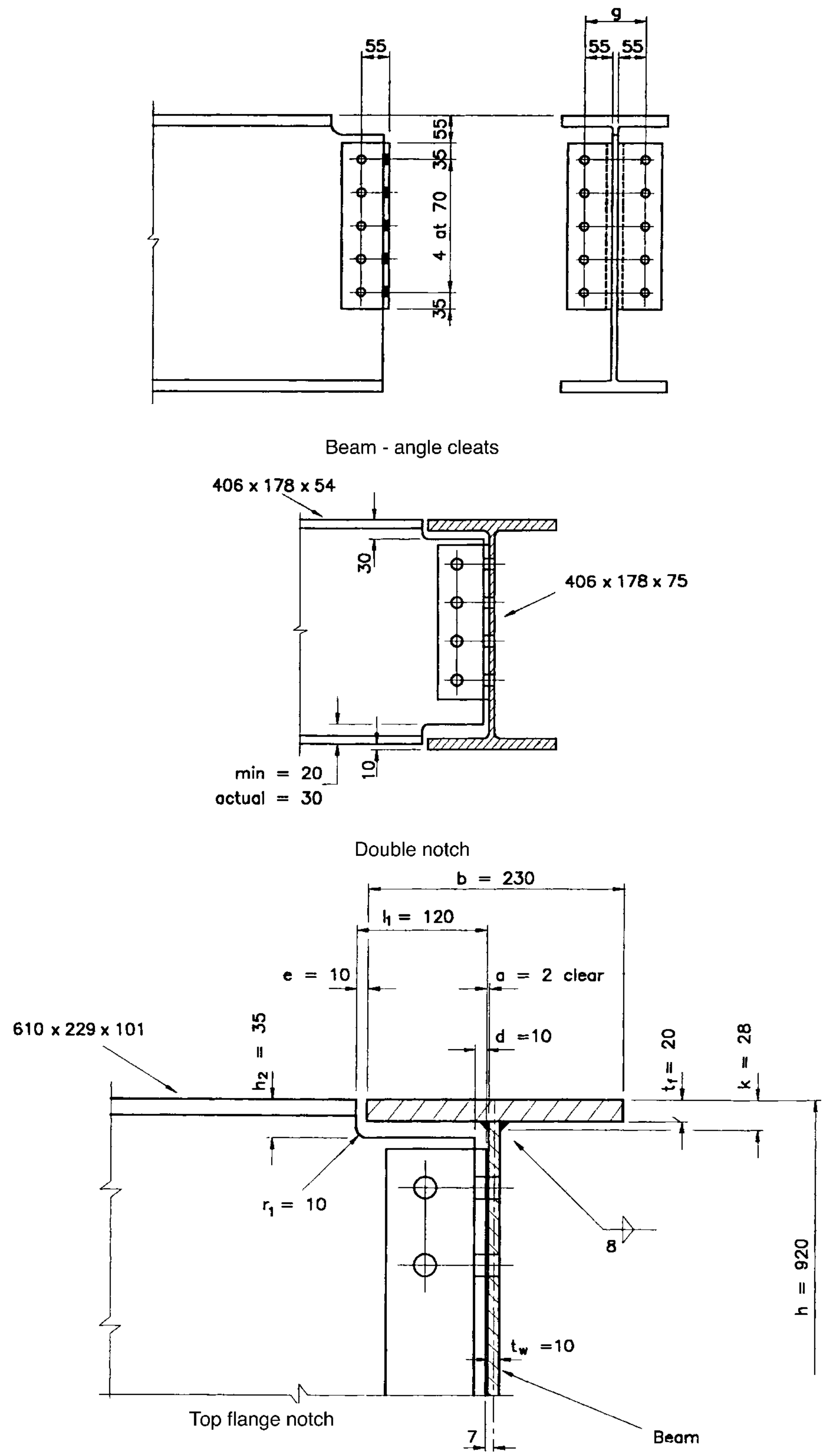
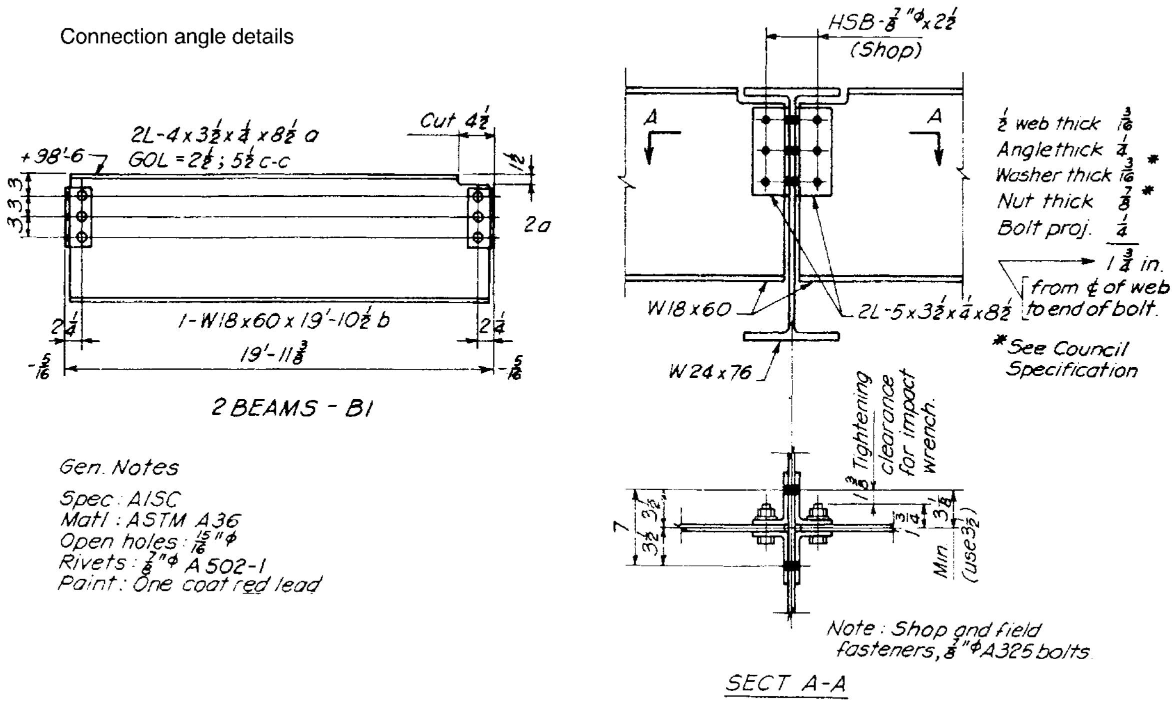


Fig. 6.1.1. Notching of flanges—bolted connection, all beams grade S275 (based on EC3 specifications)

Connection angle details



Beam gages

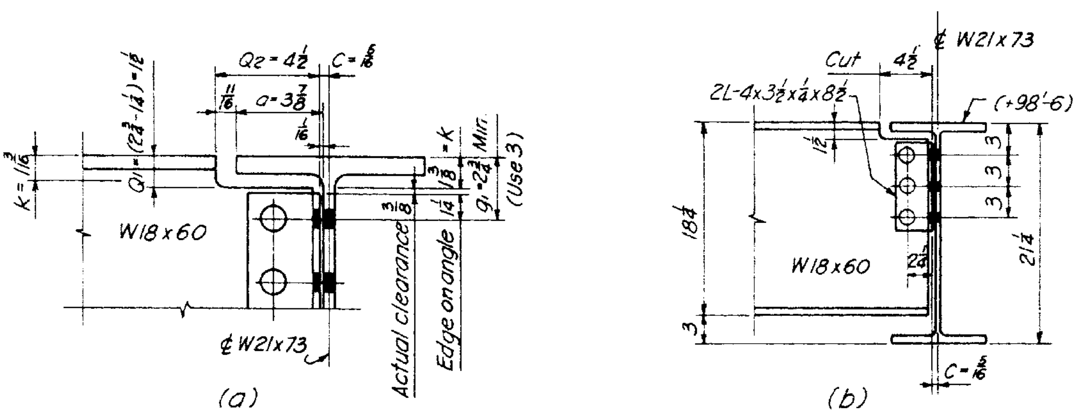


Fig. 6.1.2. Beam fabrication details (based on AISC specifications)

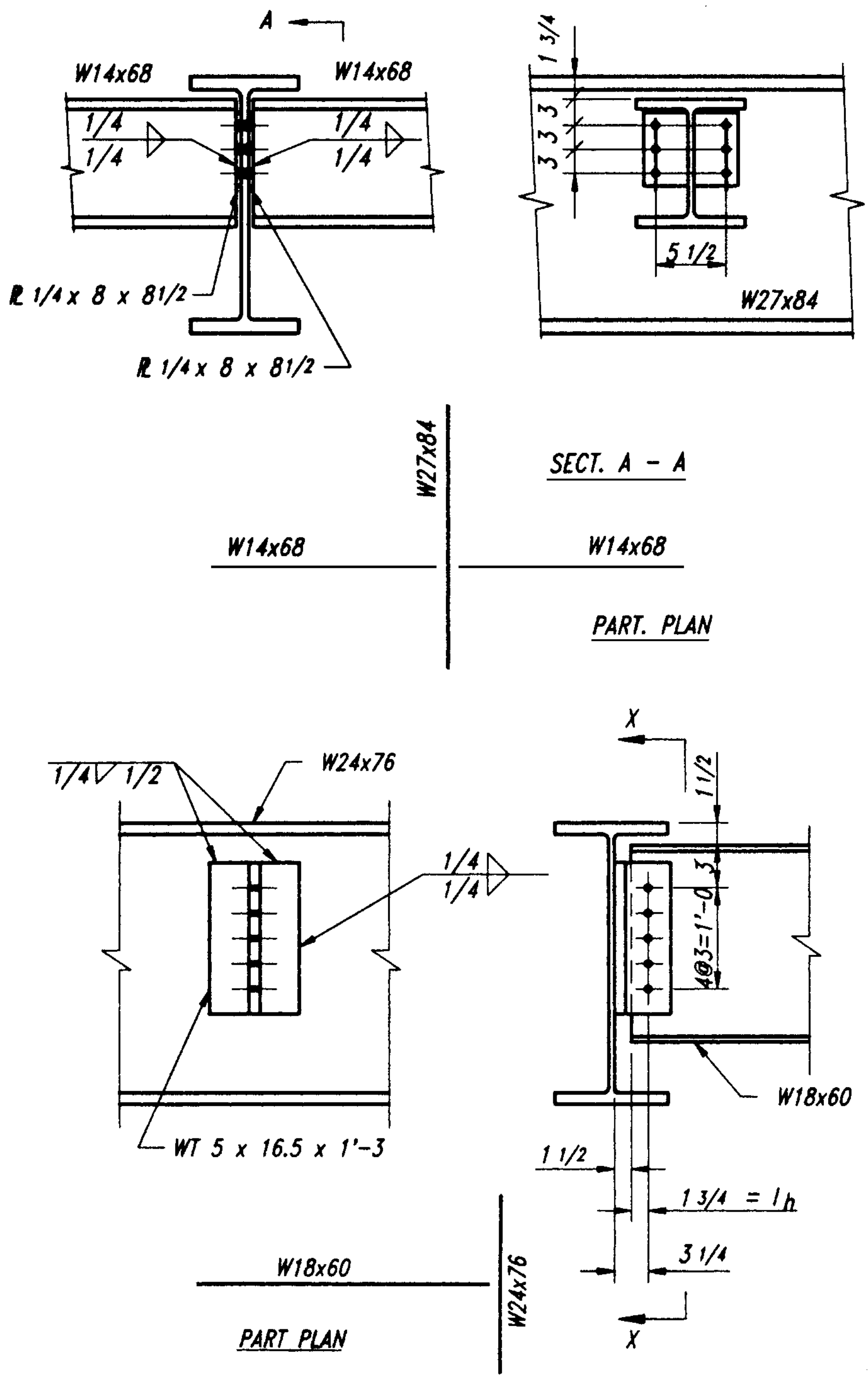


Fig. 6.1.3. *End plate shear connections of wide flange beams—bolted and welded connections (based on AISC specifications)*

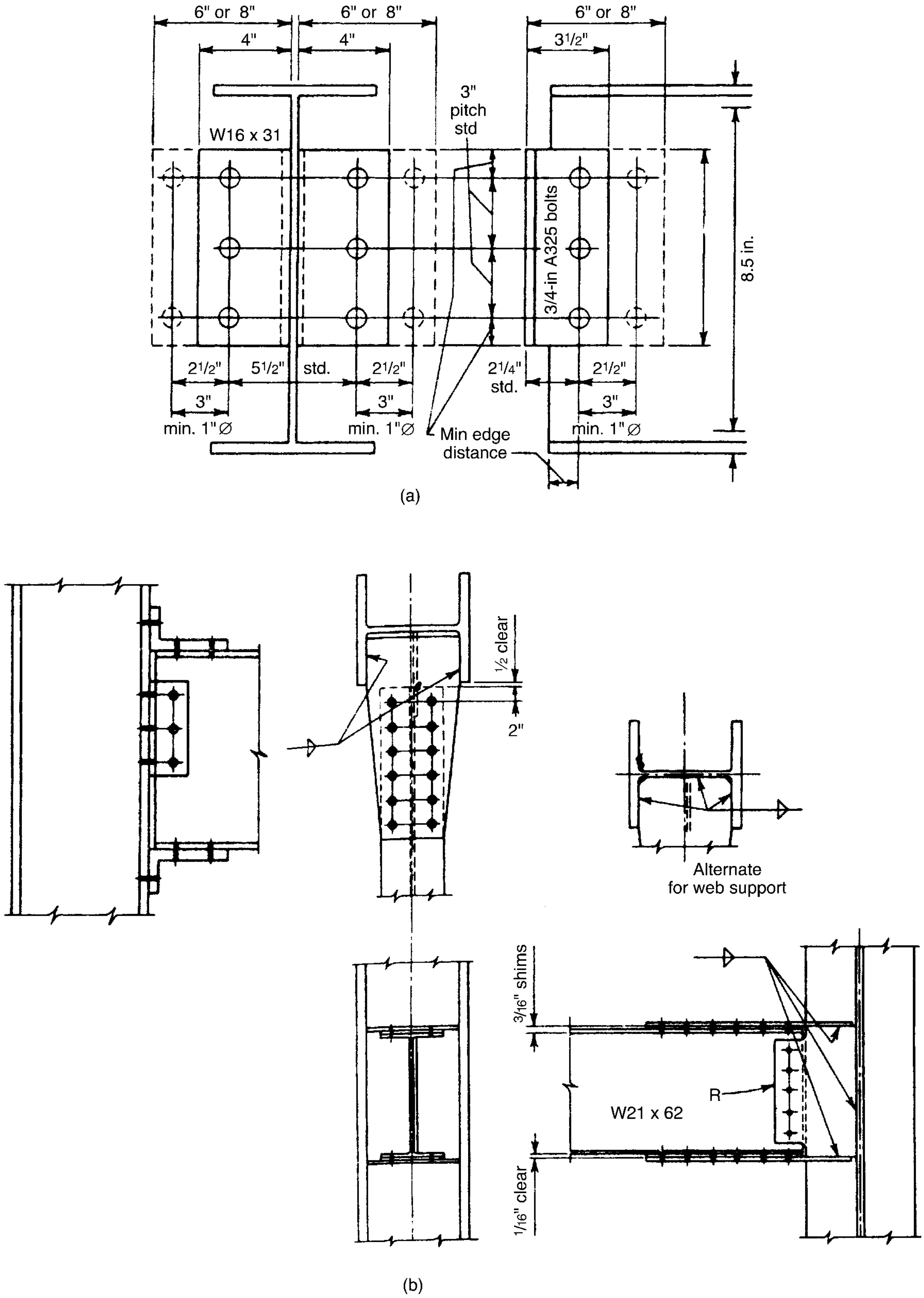


Fig. 6.1.4. Bolted framed beam connection: (a) semi-rigid connection; (b) moment connection (based on AISC/LRFD specifications)

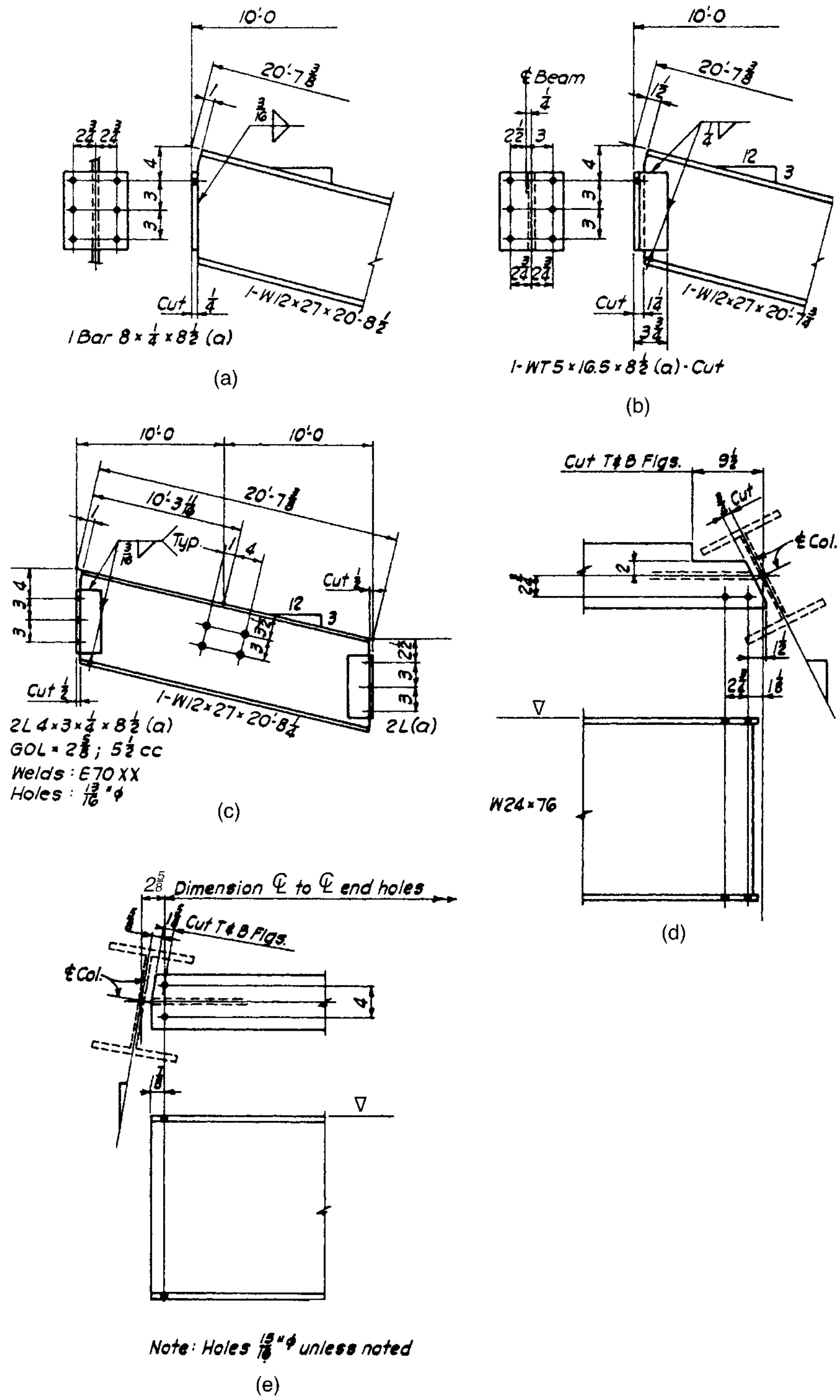
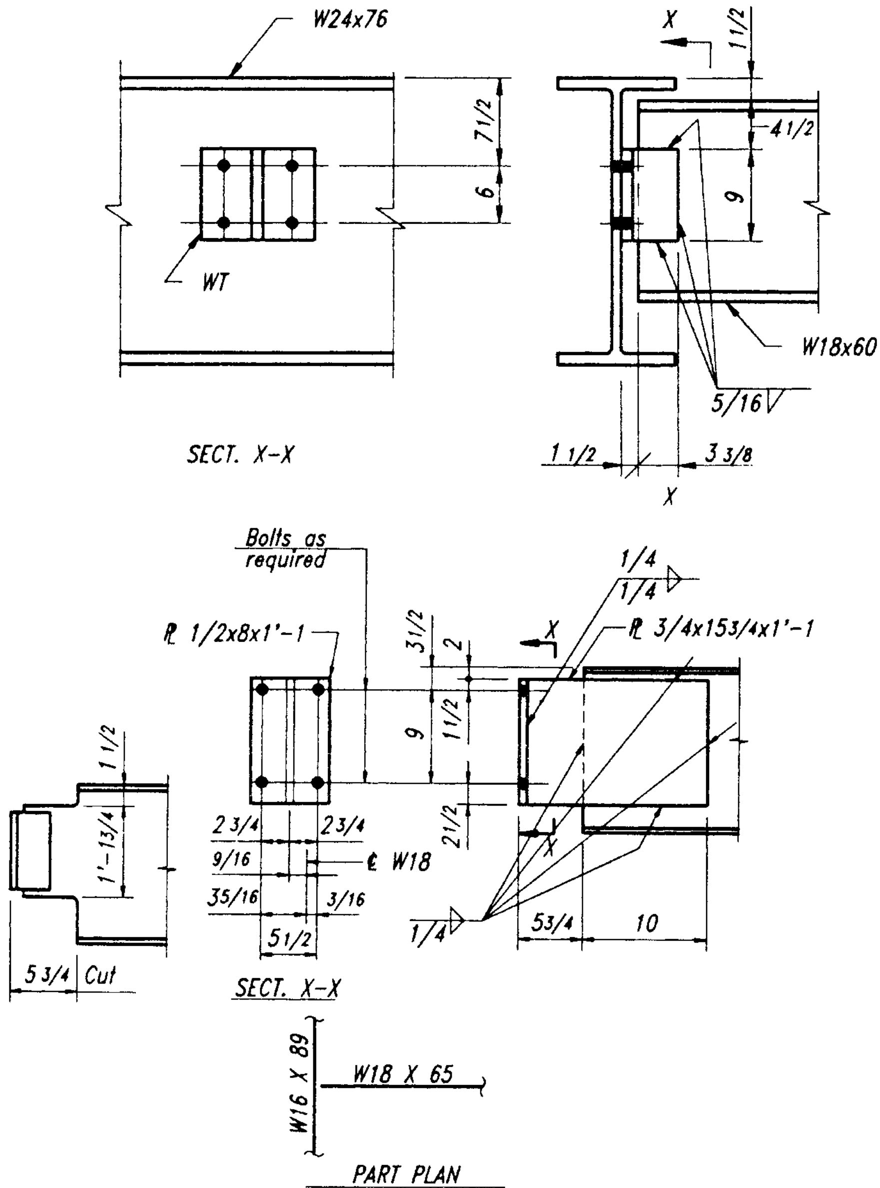


Fig. 6.1.5. Sloped and canted beam connections (based on AISC/LRFD specifications)



General Notes:
Specification – LRFD/AISC latest edition
Material – ASTM A36
Shop & Field connections – welded E70XX electrodes

Fig. 6.1.6. Web reinforcement of coped beams (based on AISC/LRFD specifications)

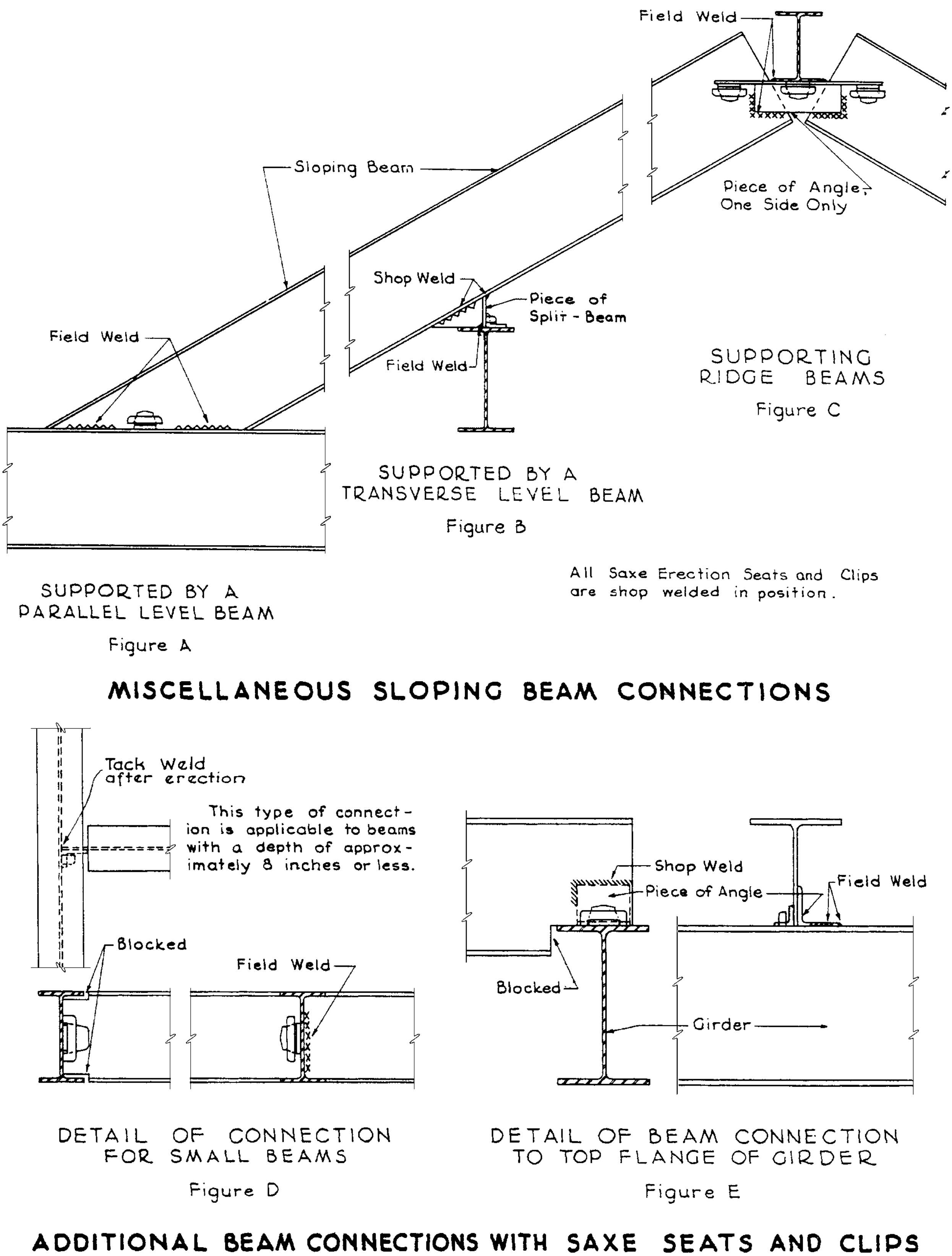


Fig. 6.1.7. Sloping beam connections using Saxe seats (based on AISC specifications). Figure used with permission of The Lincoln Electric Company

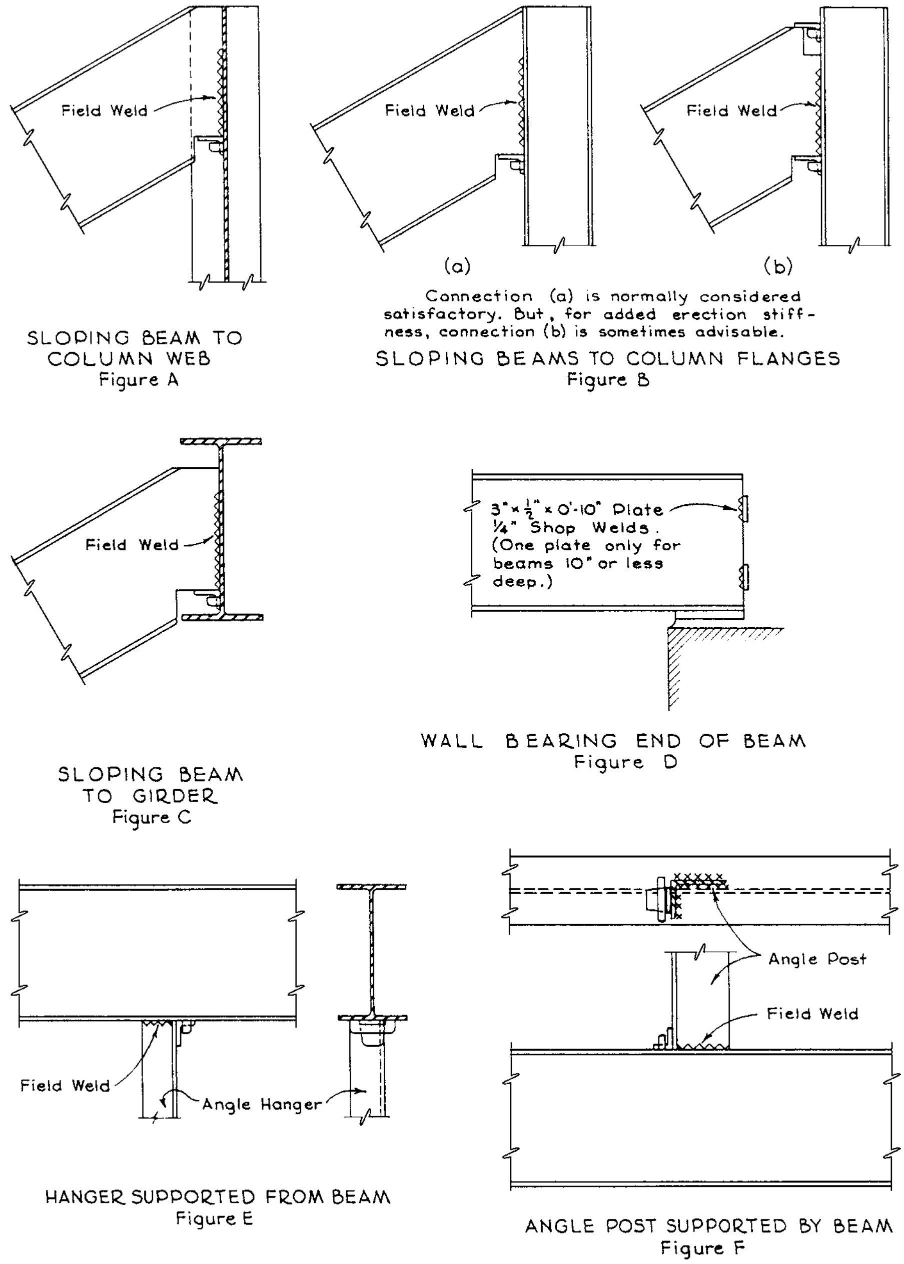


Fig. 6.1.8. Miscellaneous connections assembled with Saxe seats and clips (based on AISC specifications). Figure used with permission of The Lincoln Electric Company

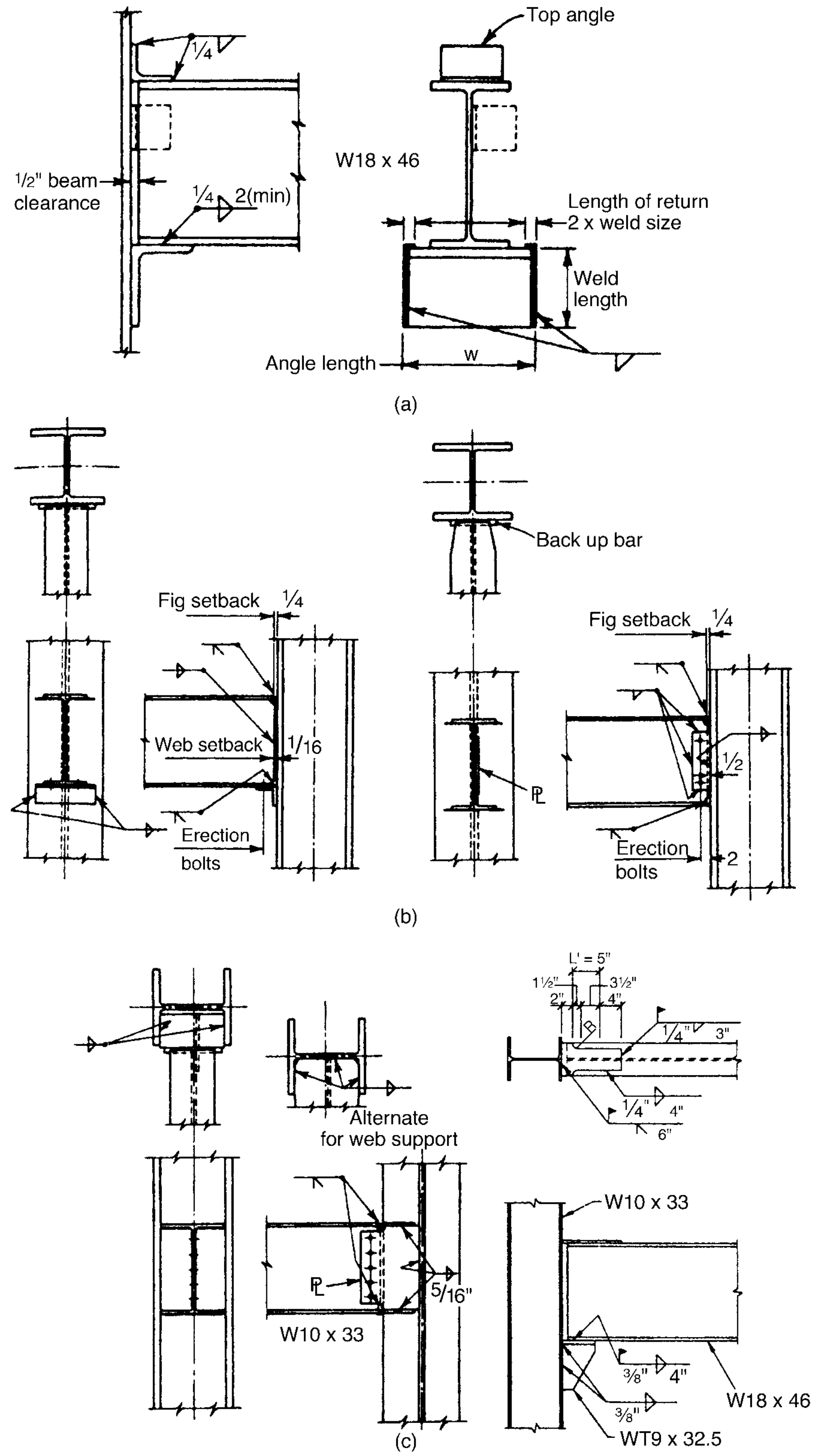


Fig. 6.1.9. Flexible and rigid connections: (a) beam–seat connections—flexible; (b) beam-to-column flange connections—moment-resistant; (c) beam-to-column web connections—moment-resistant (based on AISC/LRFD specifications)

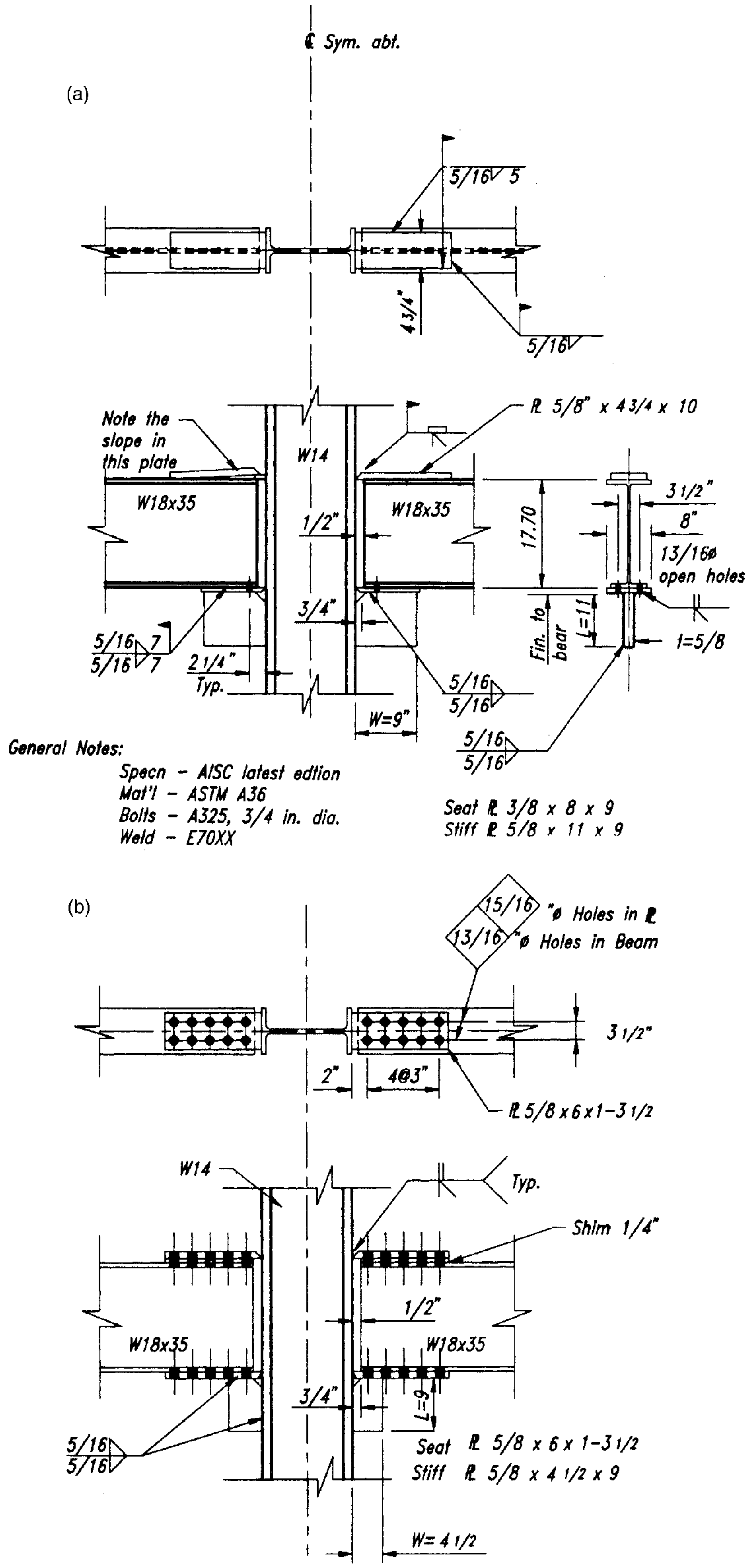


Fig. 6.1.10. Beam–column welded and bolted connections: (a) welded connections; (b) bolted connections (based on AISC/LRFD specifications)

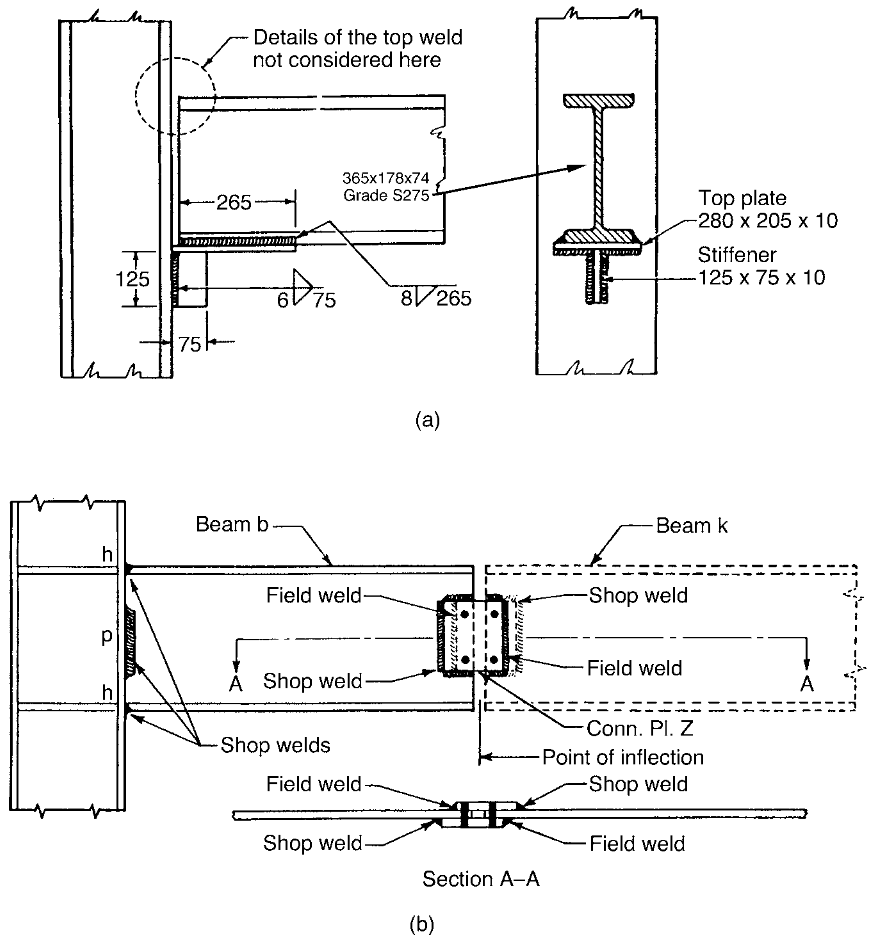
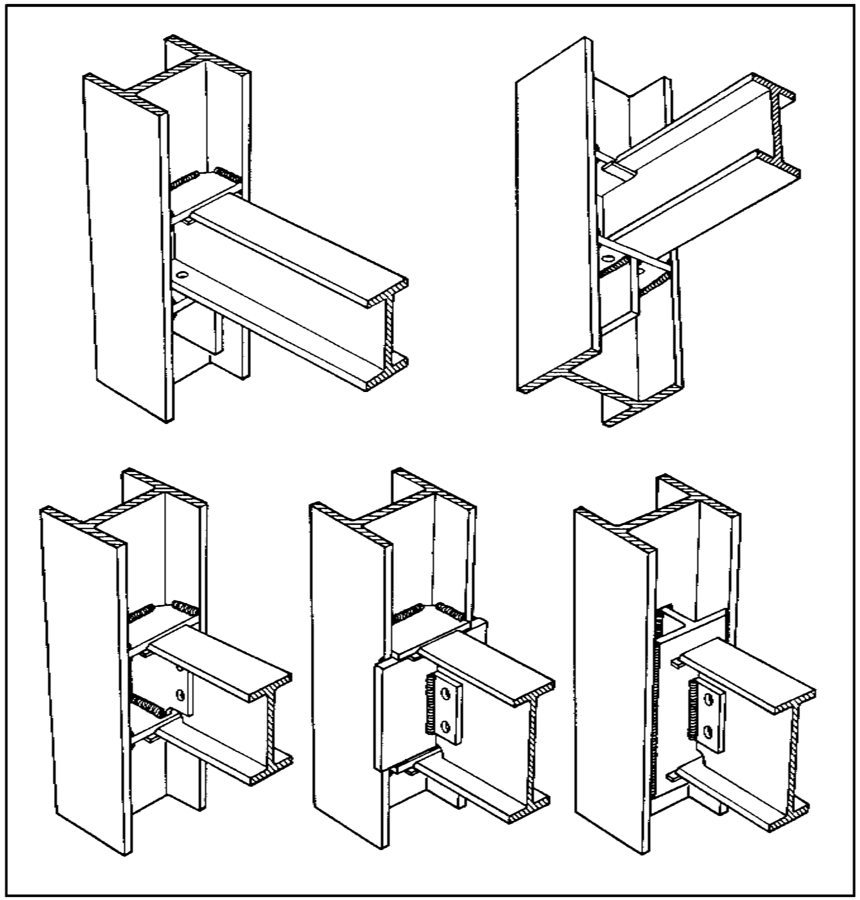
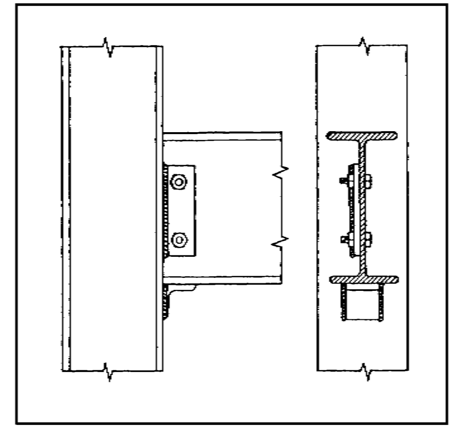


Fig. 6.1.11. Beam–column seated and spliced connections: (a) end beam to column welded connection; (b) beam–column connection with splice beam connection (field/shop welding) (based on EC3 specifications)



Example:	
All columns	305 x 305 x 283 kg/m UC grade 43
All beams	254 x 146 x 28 kg/m UB grade 43
All welds	8 mm
All bolts	HD20 grade 4.6
All angles	150 x 150



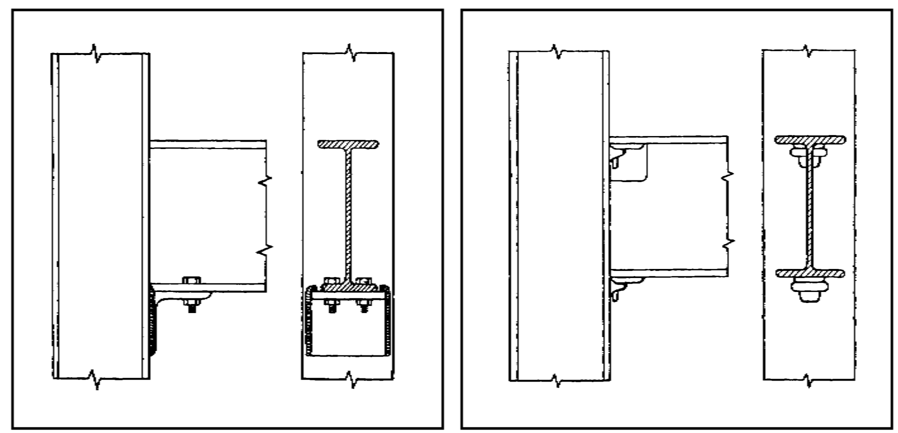
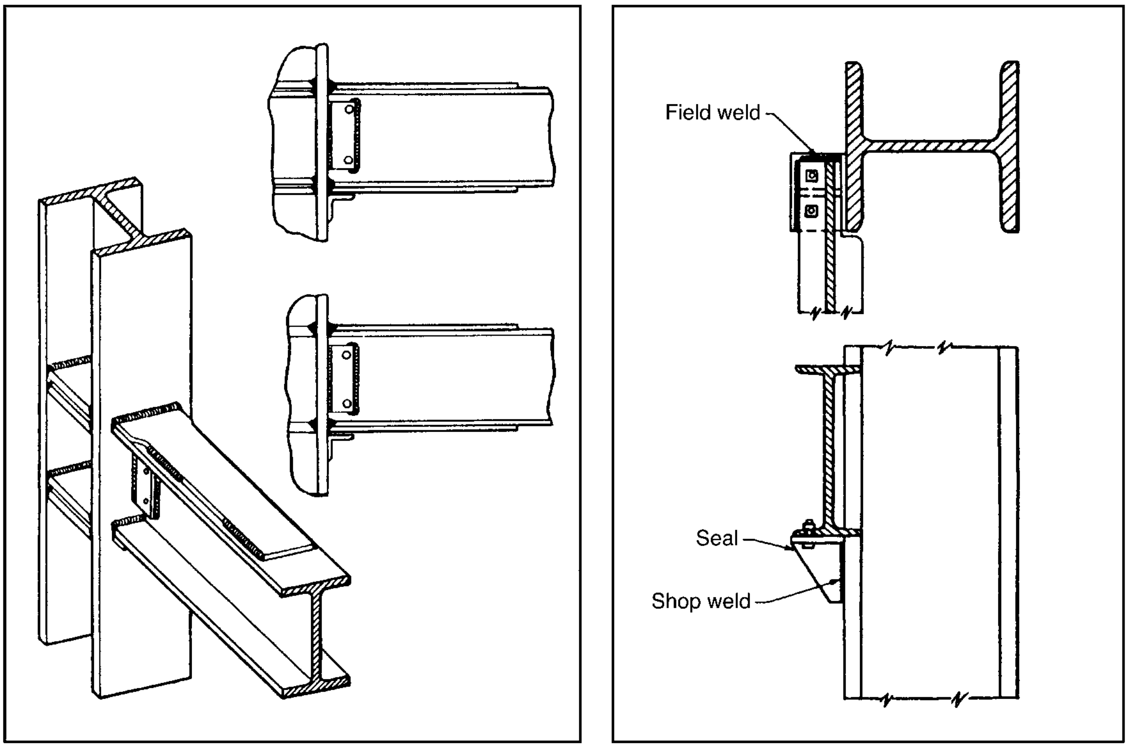


Fig. 6.1.12. End beam–column connection—projected views (based on BS 5950 specifications)

6.1A. Detailing of welded plate girders



Beam continuous over support

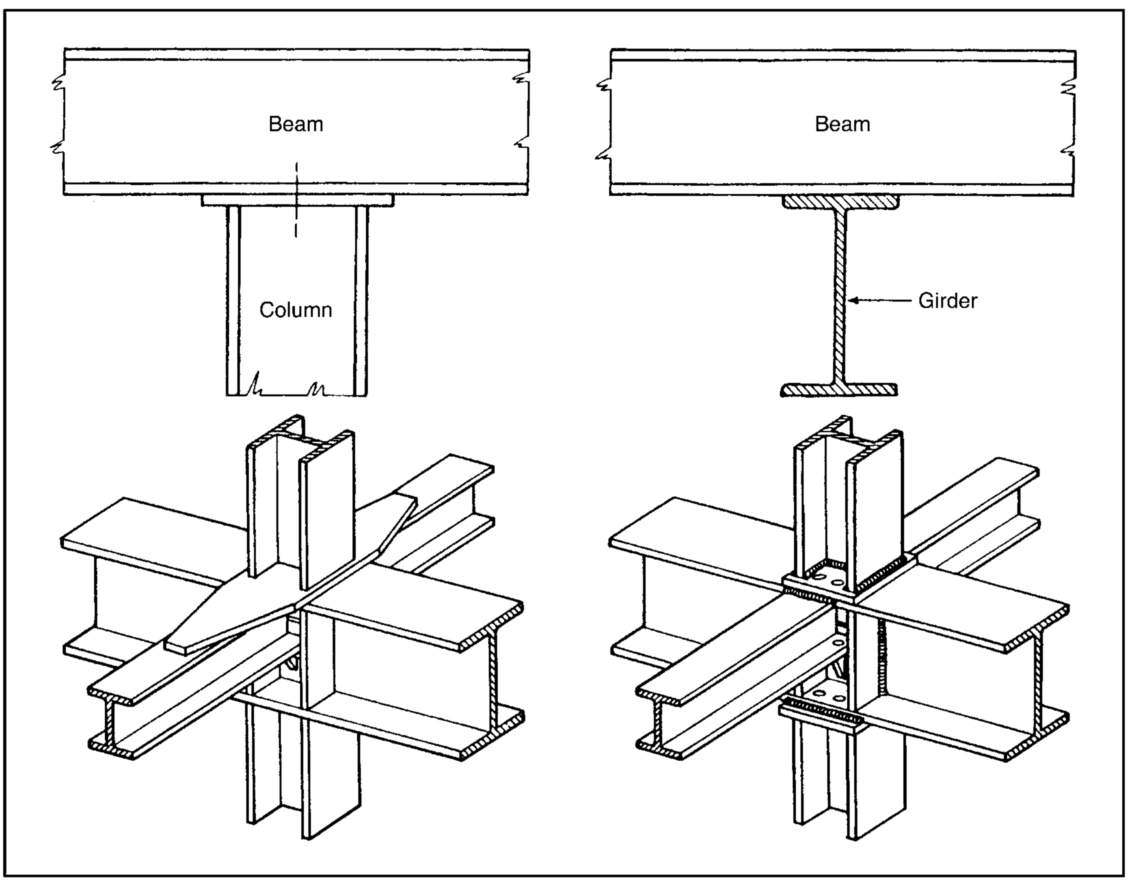
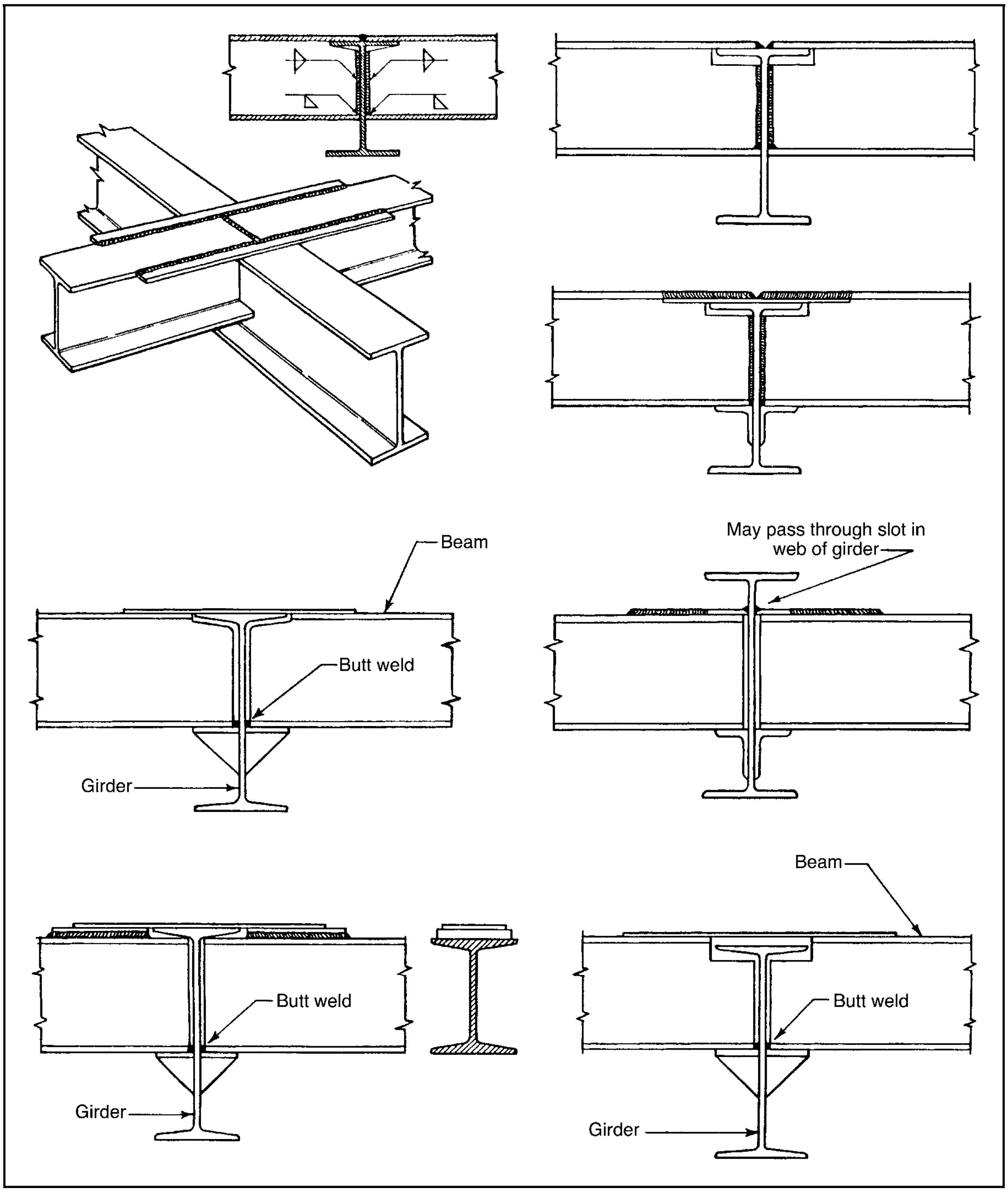


Fig. 6.1.13. Spandrel beam to columns (based on BS 5950 specifications)



Example:
All beams (major) vary from 914 x 419 x 388 UB
to 254 x 102 x 28 UB
grade 43
All columns 254 x 254 x 167 UC
grade 43
All beams (major) vary from 254 x 102 x 28 UB
to 127 x 76 x 13 UB
grade 43
All welds 8 mm
All bolts HD20 grade 4.6

Fig. 6.1.13. Continued

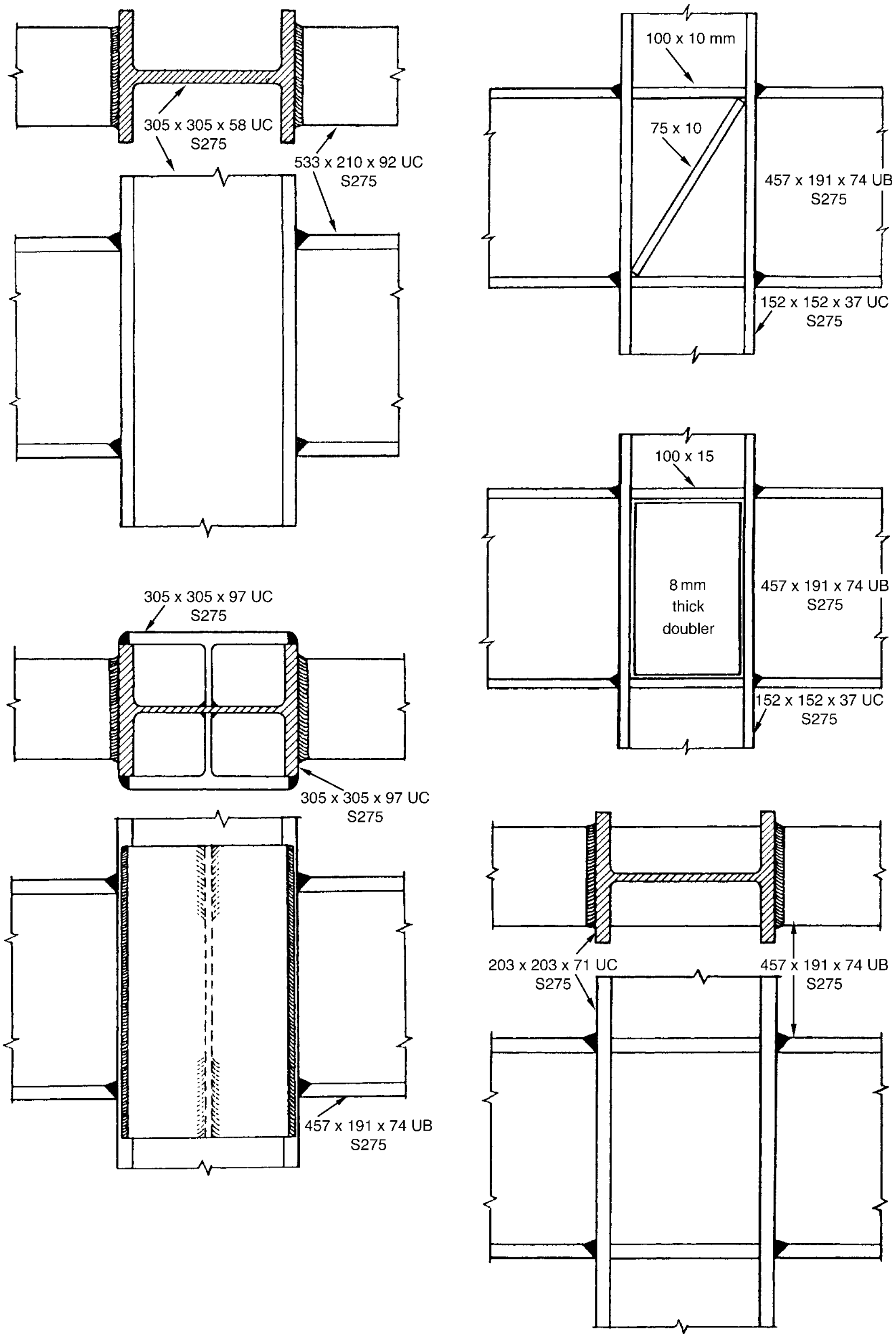
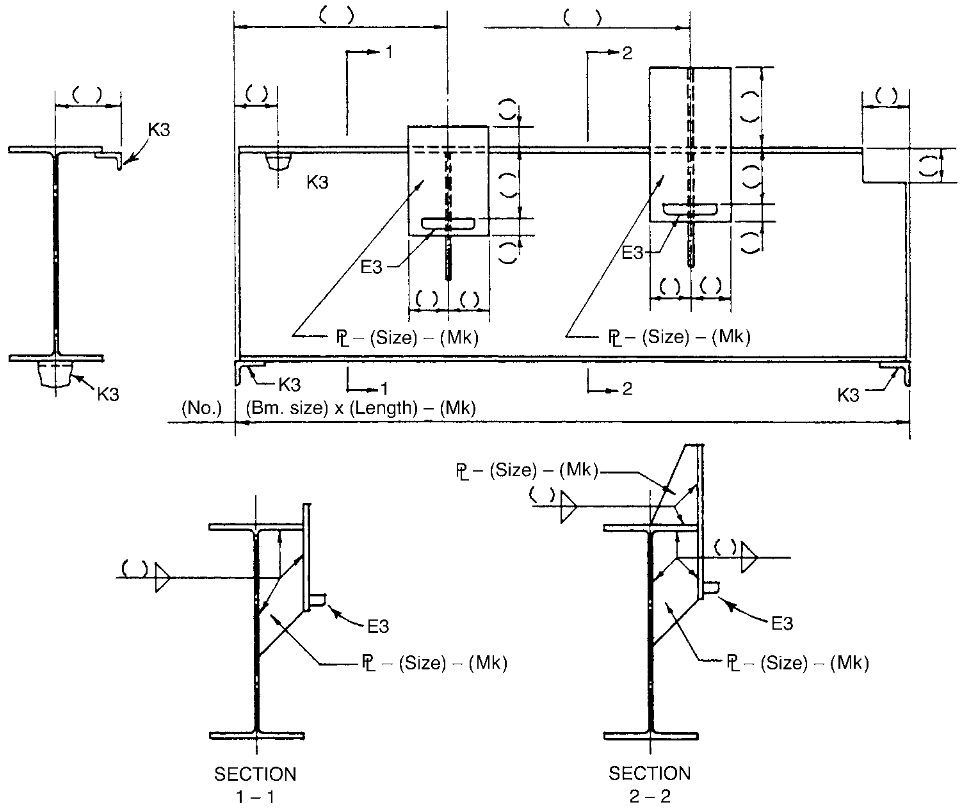


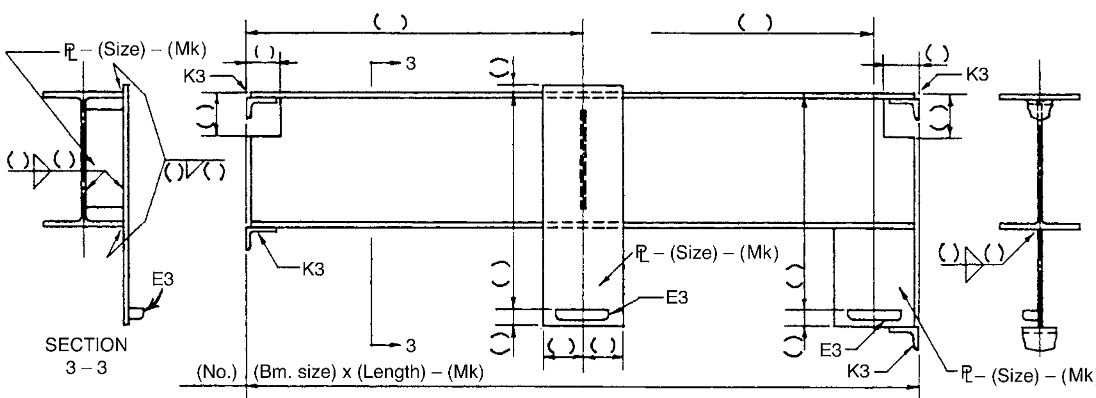
Fig. 6.1.14. Beam to column connection—all welds 6–8 mm (based on EC3 specifications)



SPECIAL BEAM CONNECTIONS

BEAM FRAMING BETWEEN COLUMN AND GIRDER

Figure A



SPECIAL BEAM CONNECTION

GIRDER FRAMING BETWEEN COLUMN FLANGES

Figure B

Dimensions required for fabrication are indicated by parenthesis, thus; ( ). Weld designations are according to the A.W.S. standards. Shop welds for the Saxe Seats and Clips are not shown on details, but are detailed typically on one sheet for the entire job.

Fig. 6.1.15. Sample shop detail drawing—beams (based on AISC specifications)

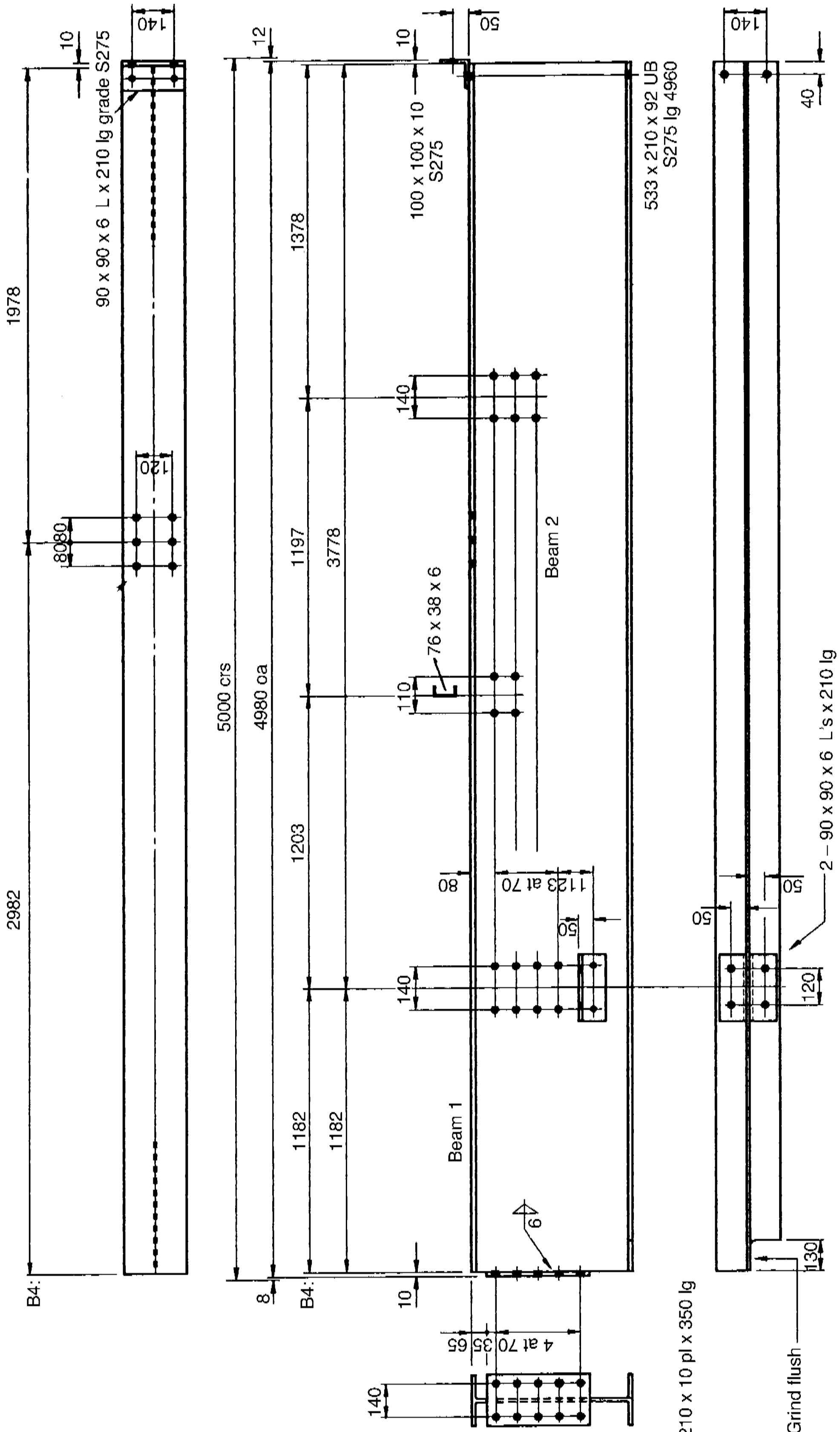
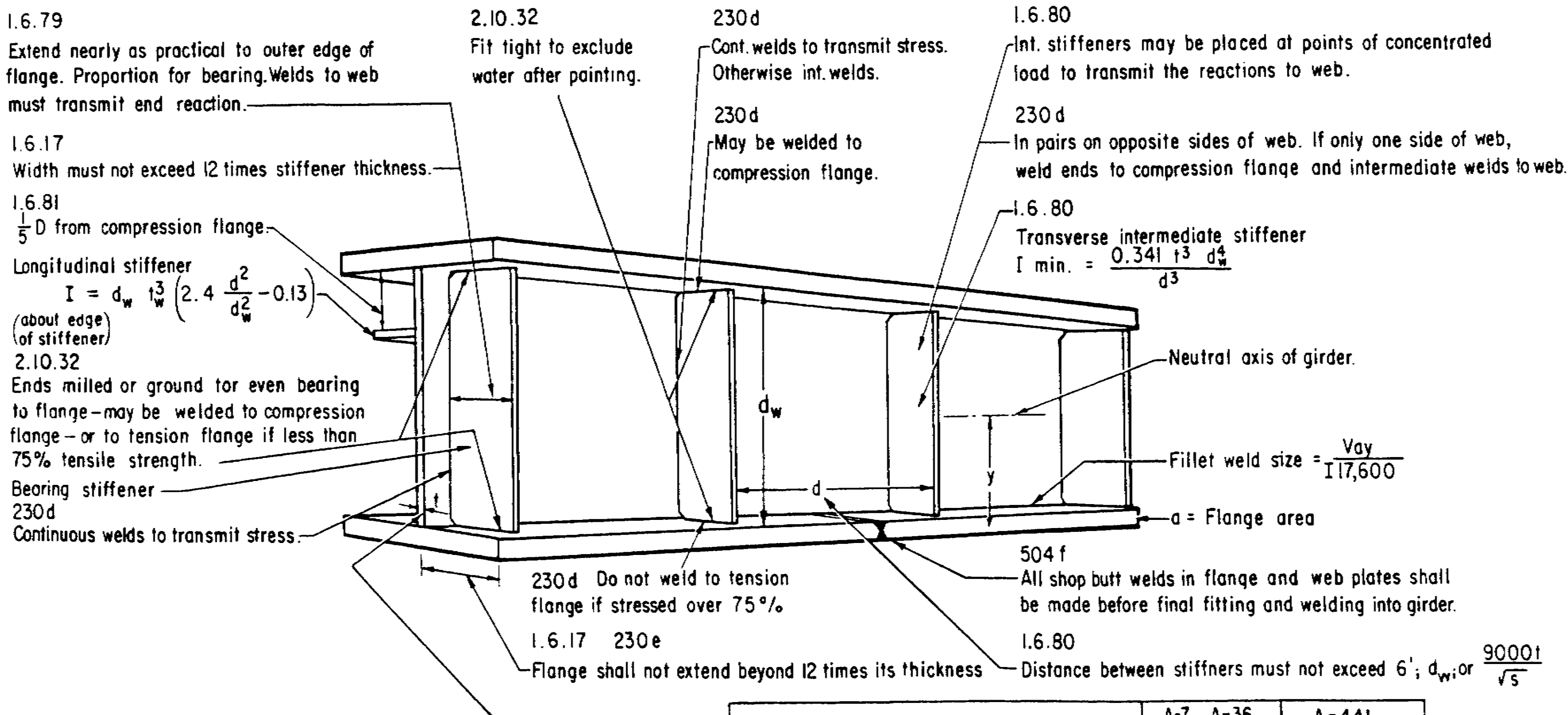


Fig. 6.1.16. Detailing of typical beam with bolted angle cleats: all bolts are HD20 grade 4.6; the beam is S275; all angles/channels S275 (based on EC3 specifications)



1.6.10
Deflection due to live load plus impact shall not exceed $\frac{1}{800}$ of the span, for cantilever arms $\frac{1}{300}$ of the span.

1.6.11
Ratio of depth to length of span shall preferably not be less than $\frac{1}{25}$, for lower depth the section shall be increased so that the maximum deflection will not be greater than if this ratio had not been exceeded.

Web thickness t	A-7, A-36 A-373	A-441 low alloy
No stiffeners (1.6.80)	$t = \frac{1}{60} d_w$	$t = \frac{1}{52} d_w$
Trans. int. stiffeners (1.6.75) simply supported or cantilever girder.	$t = \frac{1}{170} d_w$	$t = \frac{1}{140} d_w$
Trans. int. stiffeners—continuous girders at negative moment.	$t = \frac{1}{140} d_w$	$t = \frac{1}{110} d_w$
Long. stiffeners and trans.-simply supported or at positive moment of continuous girder.	$t = \frac{1}{340} d_w$	$t = \frac{1}{280} d_w$
Long. stiffeners and trans. at negative moment continuous girder. Or cantilever girder.	$t = \frac{1}{270} d_w$	$t = \frac{1}{220} d_w$

Fig. 6.1.17. Summary of plate girders—bridge (AWS and AASHTO specifications)

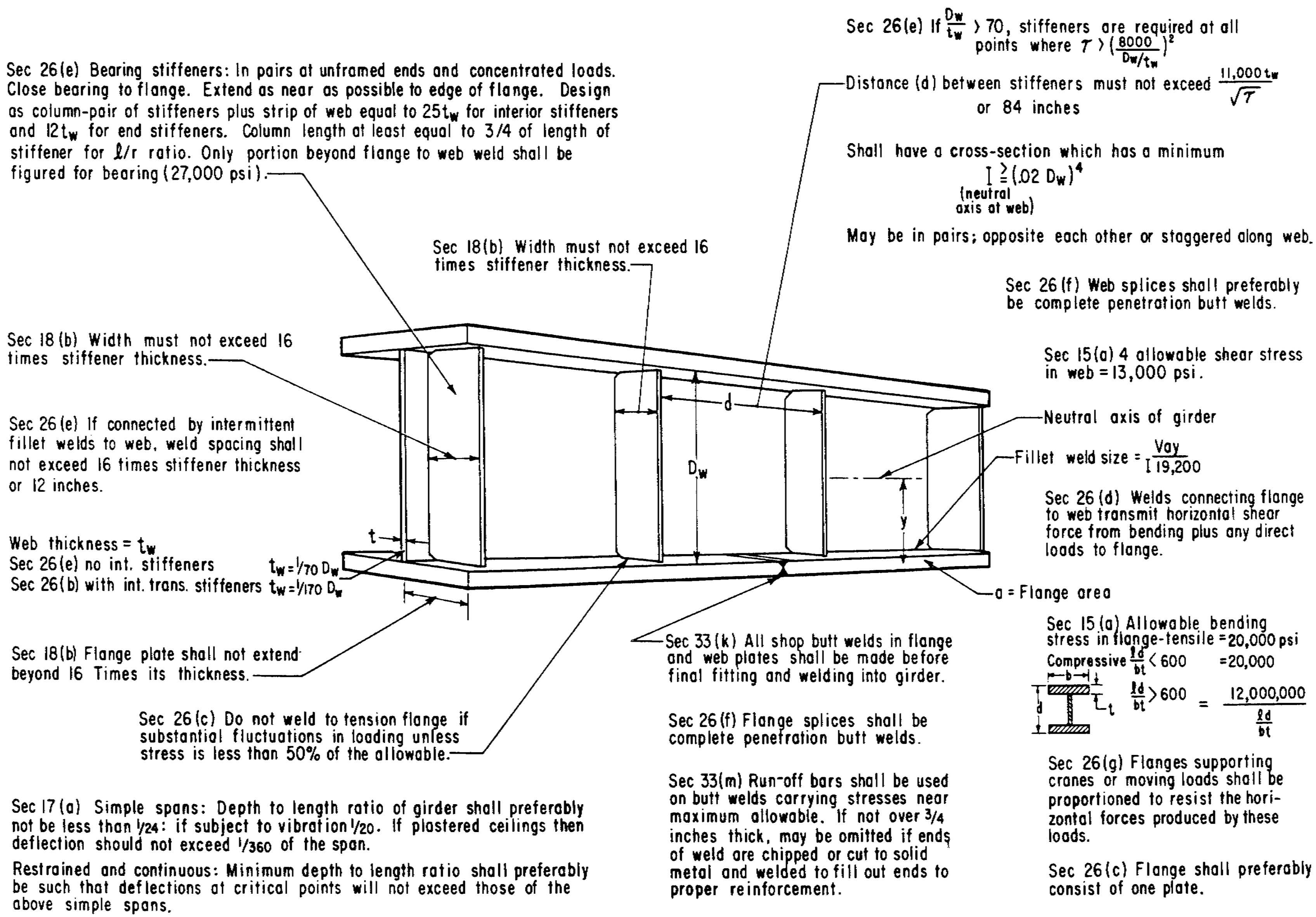


Fig. 6.1.18. Summary of plate girders—building (AISC and AWS specifications)

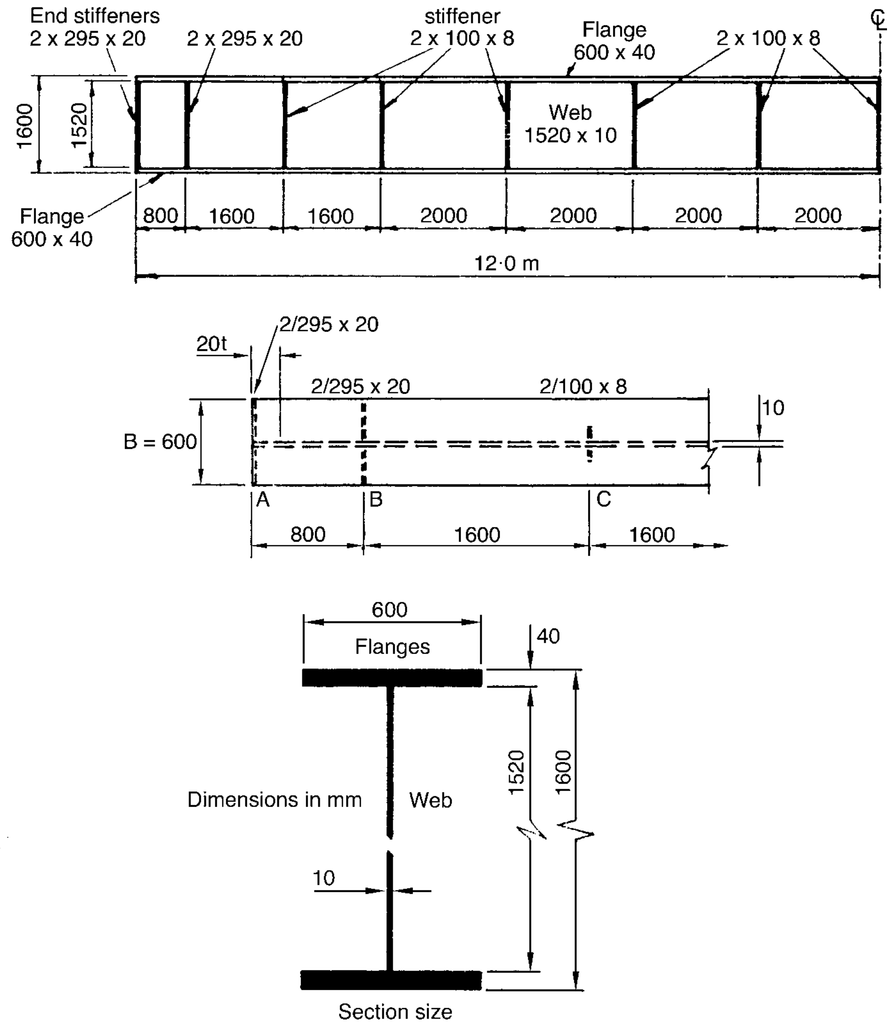
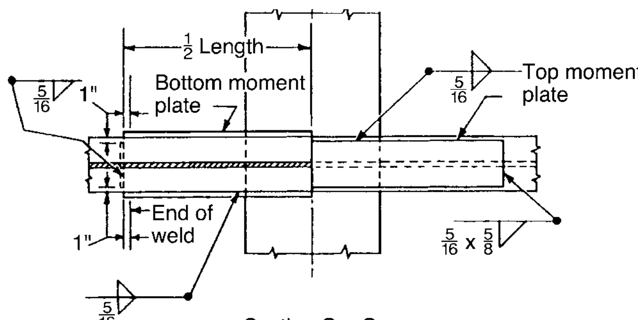


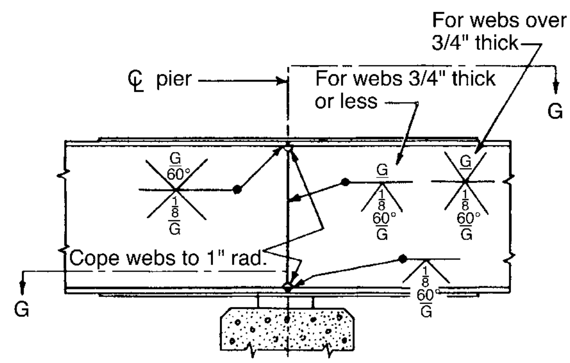
Fig. 6.1.19. Plate girders (symmetrical flanges), welded (based on BS 5950 specifications)

Beam splice welding procedure: (for 3 spans)

1. Raise the abuttment ends of the beams the tabulated amount (R).
2. Butt-weld the beam flanges and web, using the following sequence: make two passes on each flange, then two on the web, repeat, using one pass at each location, until welds are completed.
3. Weld the bottom and top moment plates.
4. Lower the beam ends to final position.

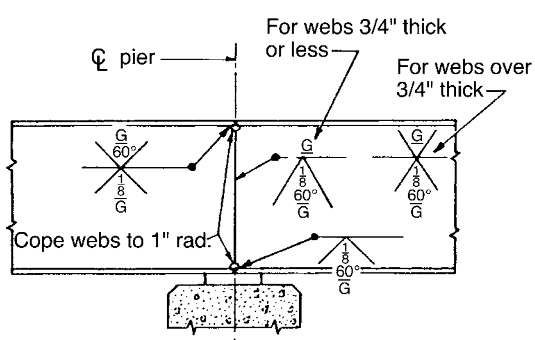


Section G – G



"G" Indicates grinding

Beam splice details with moment plates



Beam splice details without moment plates

Fig. 6.1.20. Beam splice details over supports (continuous over three spans) (based on AISC and AASHTO specifications). From Standard Specification for Highway Bridges, Copyright 1996, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used by permission

6.2. Columns and portal frames

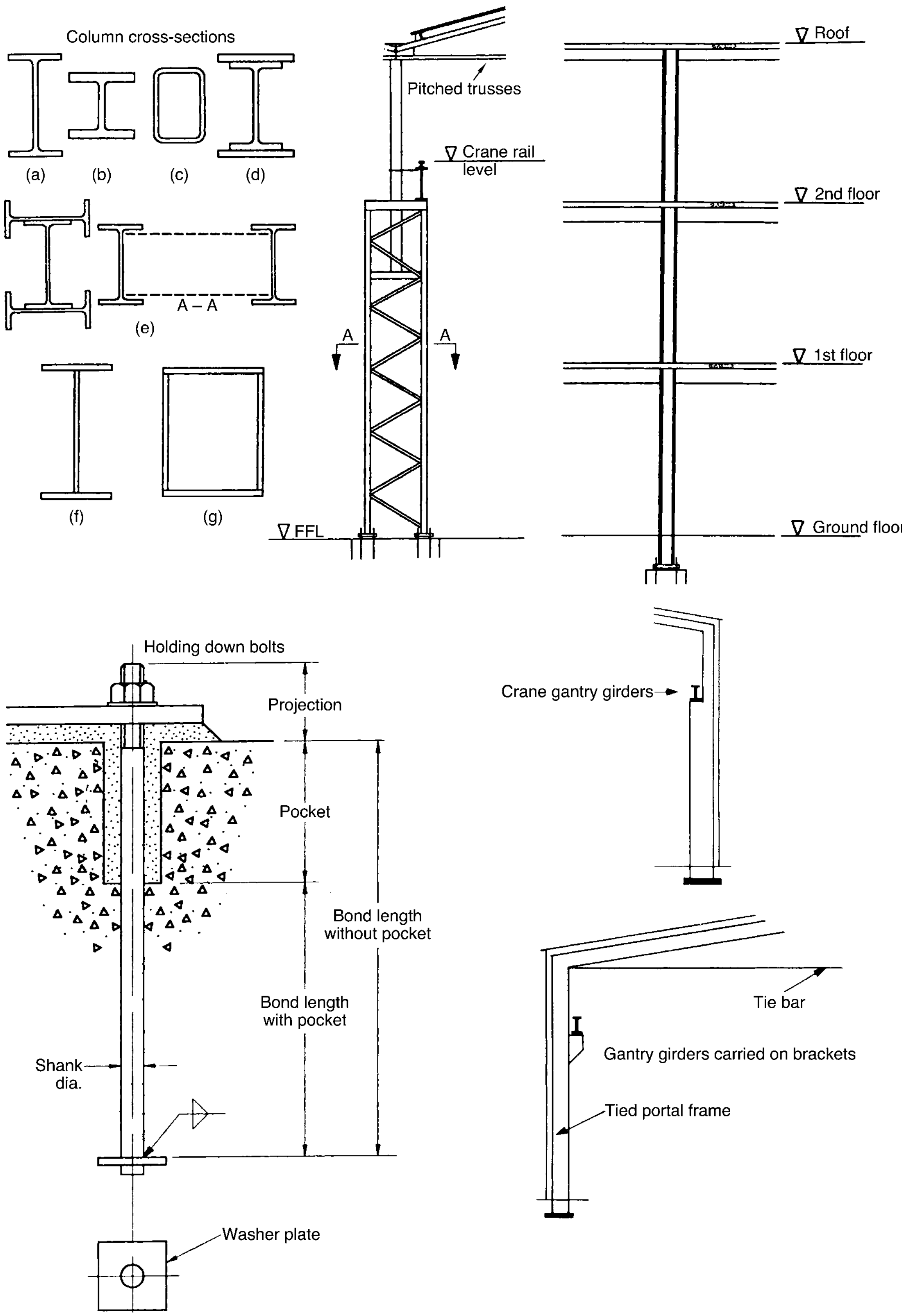


Fig. 6.2.1. Types of column, holding down bolts and gantry girders (BS 5950 specification)

W column splices

Two cases are described below, namely splice plates shop welded and field bolted and shop welded and field welded.

First case
Flange plates shop welded, field bolted
Depth D_U and D_L nominally the same

Case 1
$D_L = (D_U + \frac{1}{4})$ to $(D_U + \frac{5}{8})$
No fills.
Furnish sufficient $2\frac{1}{2} \times \frac{1}{8}$ strip shims to obtain 0 to $\frac{1}{16}$ clearance on each side.

***Splice plates, welds and fasteners:**
(1) Select width of splice plate, number and gage of fasteners, and length L_U in accordance with upper shaft size.
(2) Select thickness of splice plates, size A and lengths (X and Y) of welds and lengths L_L in accordance with lower shaft size.
(3) Add $L_U + L_L$ to obtain length of splice plates.

Case 2
$D_L = (D_U - \frac{1}{4})$
$D_L = (D_U - \frac{1}{8})$
$D_L = D_U$
$D_L = (D_U + \frac{1}{8})$
Fills on lower shaft.

***Splice plates, welds and fasteners:**
Same as for Case 1, except use weld size $(A + t)$ on lower shaft.
FILLS (shop welded under splice plates):
Fill thickness t:
Where $D_L = (D_U - \frac{1}{4})$, use $\frac{3}{16}$
$D_L = (D_U - \frac{1}{8})$, use $\frac{3}{16}$
$D_L = D_U$, use $\frac{1}{8}$
$D_L = (D_U + \frac{1}{8})$, use $\frac{1}{8}$
Fill width: same as splice plate.
Fill length: $(L_L - 2)$

Case 3
$D_L = (D_U + \frac{3}{4})$ and over.
Fills on upper shaft, minimum welds.

***Splice plates, welds and fasteners:**
Same as for Case 1.

FILLS (shop welded to upper shaft):
Fill thickness t: $\frac{1}{2}(D_L - D_U) - \frac{1}{8}$ or $-\frac{3}{16}$, whichever results in $\frac{1}{8}$-in. multiples of fill thickness.
Weld size B:

Weld length: $(L_U - \frac{1}{4})$
Fill width: Width of splice plate
Fill length: $(L_U - \frac{1}{4})$

Second case
Flange plates shop and field welded
Depth D_U nominally 2 in. less than depth D_L

Case 4
Fills on upper shaft, developed for bearing.
Fill width less than upper shaft flange width.

***Splice plates and splice welds:**
Same as Case 1.

FILLS (shop welded to upper shaft):
Fill thickness: t: $\frac{1}{2}(D_L - D_U) - \frac{1}{16}$
Weld size B:

Max.: $\frac{5}{16}$ (preferred) or $(t - \frac{1}{16})$ or t,

Weld length $L_B \geq (A_f f_p)/2f_R \geq (L/2 + 1\frac{1}{2})$ in which A_f = finished contact area of one fill, f_R = allowable shear value of one linear inch of weld, size B, and f_p = computed bearing stress in fill
Fill width
Min.: (Splice plate width) + $2N$
Max.: (Upper shaft flg. width) − $2M$
Fill length: L_B

Case 5
Fills on upper shaft, developed for bearing.
Fill width greater than upper shaft flange width.
Use Case 5 only when spaces M and N, Case 4, are inadequate for welds B and A, or when fills must be widened to obtain additional bearing area.

***Splice plates and splice welds:**
Same as Case 1.

FILLS (shop welded to upper shaft):
Fill thickness: $\frac{1}{2}(D_L - D_U) - \frac{1}{16}$
Weld size B:

Max.: $\frac{5}{16}$ (preferred) or $(T_U - \frac{1}{16})$ or T_U.

Weld length L_B: Same as Case 4
Fill width: (Splice plate width) + $2N$, or (Upper shaft figure width) + $2M$
Round greater value up to next quarter inch.
Fill length: L_B

Note:
1. *Min. AISC, ASD and LRFD specification.
2. 1 inch = 25.4 mm.
3. If L_B = fill length is excessive place weld size B across and offill and reduce L_B by $\frac{1}{2}$ or to $L/2 + 1\frac{1}{2}$. Disregard return welds in Case 2.

Fig. 6.2.2A. W column splice construction examples

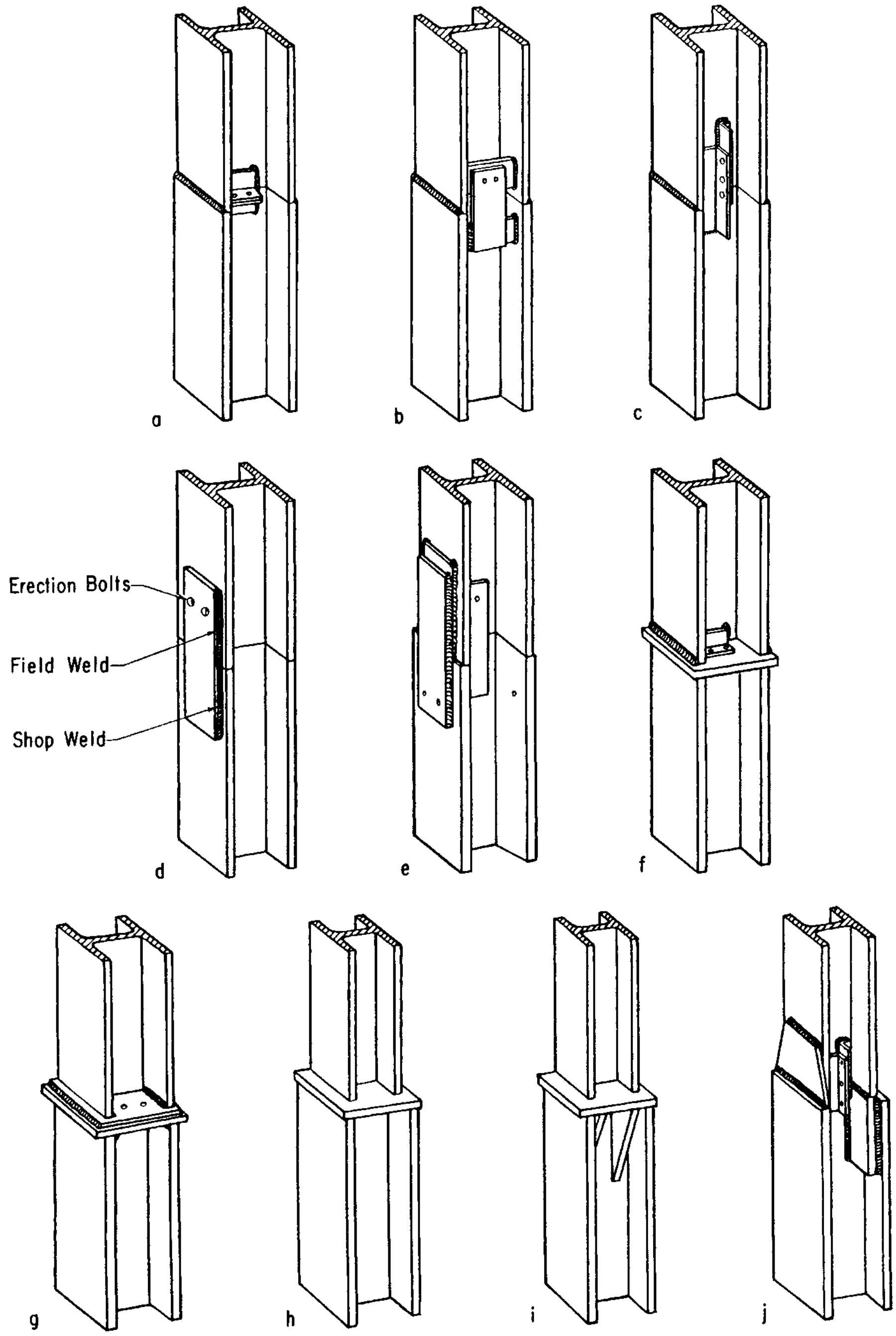


Fig. 6.2.2B. Miscellaneous column splices—projected view (AISC specification)

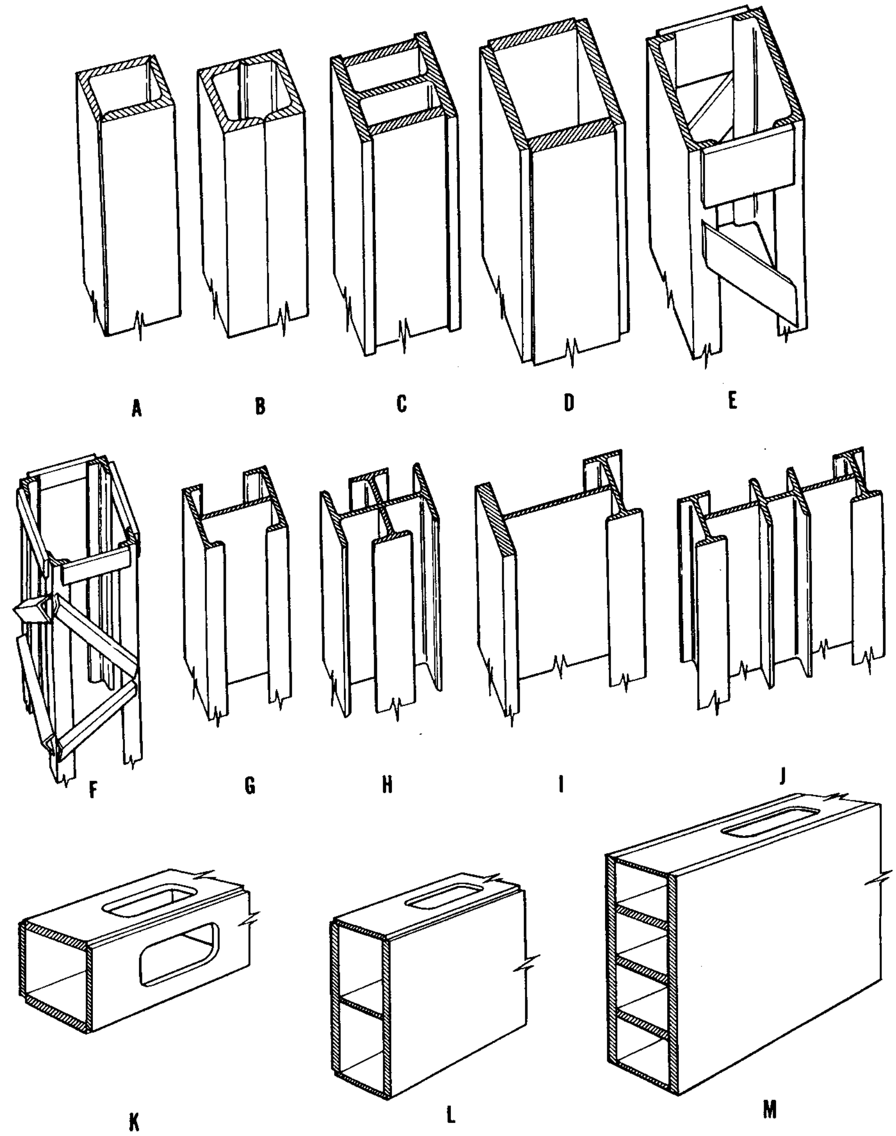
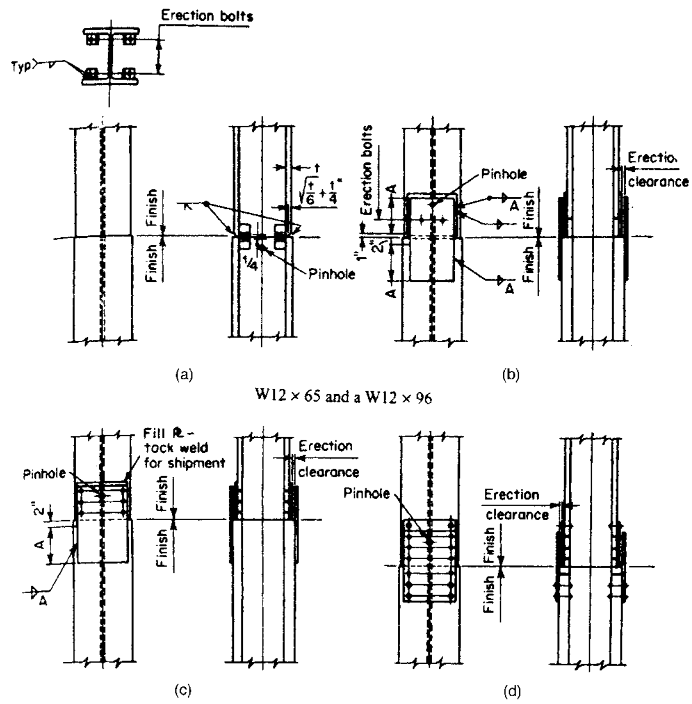


Fig. 6.2.3. Built up compression members—projected view (AISC specification)



Column Size	Splice Plate				Fasteners		Welds		
	Width	Thk.	Length L_U	Length L_L	No. of Rows	Gage G	Size A	Length X	Length Y
W14 × 455 & over	14	$\frac{5}{8}$	$12\frac{1}{4}$	9	3	$11\frac{1}{2}$	$\frac{1}{2}$	5	7
W14 × 311 to 426	12	$\frac{5}{8}$	$12\frac{1}{4}$	8	3	$9\frac{1}{2}$	$\frac{1}{2}$	4	6
W14 × 211 to 283	12	$\frac{1}{2}$	$12\frac{1}{4}$	8	3	$9\frac{1}{2}$	$\frac{3}{8}$	4	6
W14 × 90 to 193	12	$\frac{3}{8}$	$9\frac{1}{4}$	8	2	$9\frac{1}{2}$	$\frac{5}{16}$	4	6
W14 × 61 to 82	8	$\frac{3}{8}$	$9\frac{1}{4}$	8	2	$5\frac{1}{2}$	$\frac{5}{16}$	3	6
W14 × 43 to 53	6	$\frac{5}{16}$	$9\frac{1}{4}$	7	2	$3\frac{1}{2}$	$\frac{1}{4}$	2	5
W12 × 120 to 336	8	$\frac{1}{2}$	$9\frac{1}{4}$	8	2	$5\frac{1}{2}$	$\frac{3}{8}$	4	6
W12 × 53 to 106	8	$\frac{3}{8}$	$9\frac{1}{4}$	8	2	$5\frac{1}{2}$	$\frac{5}{16}$	3	6
W12 × 40 to 50	6	$\frac{5}{16}$	$9\frac{1}{4}$	7	2	$3\frac{1}{2}$	$\frac{1}{4}$	2	5
W10 × 49 to 112	8	$\frac{3}{8}$	$9\frac{1}{4}$	8	2	$5\frac{1}{2}$	$\frac{5}{16}$	3	6
W10 × 33 to 45	6	$\frac{5}{16}$	$9\frac{1}{4}$	7	2	$3\frac{1}{2}$	$\frac{1}{4}$	2	5
W8 × 31 to 67	6	$\frac{3}{8}$	$9\frac{1}{4}$	7	2	$3\frac{1}{2}$	$\frac{5}{16}$	2	5
W8 × 24 & 28	5	$\frac{5}{16}$	$9\frac{1}{4}$	6	2	$3\frac{1}{2}$	$\frac{1}{4}$	2	4

Gages shown may be modified if necessary to accommodate fittings elsewhere on the columns.

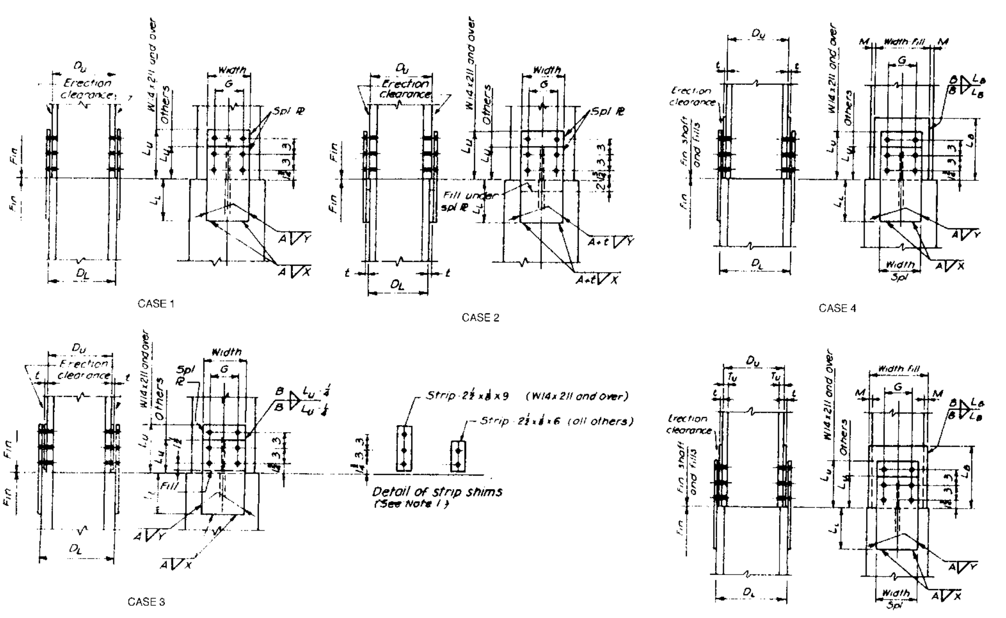


Fig. 6.2.4. Column member splices (based on AISC/ASD specifications, adapted by LRFD)

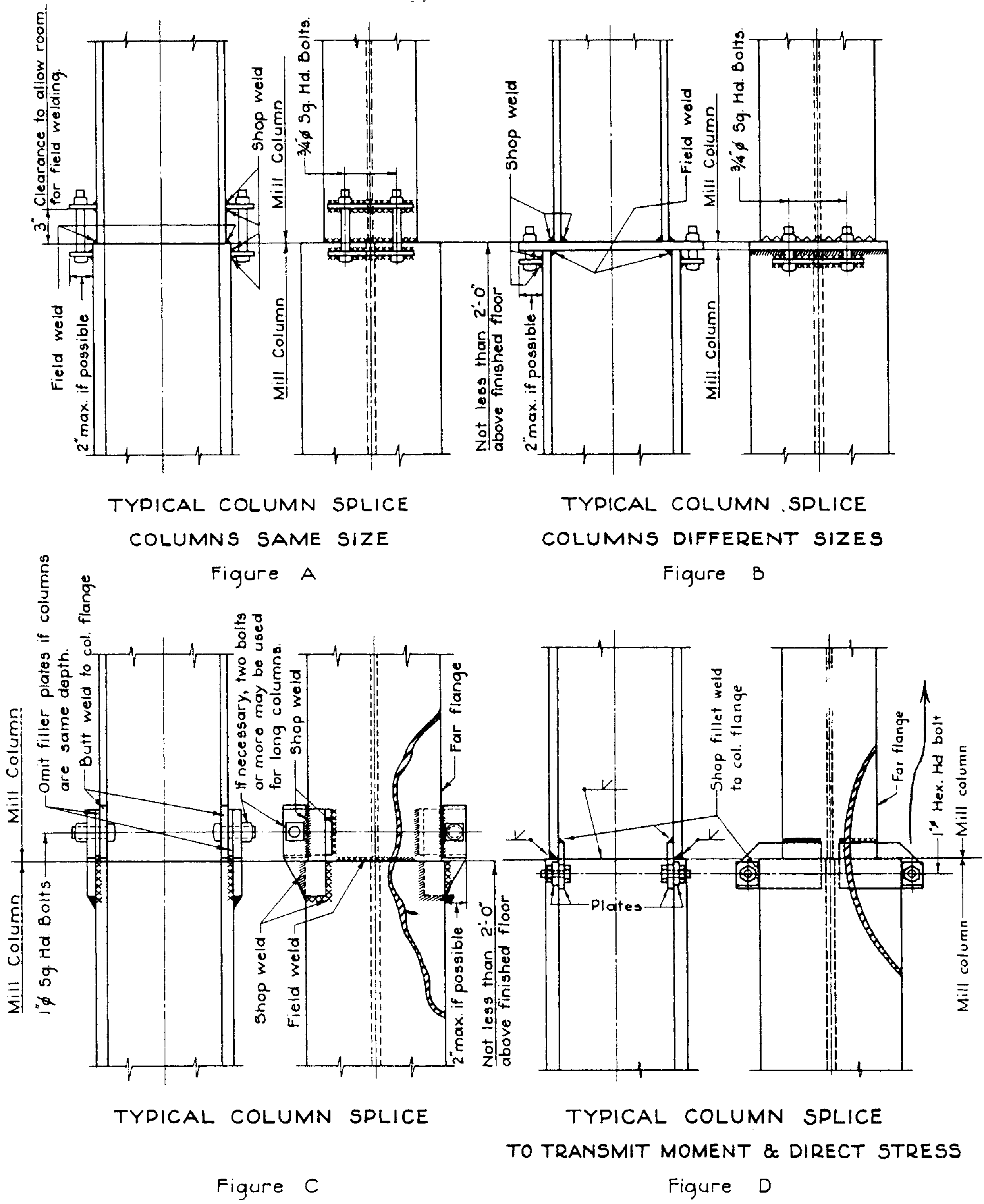


Fig. 6.2.5. Column splice fabrication details (based on AISC/LRFD specifications). Figure used with permission of The Lincoln Electric Company

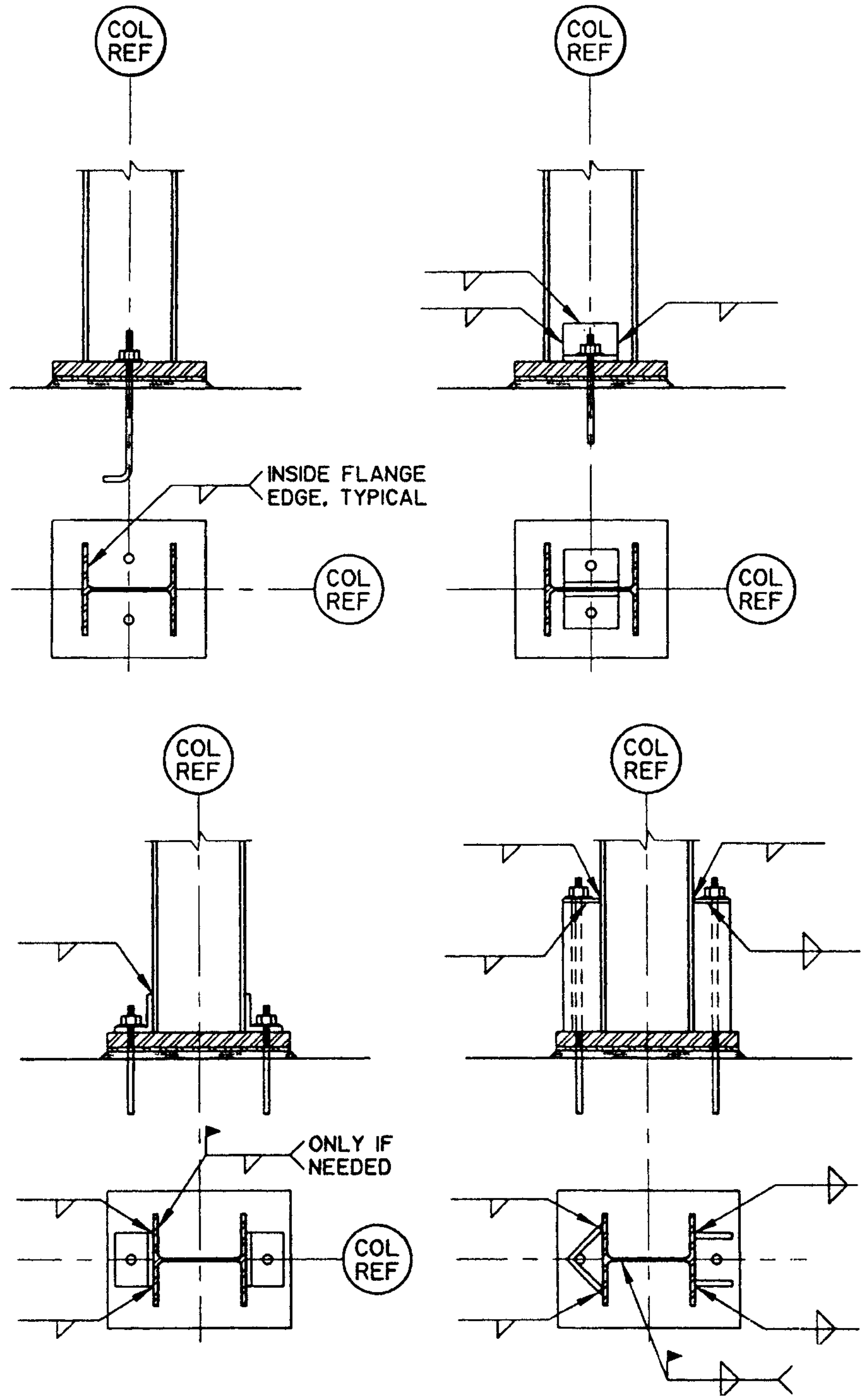


Fig. 6.2.6. Column bases (based on EC3 specifications)

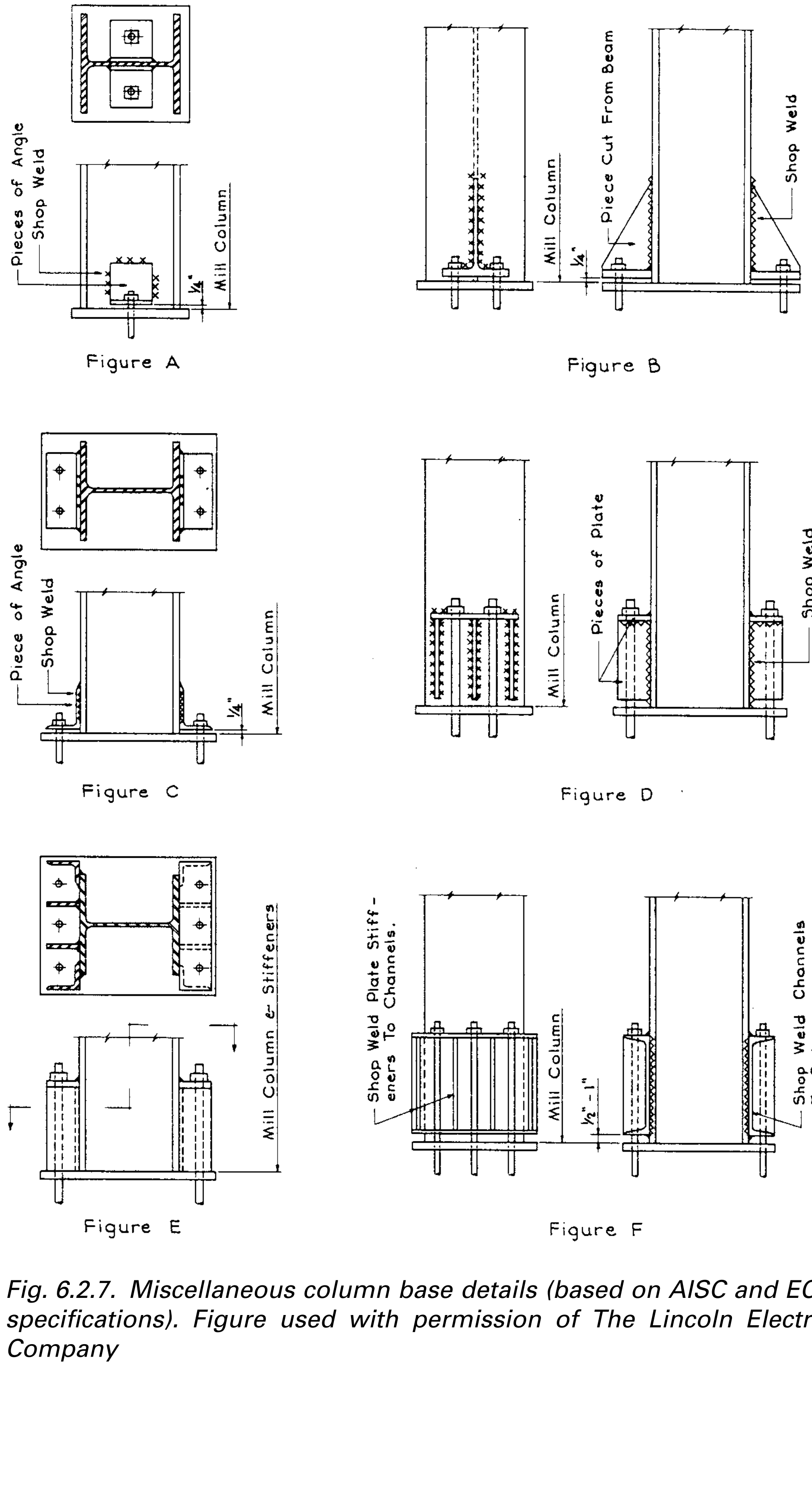


Fig. 6.2.7. Miscellaneous column base details (based on AISC and EC3 specifications). Figure used with permission of The Lincoln Electric Company

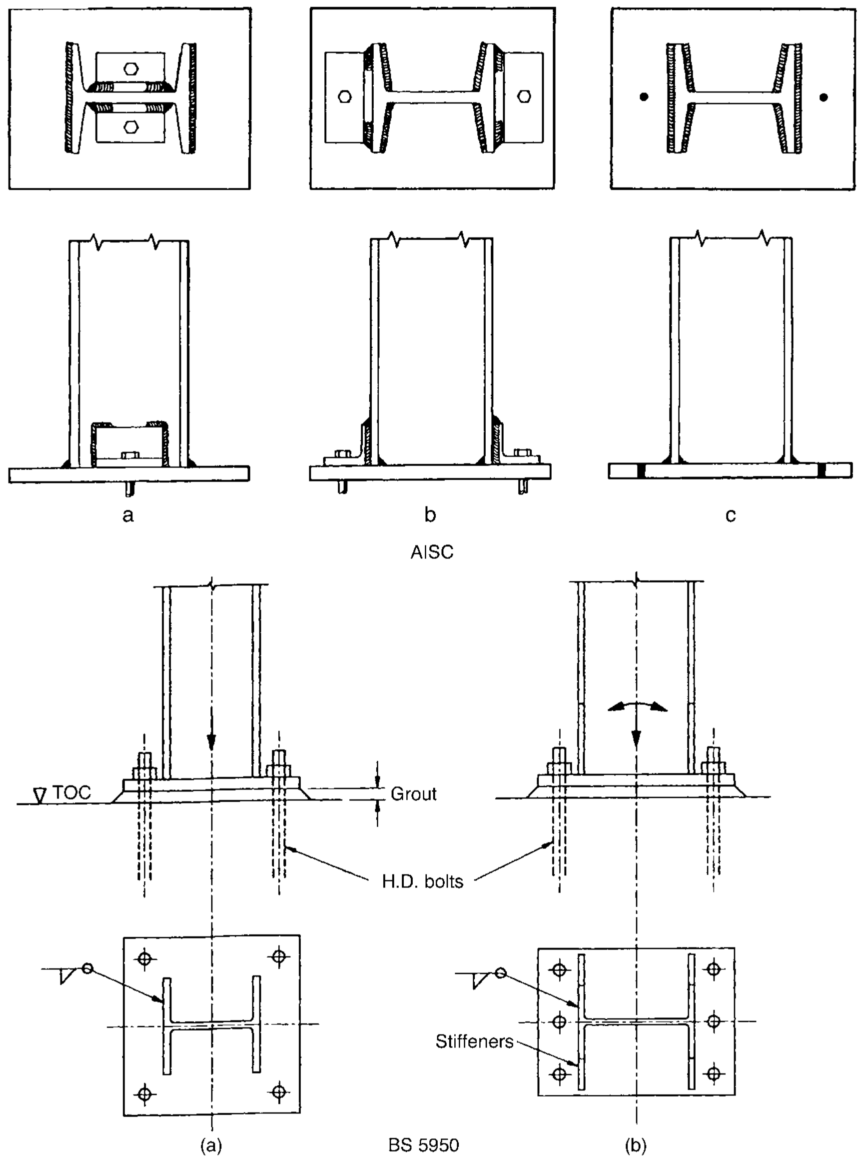


Fig. 6.2.8. Miscellaneous column base details (based on AISC/BS 5950 specifications)

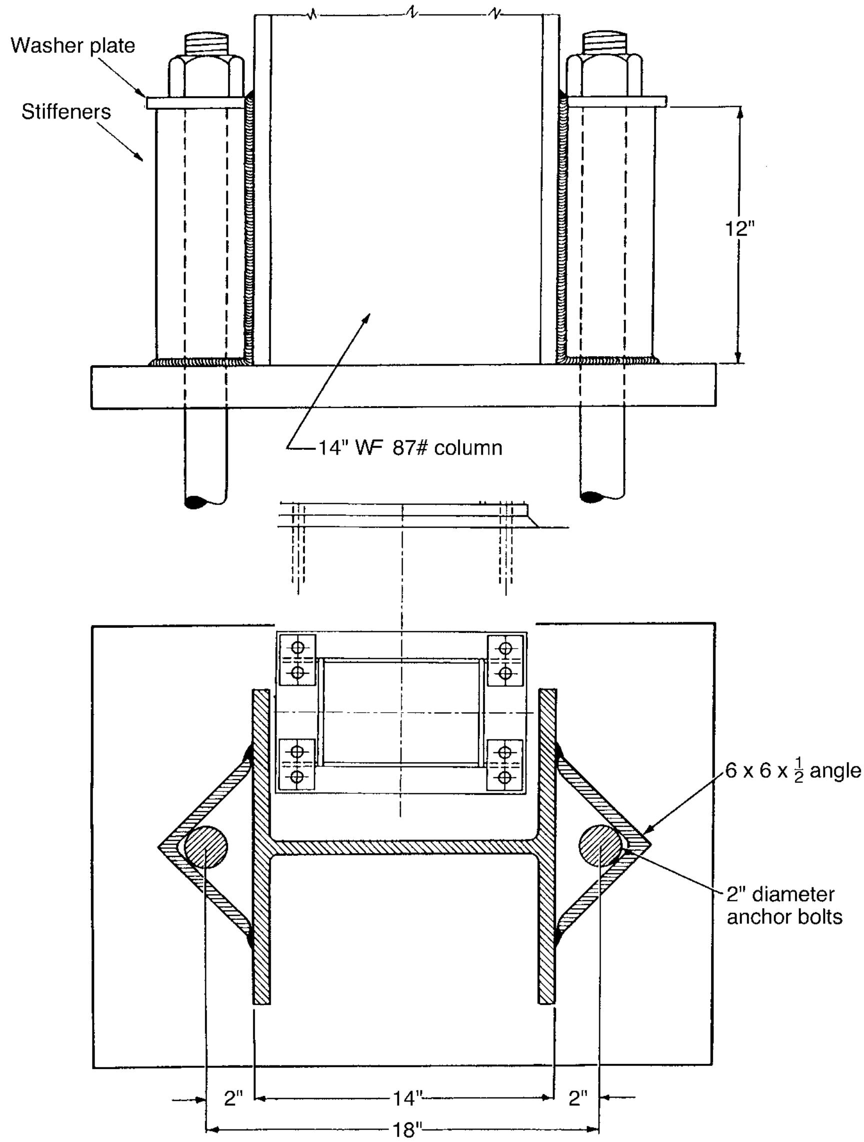


Fig. 6.2.9. Column base details (based on AISC and EC3 specifications)

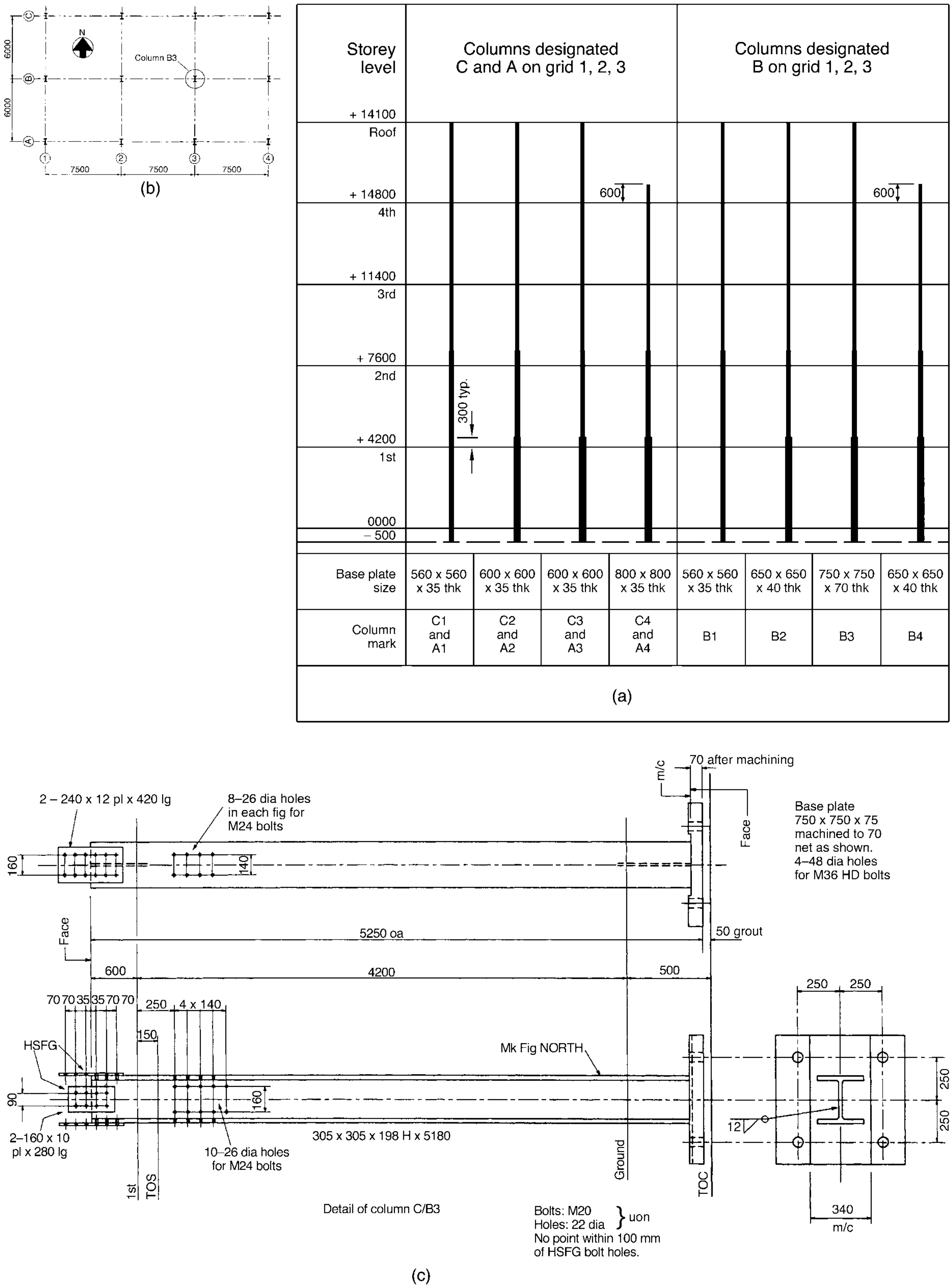


Fig. 6.2.10. Multi-storey building column: (a) column schedule; (b) key plan grid (based on BS 5950 and EC3 specifications); (c) detailing

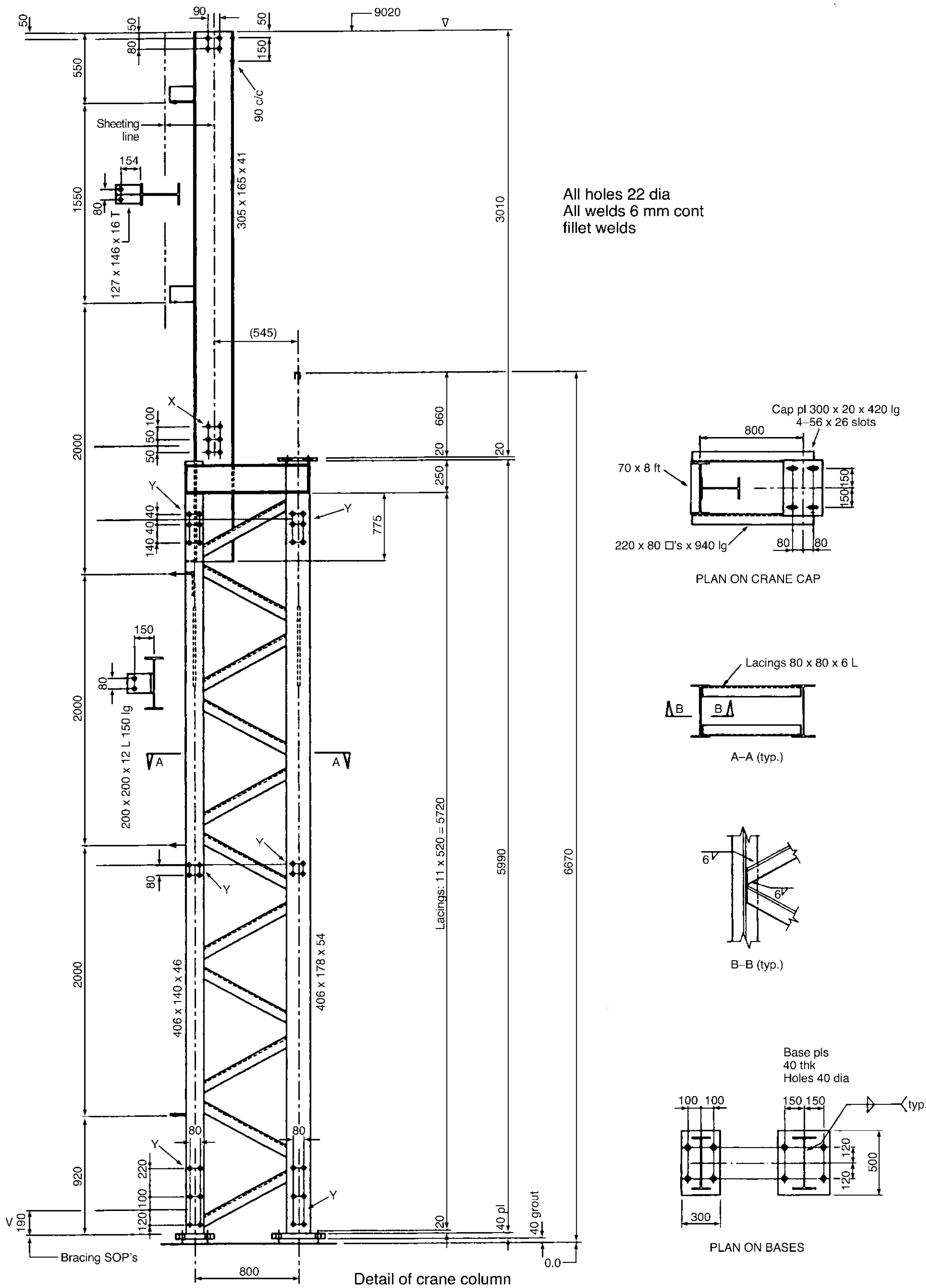


Fig. 6.2.11. Column detailing practice—trussed column (based on BS 5950 and EC3 specifications)

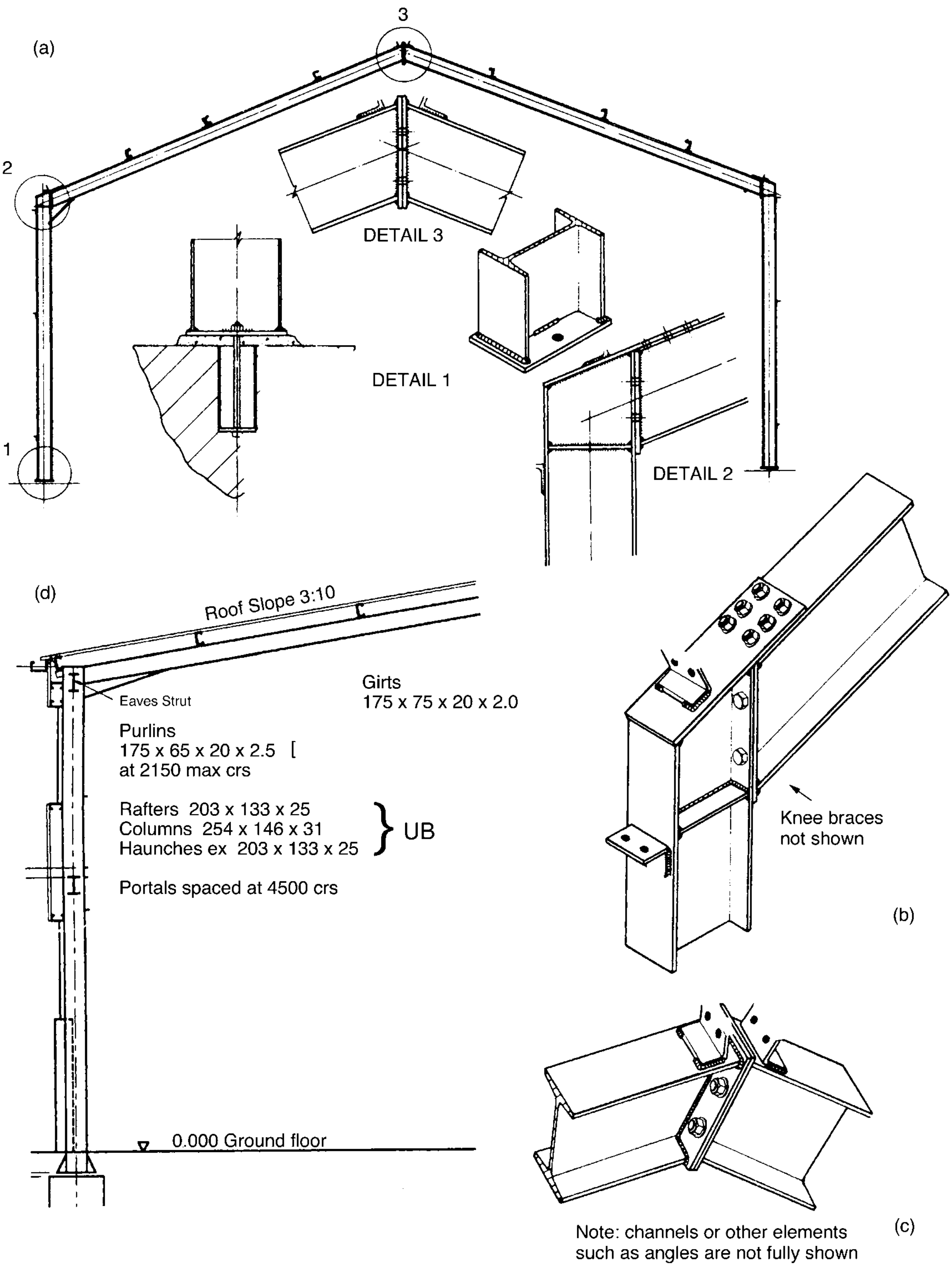


Fig. 6.2.12. Design details of portal frames and projections (based on BS 5950 specifications): (a)–(c) isomeric views; (d) sectional elevation

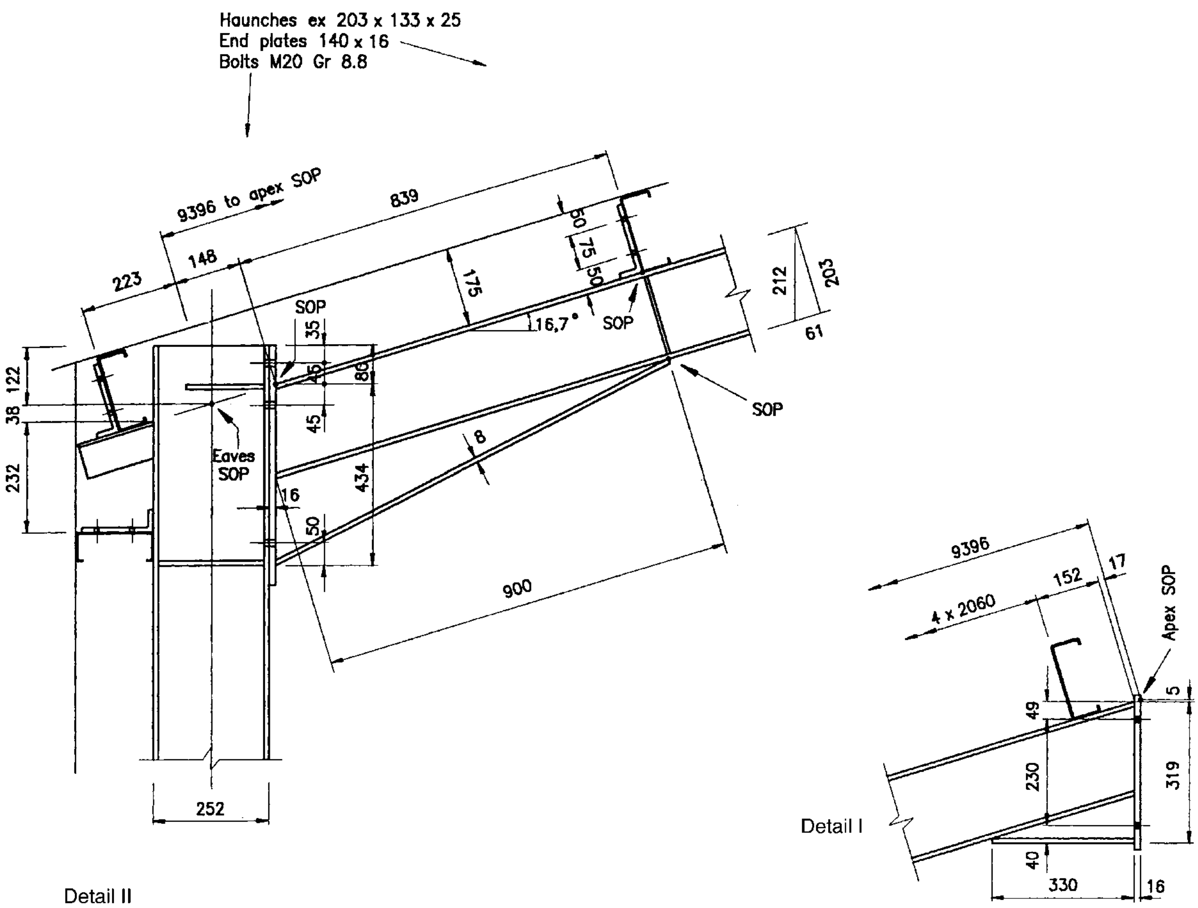
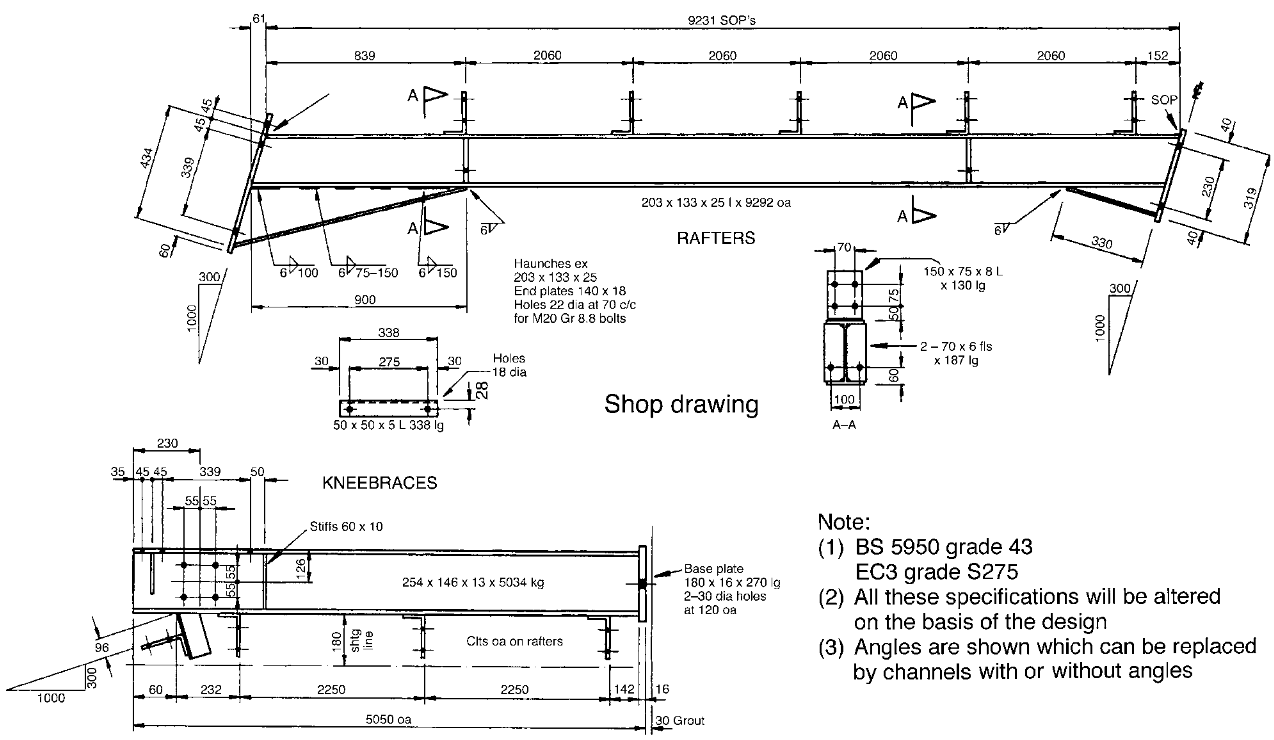


Fig. 6.2.13. Structural details of portal frames (based on BS 5950 and EC3 specifications)



Details of portal frame members

Fig. 6.2.14. Pre-set of portal frames—fabrication drawing (based on BS 5950 and EC3 specifications)

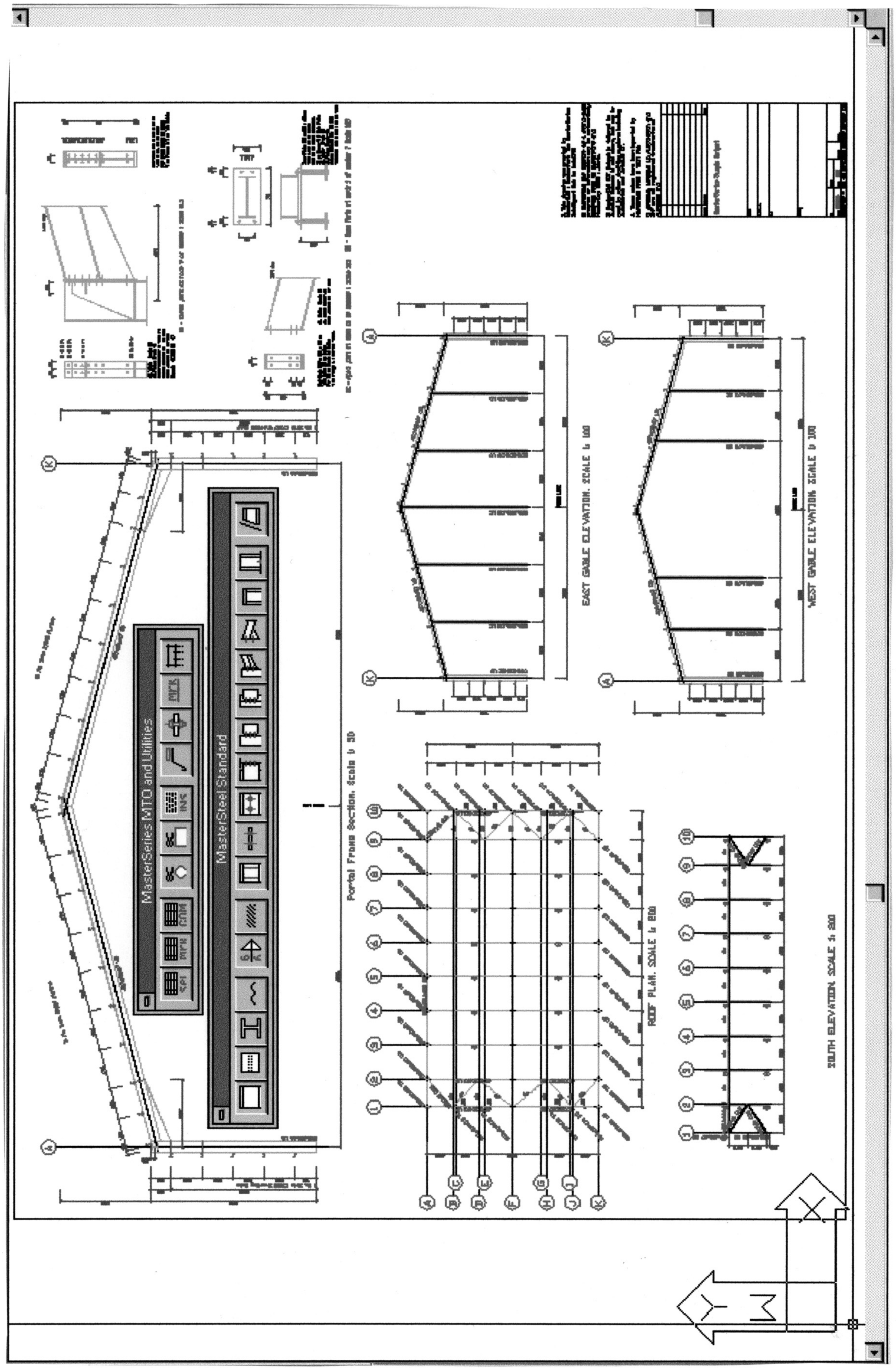


Fig. 6.2.15. Computer-aided structural details of portal frames—MasterSeries (based on BS 5950 specifications)

6.3. Trusses, lattice girders and trussed frames

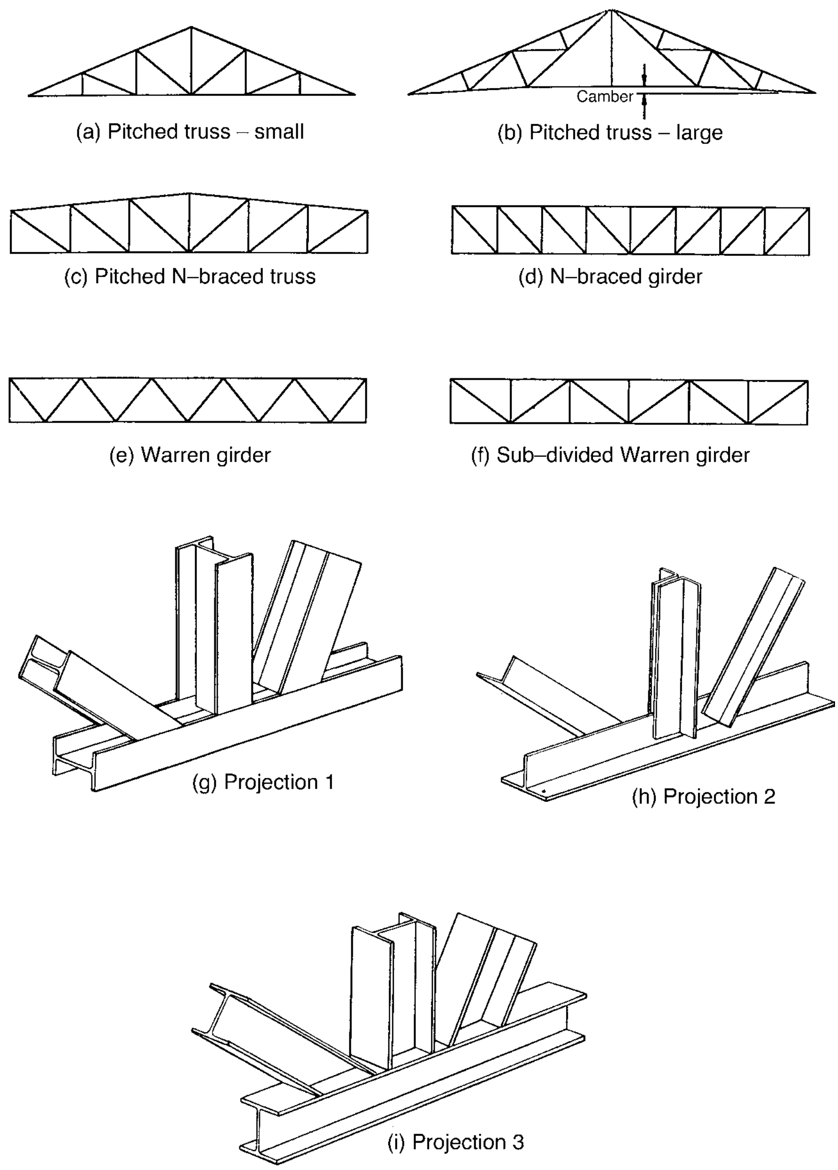


Fig. 6.3.1. Types of truss and lattice girder and truss joints—isometric views

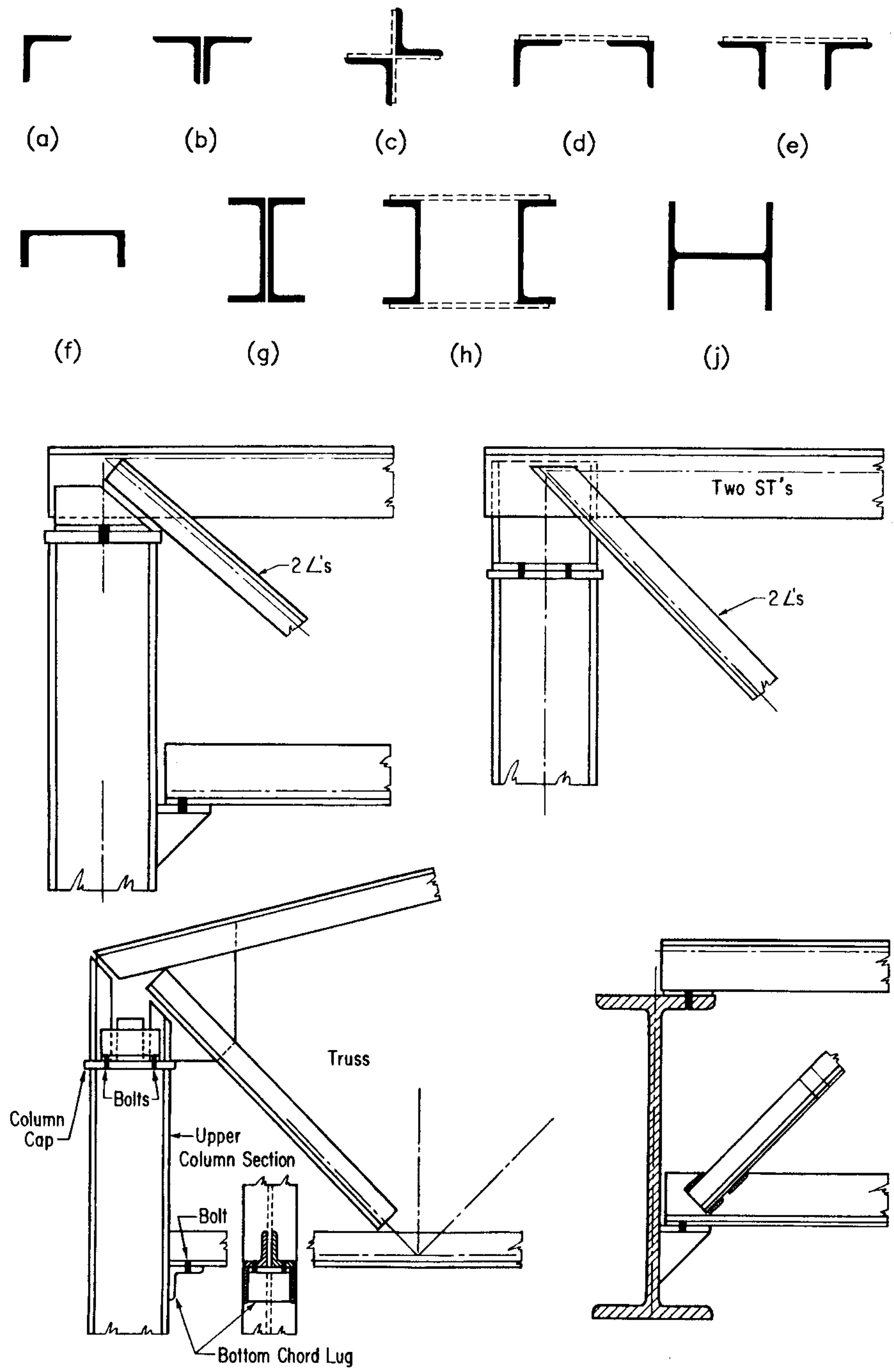


Fig. 6.3.2. Chord and bracing sections and details (based on BS 5950, EC3 and AISC specifications)

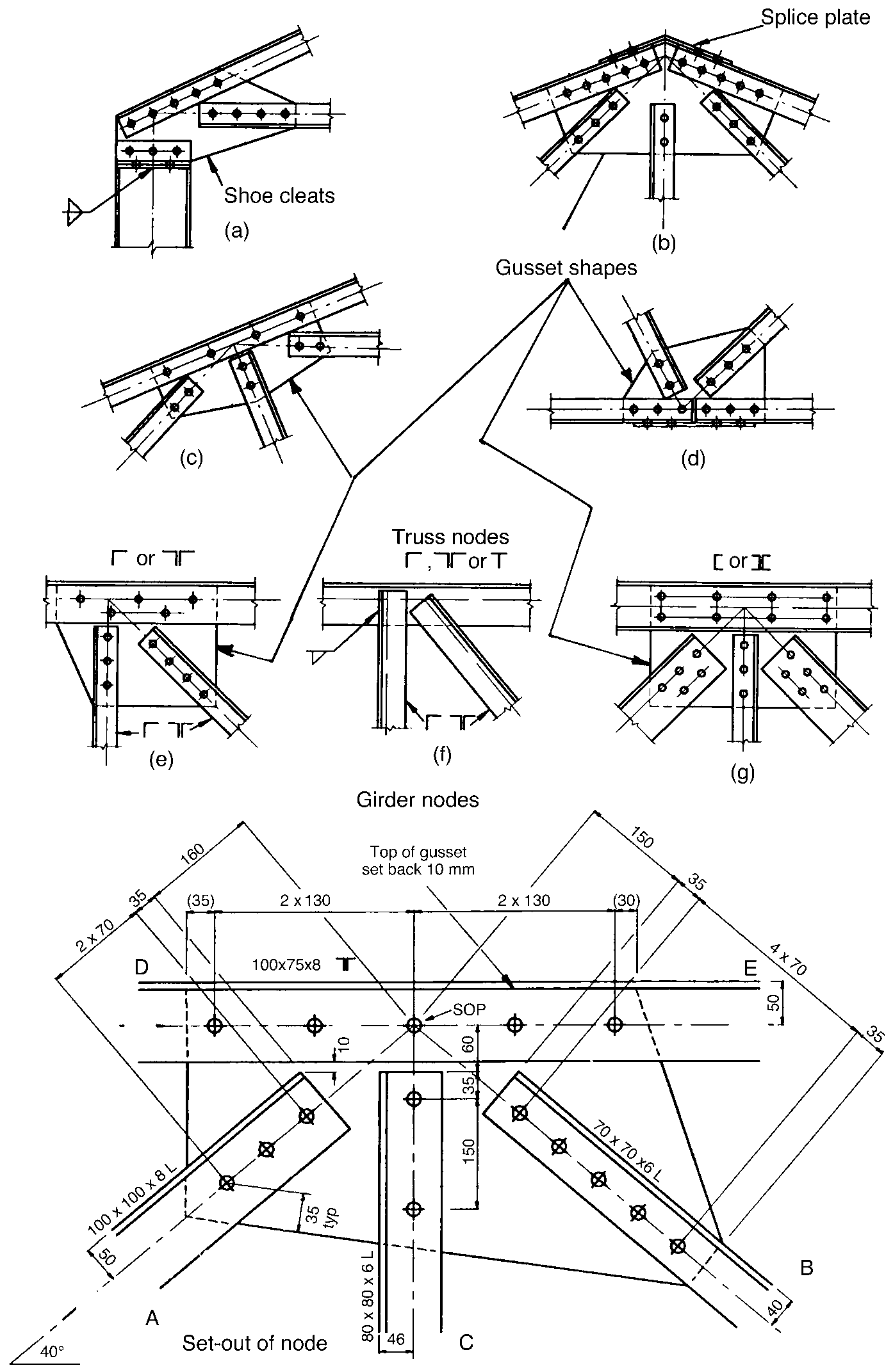


Fig. 6.3.3. Node points—bolted construction (based on BS 5950 and EC3 specifications)

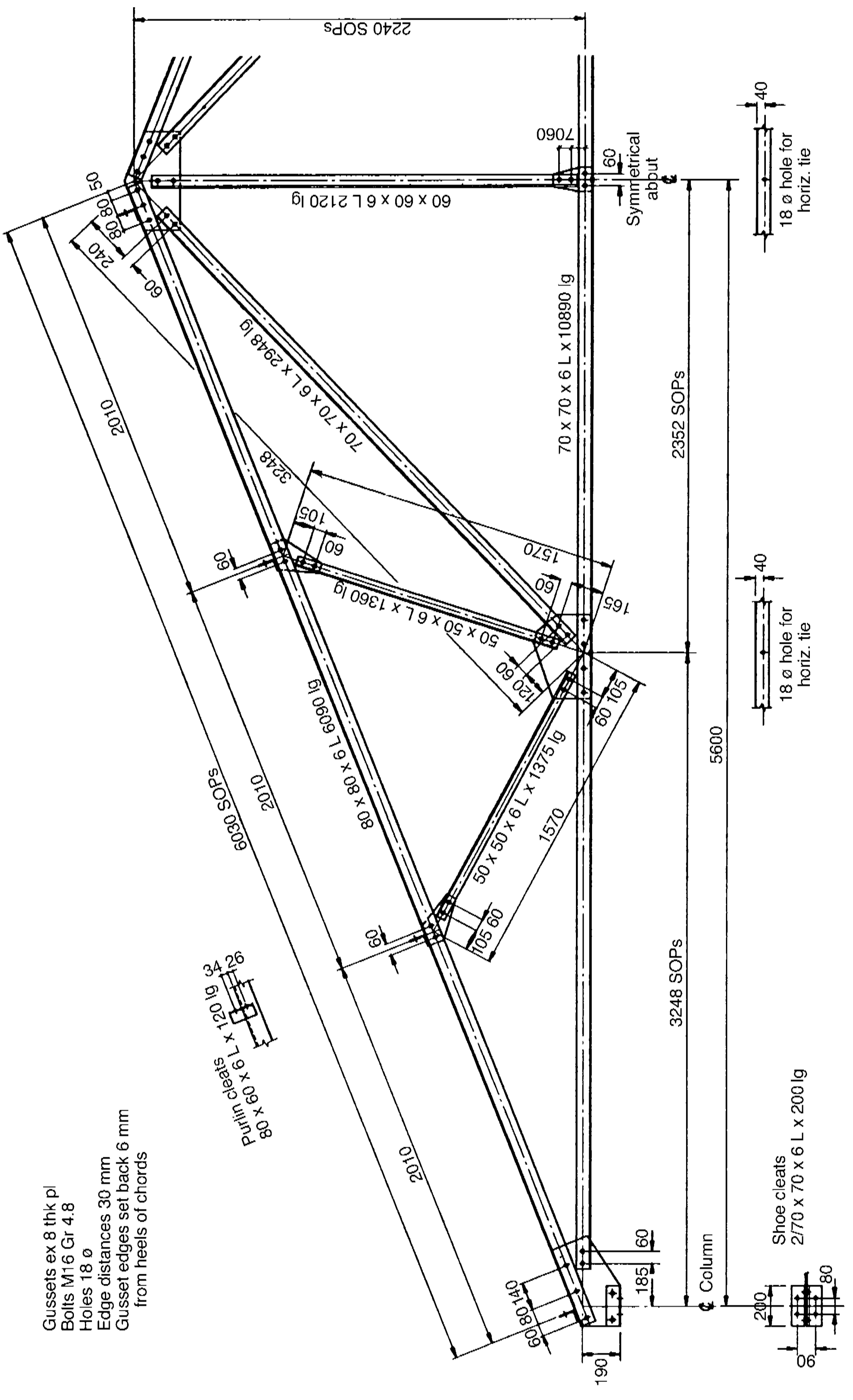


Fig. 6.3.4. Detailing of bolted truss (based on EC3 specifications)

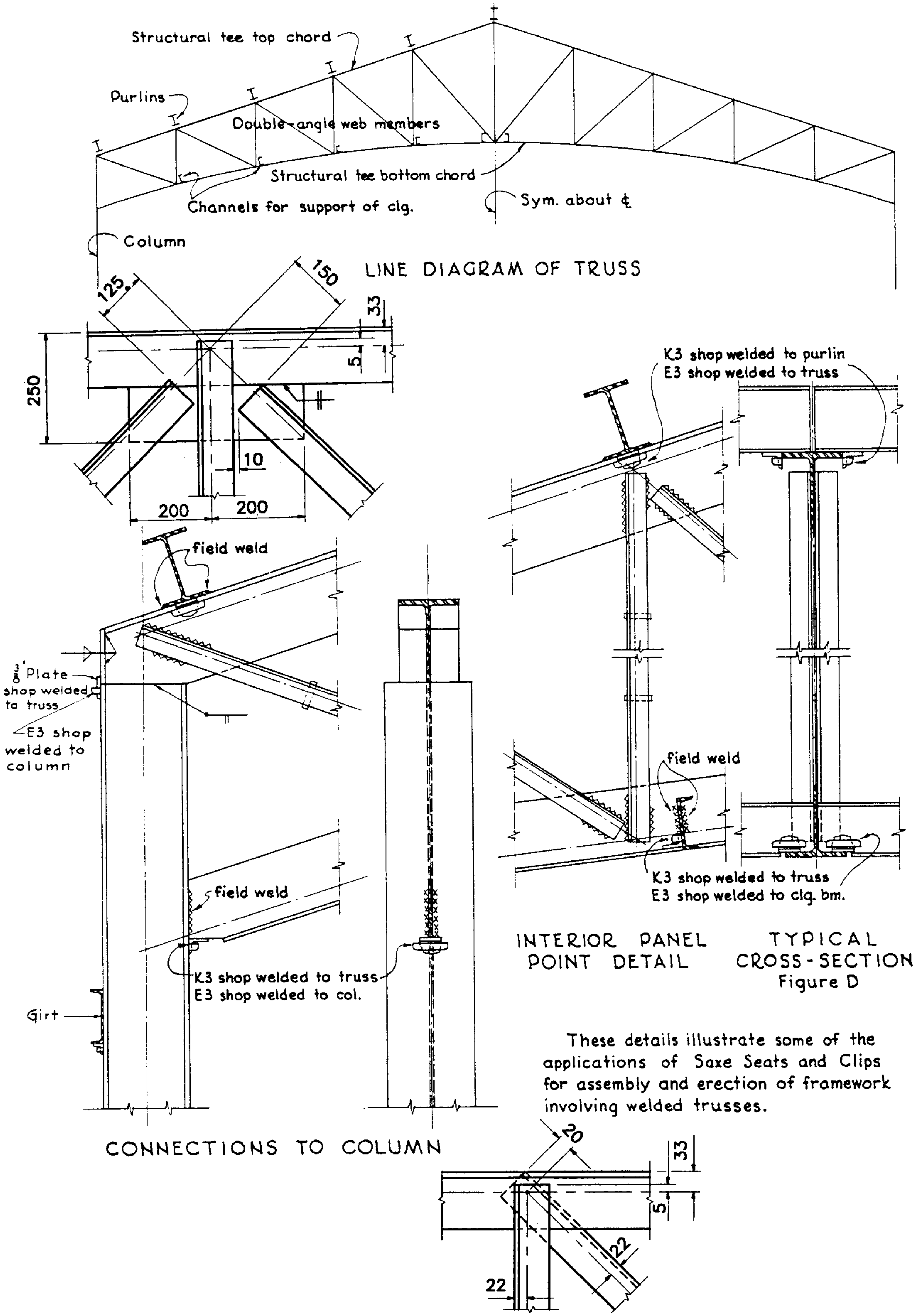


Fig. 6.3.5. Node points—welded construction of an arched truss (based on Lincoln Electric Co. specifications). Figure used with permission of The Lincoln Electric Company

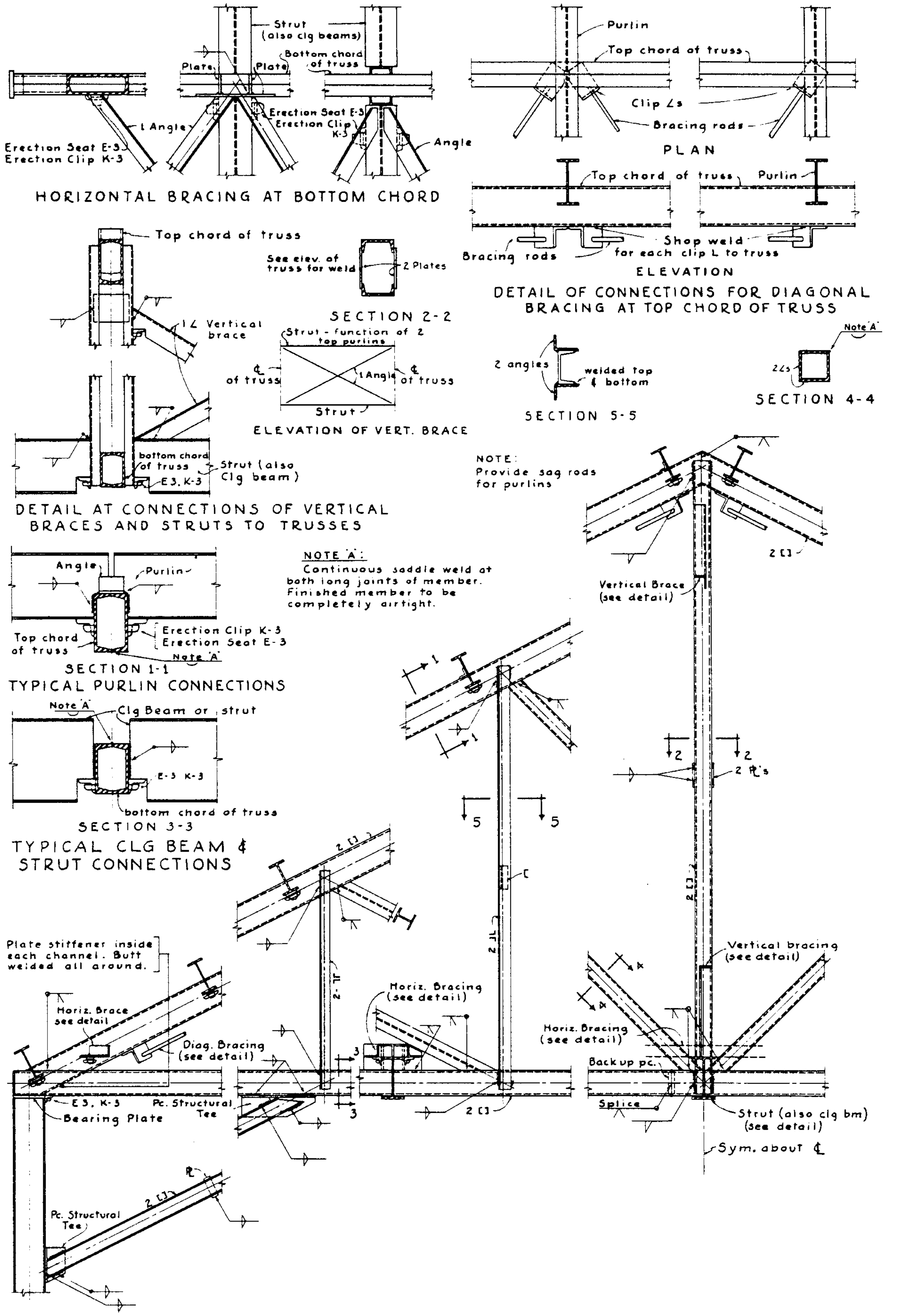


Fig. 6.3.6. Typical roof truss and details (based on AISC and Lincoln Electric Co. specifications). Figure used with permission of The Lincoln Electric Company

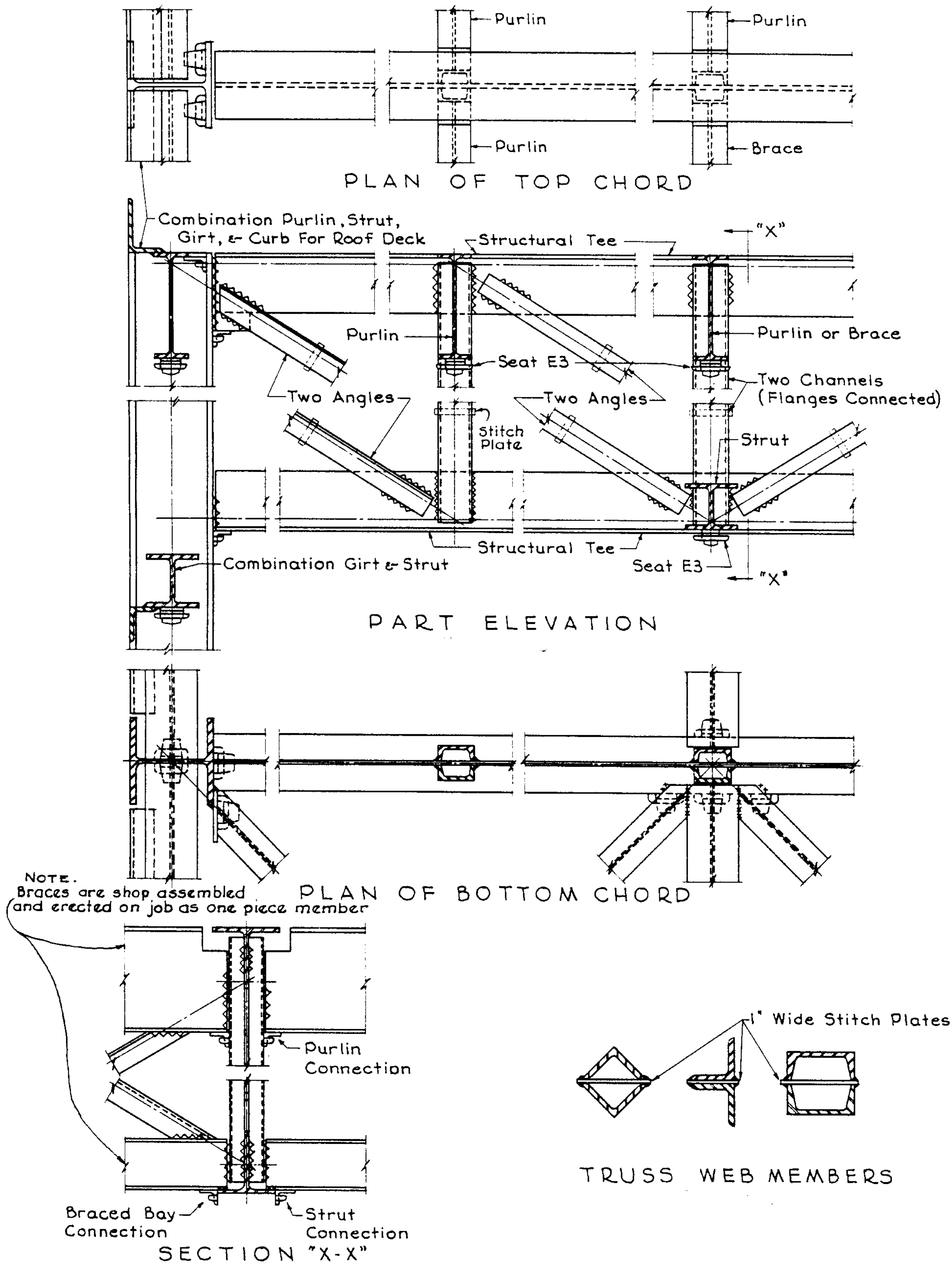


Fig. 6.3.7. Welded truss and details (based on AISC and Lincoln Electric Co. specifications). Figure used with permission of The Lincoln Electric Company

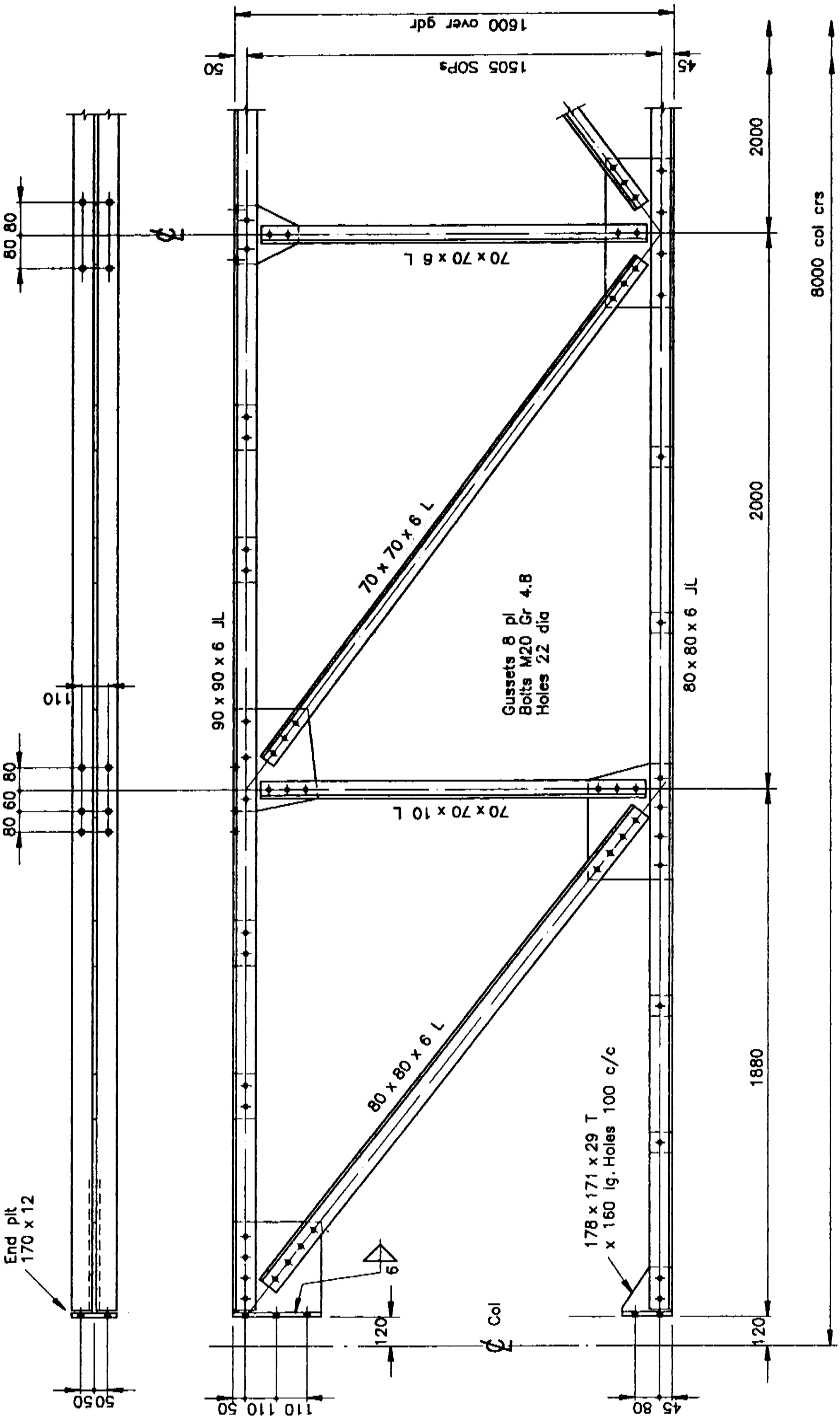


Fig. 6.3.8. Detailing of a bolted roof girder (based on EC3 specifications)

6.4. Welded tubular steel construction

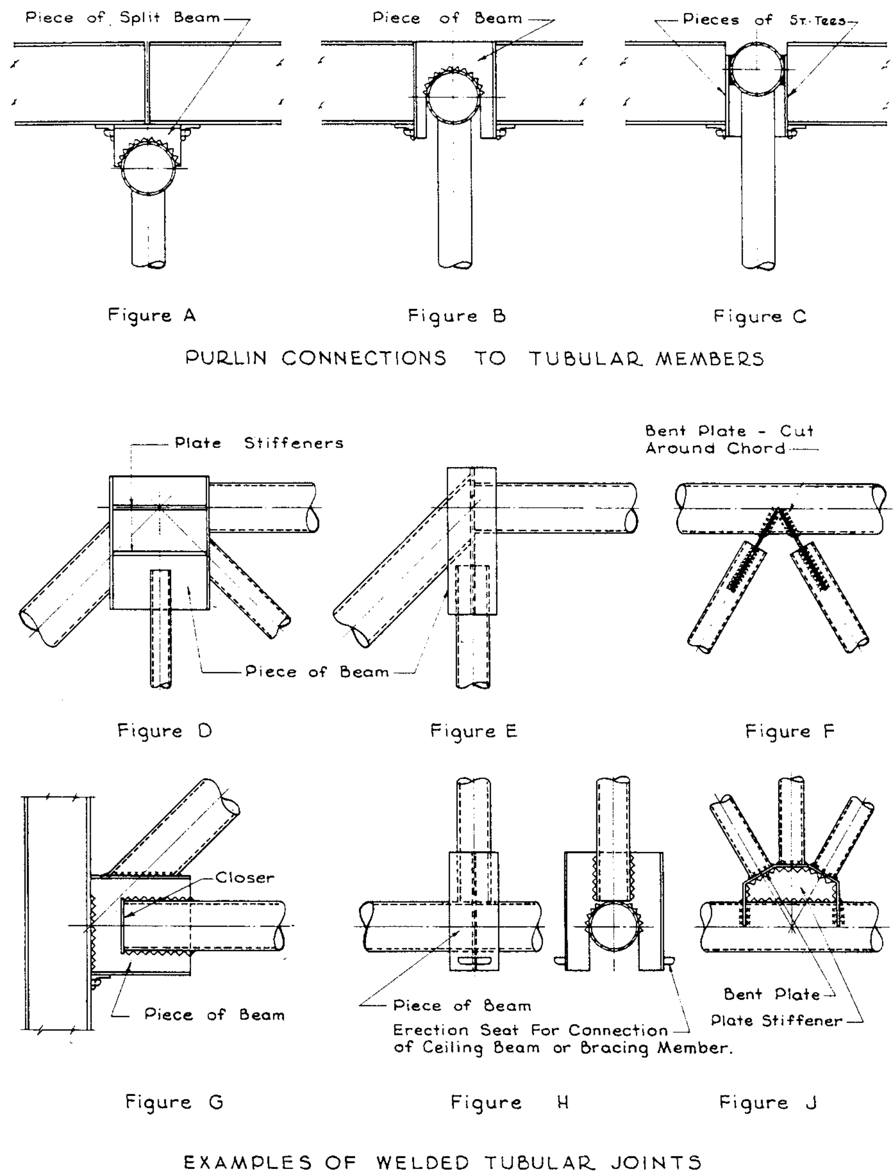


Fig. 6.4.1. Welded tubular steel construction (based on Lincoln Electric Co.). Figure used with permission of The Lincoln Electric Company

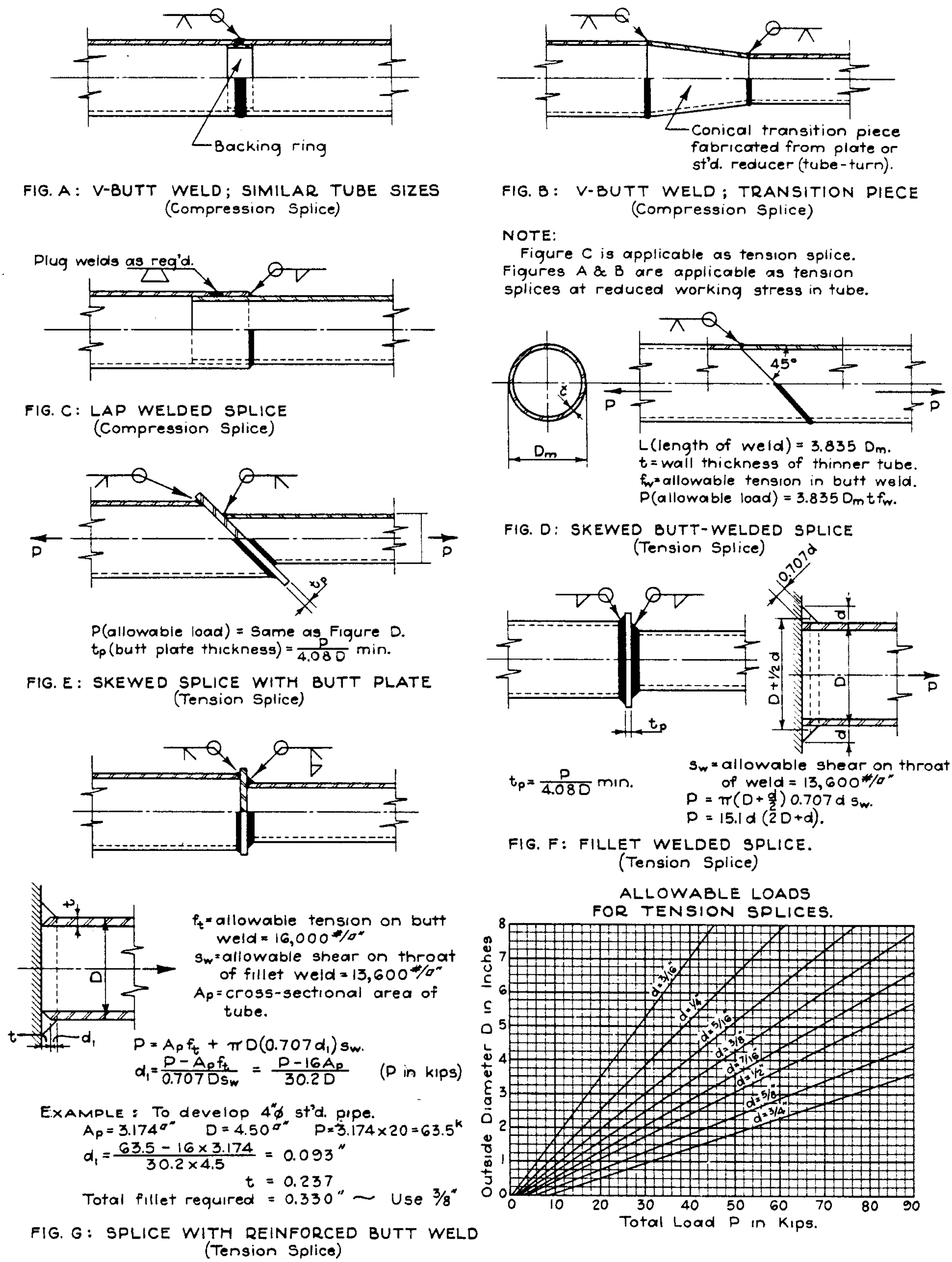


Fig. 6.4.2. Welded tubular steel splices (based on AISC specifications). Copyright: American Institute of Steel Construction, Inc. Reprinted with permission. All rights reserved

7. Steel buildings — case studies

Every effort has been made to conform to the recommendations made by the British and European (EC3) codes. The figures within this chapter are labelled in accordance with BS 5950. To convert to EC3 recommendations only the steel grades need to be altered.

7.1. Steelwork detailing based on British and European codes

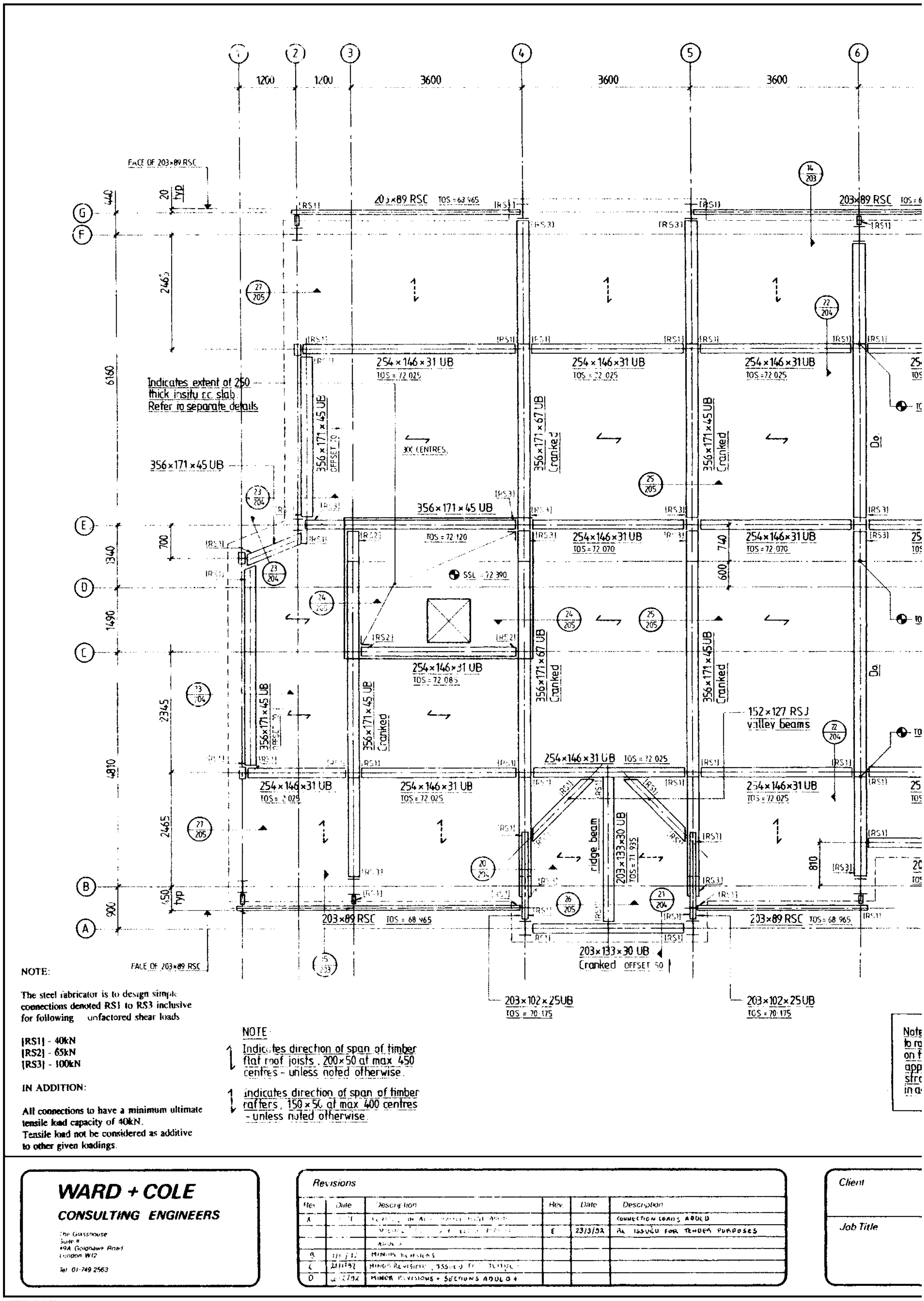
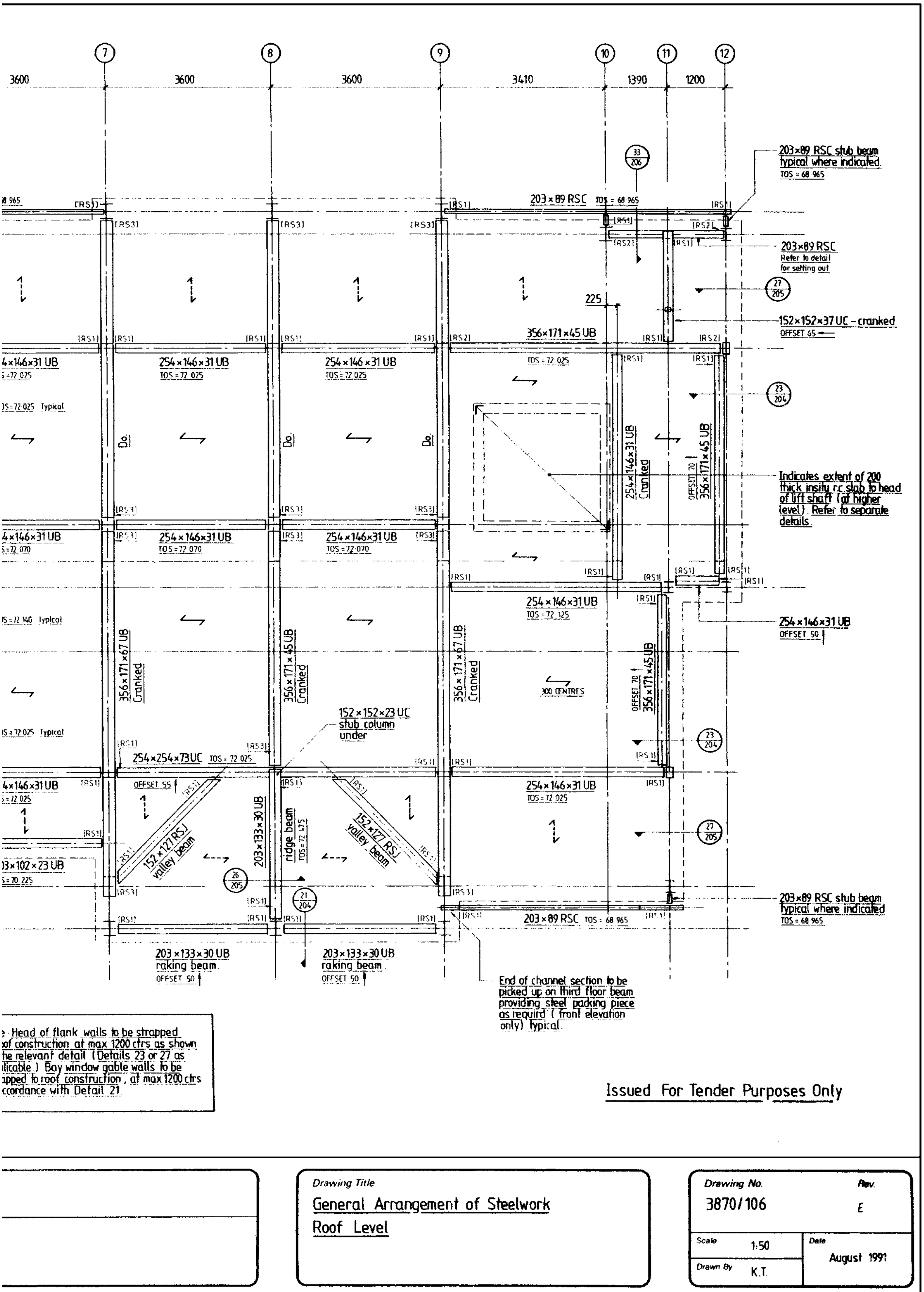


Fig. 7.1.1. General arrangement of steelwork—roof level



7
8
9
10
11
12
3600
3600
3600
3410
1390
1200
203×89 RSC stub beam typical where indicated. TOS = 68 965
203×89 RSC TOS = 68 965
203×89 RSC Refer to detail for setting out
225
152×152×37 UC – cranked OFFSET 65
356×171×45 UB
254×146×31 UB TOS = 72 025
254×146×31 UB TOS = 72 070
Indicates extent of 200 thick insitu r.c. slab to head of lift shaft (at higher level). Refer to separate details
254×146×31 UB Cranked
356×171×45 UB
254×146×31 UB TOS = 72 125
254×146×31 UB OFFSET 50
356×171×67 UB Cranked
356×171×45 UB Cranked
300 CENTRES
152×152×23 UC stub column under
254×254×73UC TOS = 72 025
OFFSET 55
254×146×31 UB TOS = 72 025
152×127 RSJ valley beam
203×133×30 UB
ridge beam
203×102×23 UB
203×133×30 UB raking beam OFFSET 50
203×89 RSC TOS = 68 965
203×89 RSC stub beam typical where indicated TOS = 68 965
End of channel section to be picked up on third floor beam providing steel packing piece as required (front elevation only) typical
Head of flank walls to be strapped of construction at max 1200 ctrs as shown he relevant detail (Details 23 or 27 as licable.) Bay window gable walls to be pped to roof construction, at max 1200 ctrs ccordance with Detail 21
Issued For Tender Purposes Only
Drawing Title
General Arrangement of Steelwork
Roof Level
Drawing No.
3870/106
Rev.
E
Scale 1:50
Date August 1991
Drawn By K.T.

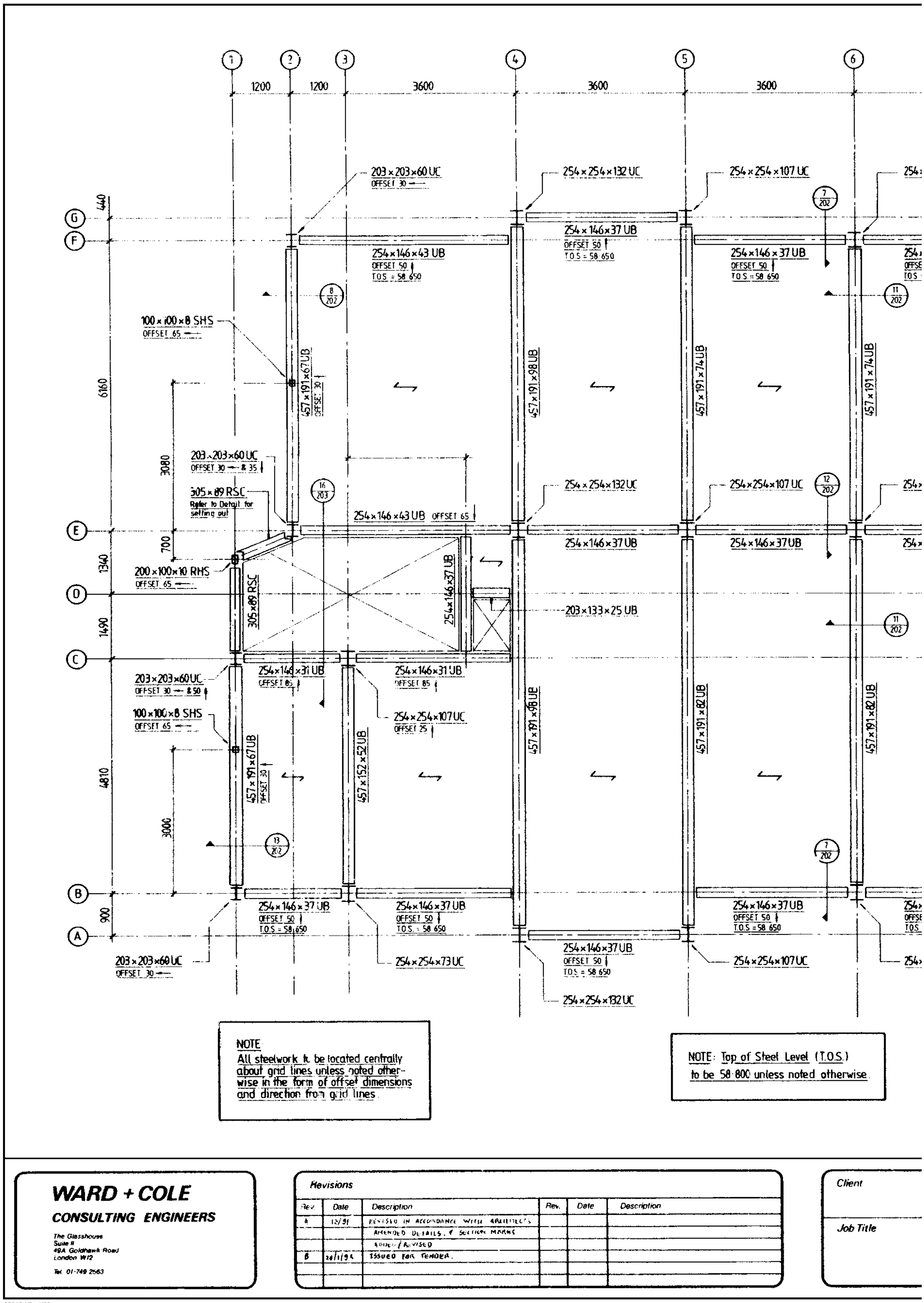
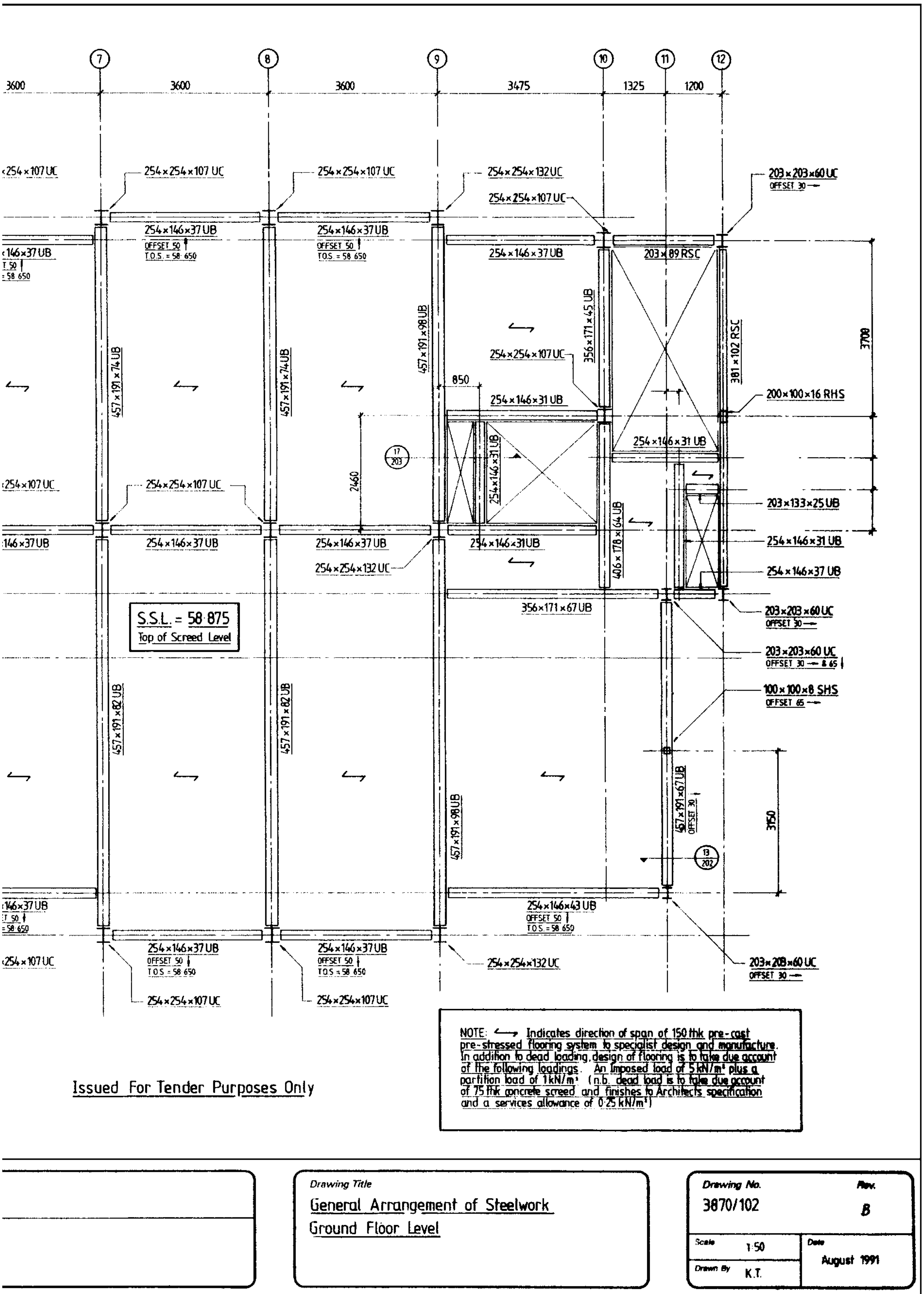


Fig. 7.1.2. General arrangement of steelwork—ground floor level


3600
3600
3600
3475
1325
1200
254×254×107 UC
254×254×132 UC
203×203×60 UC
OFFSET 30
254×146×37 UB
OFFSET 50
T.O.S. = 58 650
203×89 RSC
356×171×45 UB
381×102 RSC
457×191×74 UB
457×191×98 UB
3700
850
254×146×31 UB
200×100×16 RHS
2460
203×133×25 UB
406×178×64 UB
356×171×67 UB
S.S.L. = 58·875
Top of Screed Level
100×100×8 SHS
OFFSET 65
457×191×82 UB
457×191×67 UB
3150
254×146×43 UB
NOTE: ⟷ Indicates direction of span of 150 thk pre-cast pre-stressed flooring system to specialist design and manufacture. In addition to dead loading, design of flooring is to take due account of the following loadings. An Imposed load of 5 kN/m² plus a partition load of 1 kN/m² (n.b. dead load is to take due account of 75 thk concrete screed and finishes to Architects specification and a services allowance of 0·25 kN/m²)
Issued For Tender Purposes Only
Drawing Title
General Arrangement of Steelwork
Ground Floor Level
Drawing No.
3870/102
Rev.
B
Scale
1:50
Date
August 1991
Drawn By
K.T.

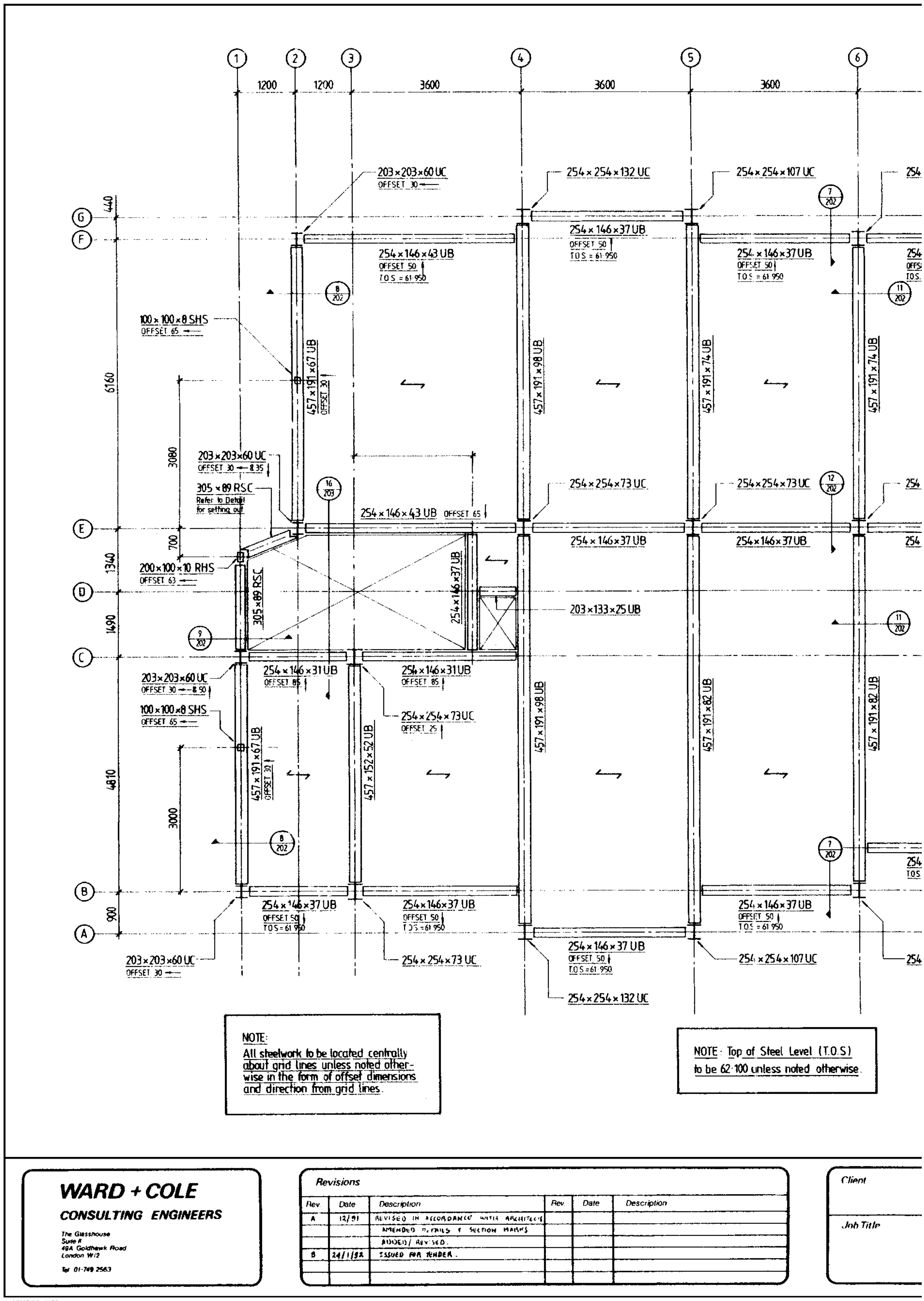
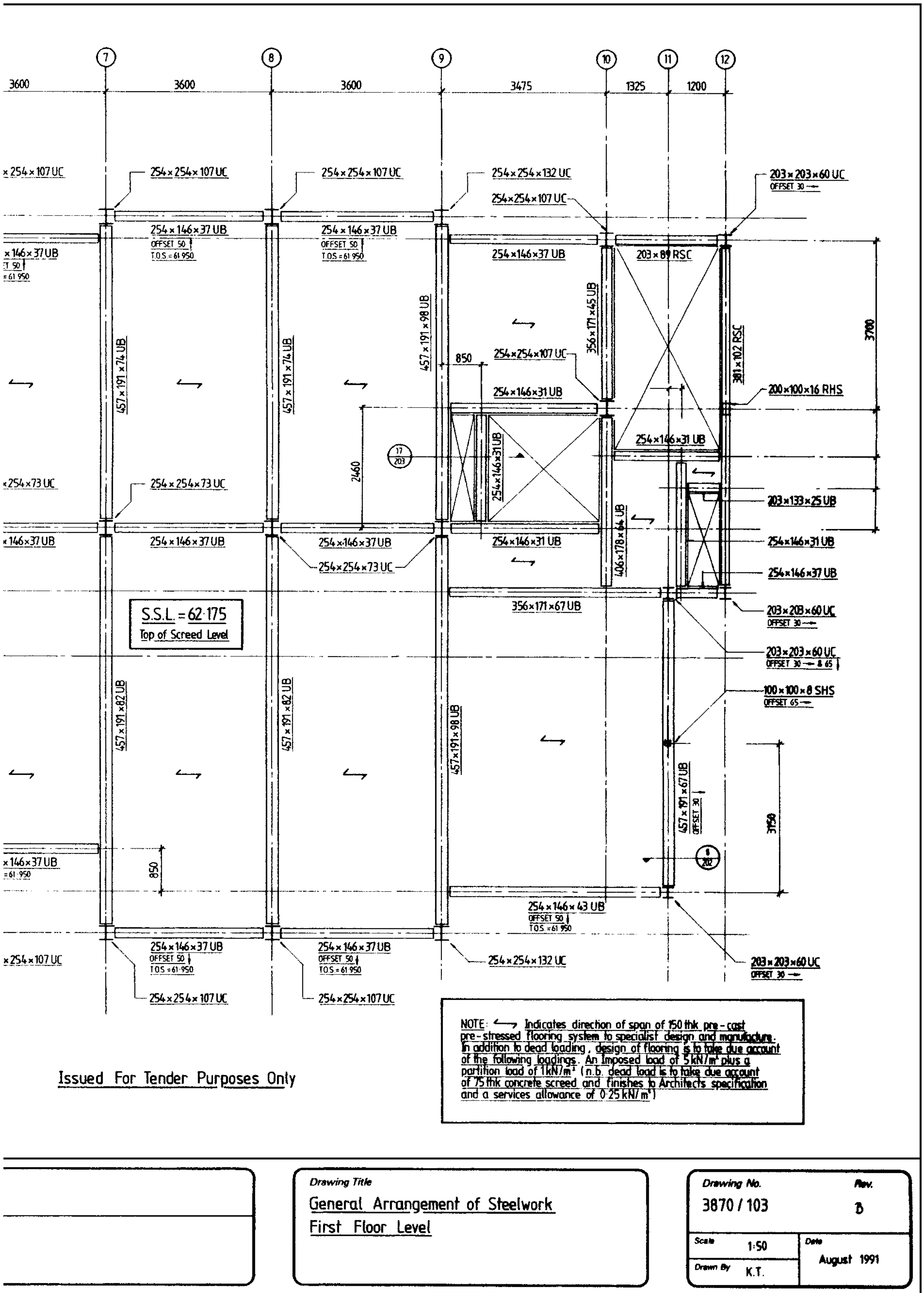


Fig. 7.1.3. General arrangement of steelwork—first floor level


S.S.L. = 62·175
Top of Screed Level
NOTE: ⟵ Indicates direction of span of 150 thk pre-cast pre-stressed flooring system to specialist design and manufacture. In addition to dead loading, design of flooring is to take due account of the following loadings. An Imposed load of 5 kN/m² plus a partition load of 1 kN/m² (n.b. dead load is to take due account of 75 thk concrete screed and finishes to Architects specification and a services allowance of 0·25 kN/m²)
Issued For Tender Purposes Only
Drawing Title
General Arrangement of Steelwork
First Floor Level
Drawing No.
3870 / 103
Rev.
B
Scale
1:50
Date
August 1991
Drawn By
K.T.

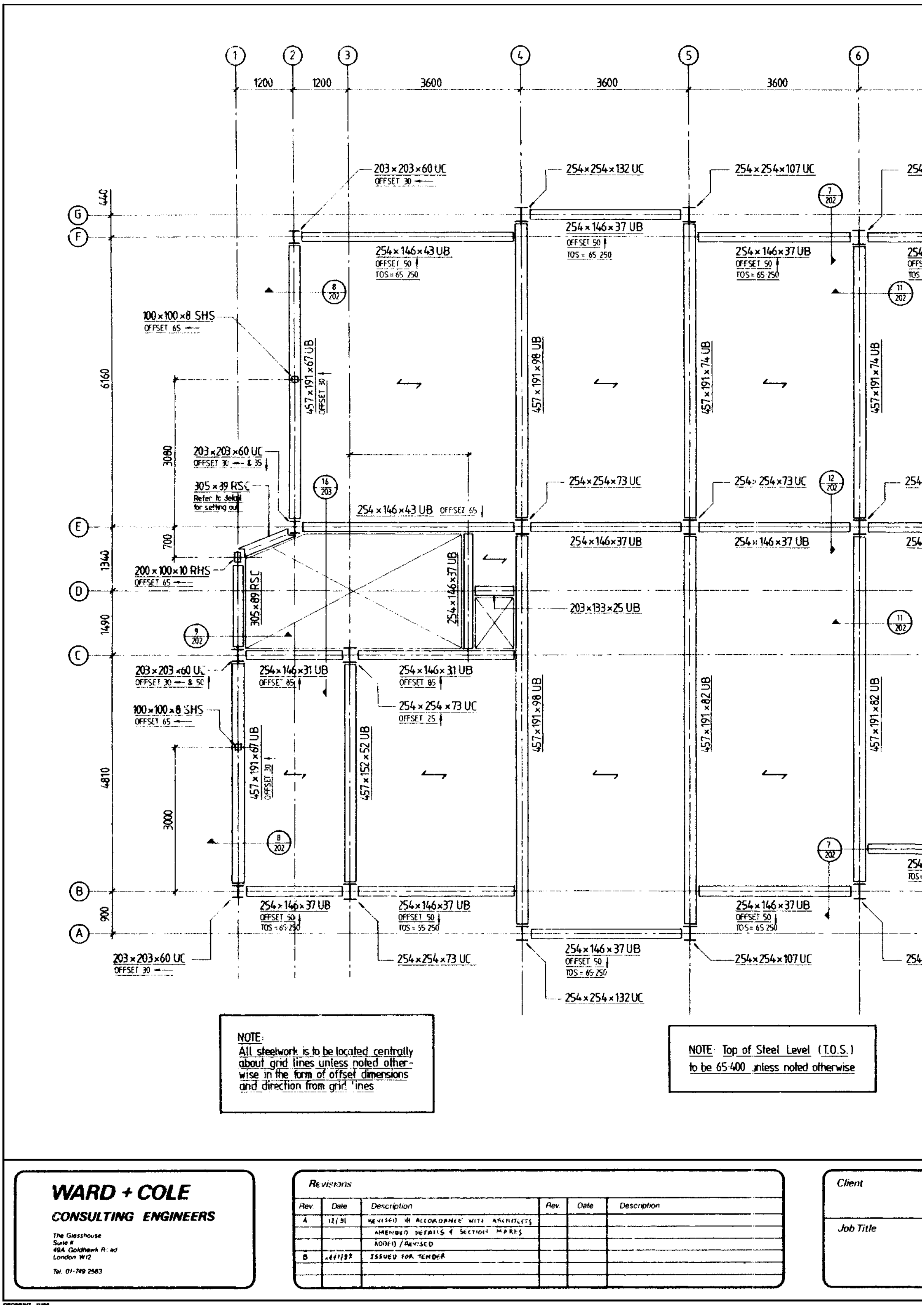
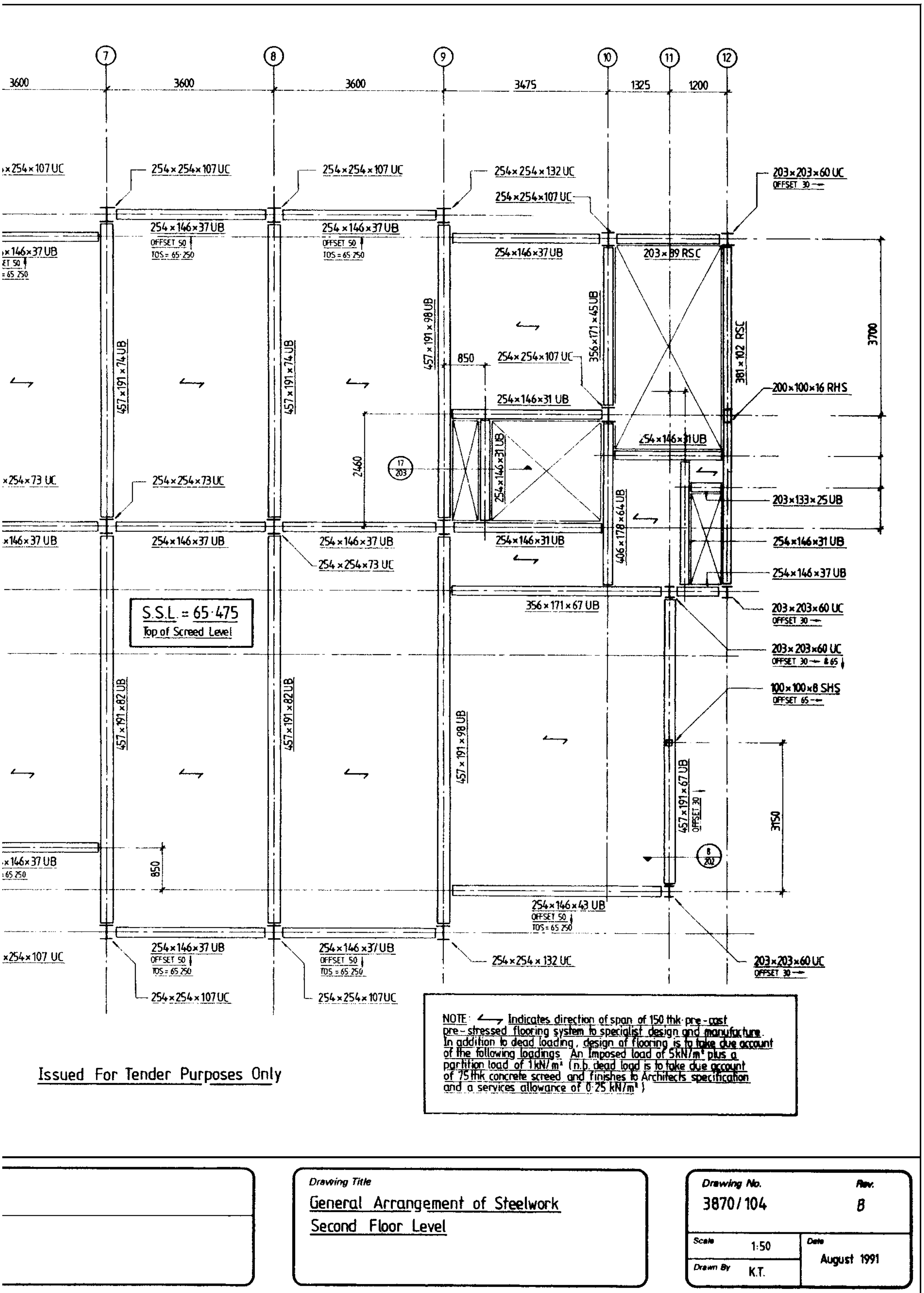


Fig. 7.1.4. General arrangement of steelwork—second floor level



3600
3600
3600
3475
1325
1200
254×254×107 UC
254×254×132 UC
203×203×60 UC
OFFSET 30
254×146×37 UB
OFFSET 50
TOS = 65·250
203×89 RSC
356×171×45 UB
381×102 RSC
3700
457×191×74 UB
457×191×98 UB
850
254×146×31 UB
200×100×16 RHS
2460
254×254×73 UC
203×133×25 UB
406×178×64 UB
356×171×67 UB
S.S.L. = 65·475
Top of Screed Level
100×100×8 SHS
OFFSET 65
457×191×82 UB
457×191×67 UB
3150
254×146×43 UB
NOTE: Indicates direction of span of 150 thk pre-cast pre-stressed flooring system to specialist design and manufacture. In addition to dead loading, design of flooring is to take due account of the following loadings. An Imposed load of 5kN/m² plus a partition load of 1kN/m² (n.b. dead load is to take due account of 75 thk concrete screed and finishes to Architects specification and a services allowance of 0·25 kN/m²)
Issued For Tender Purposes Only
Drawing Title
General Arrangement of Steelwork
Second Floor Level
Drawing No.
3870/104
Rev.
B
Scale
1:50
Date
August 1991
Drawn By
K.T.

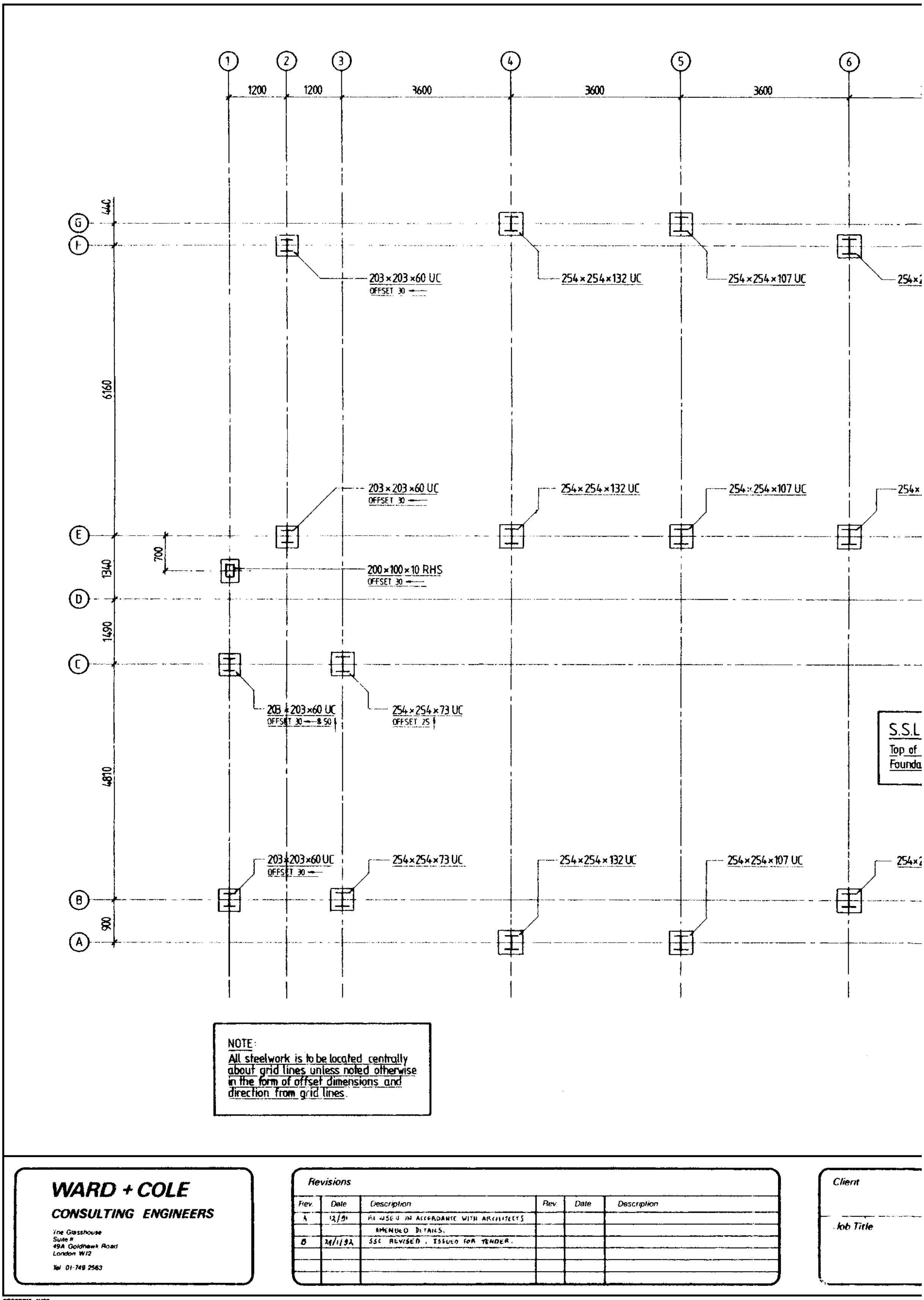
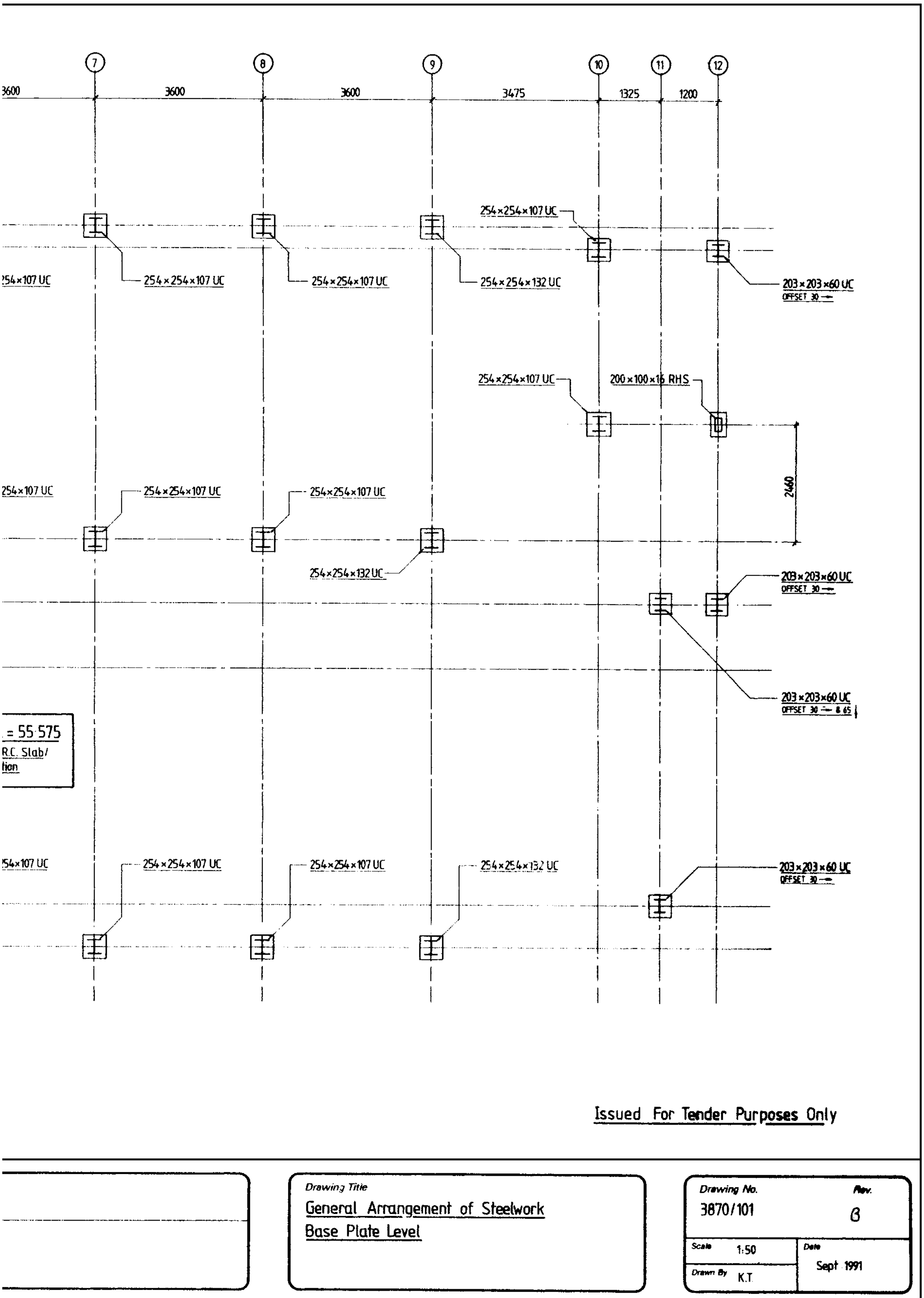


Fig. 7.1.5. General arrangement of steelwork—base plate level


3600
3600
3600
3475
1325
1200
254×254×107 UC
254×254×107 UC
254×254×132 UC
203×203×60 UC
OFFSET 30
254×254×107 UC
200×100×16 RHS
2460
254×254×107 UC
254×254×107 UC
254×254×132 UC
203×203×60 UC
OFFSET 30
203×203×60 UC
OFFSET 30 & 65
= 55.575
R.C. Slab/
254×254×107 UC
254×254×107 UC
254×254×132 UC
203×203×60 UC
OFFSET 30
Issued For Tender Purposes Only
Drawing Title
General Arrangement of Steelwork
Base Plate Level
Drawing No.
3870/101
Rev.
B
Scale 1:50
Date Sept 1991
Drawn By K.T

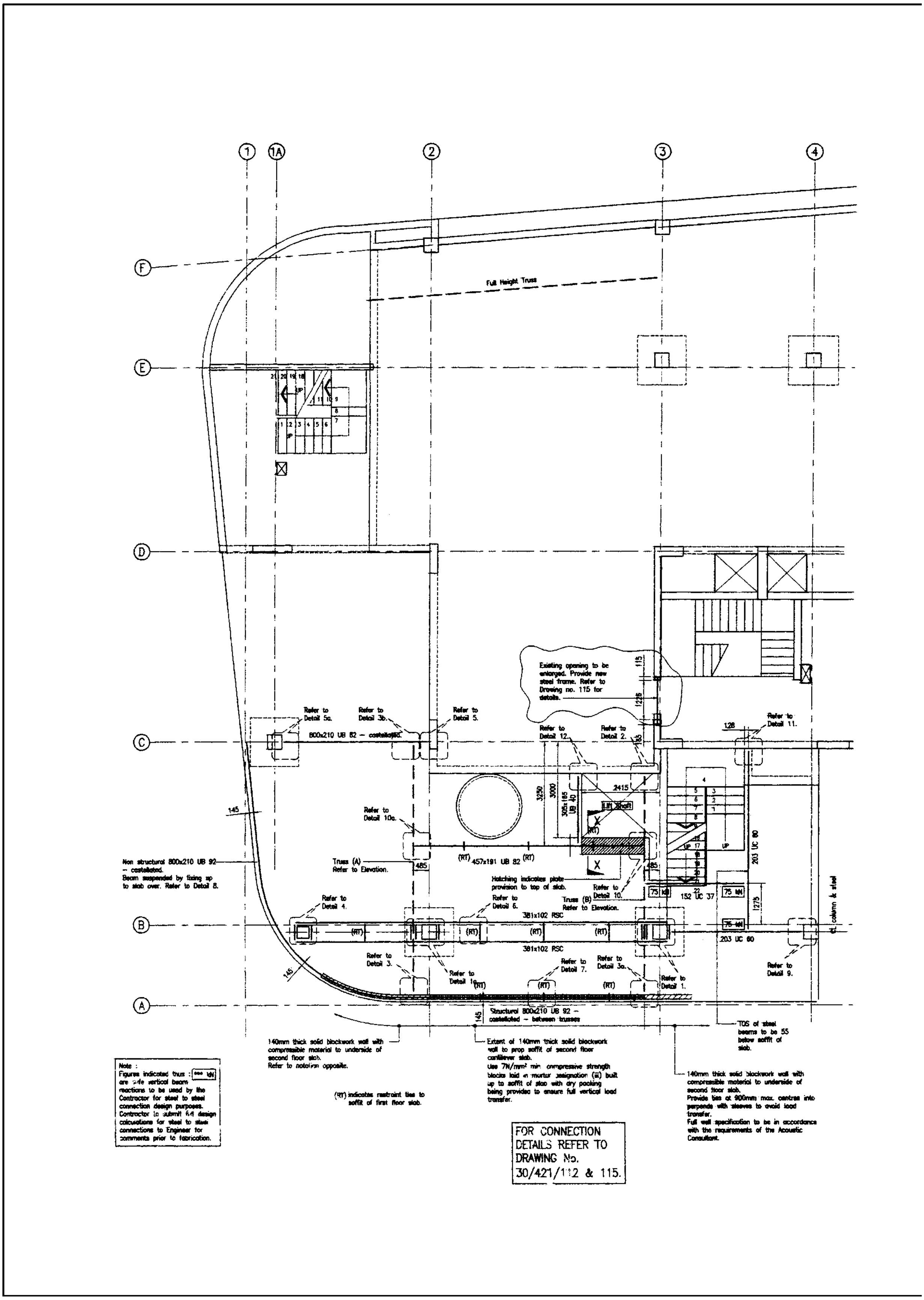
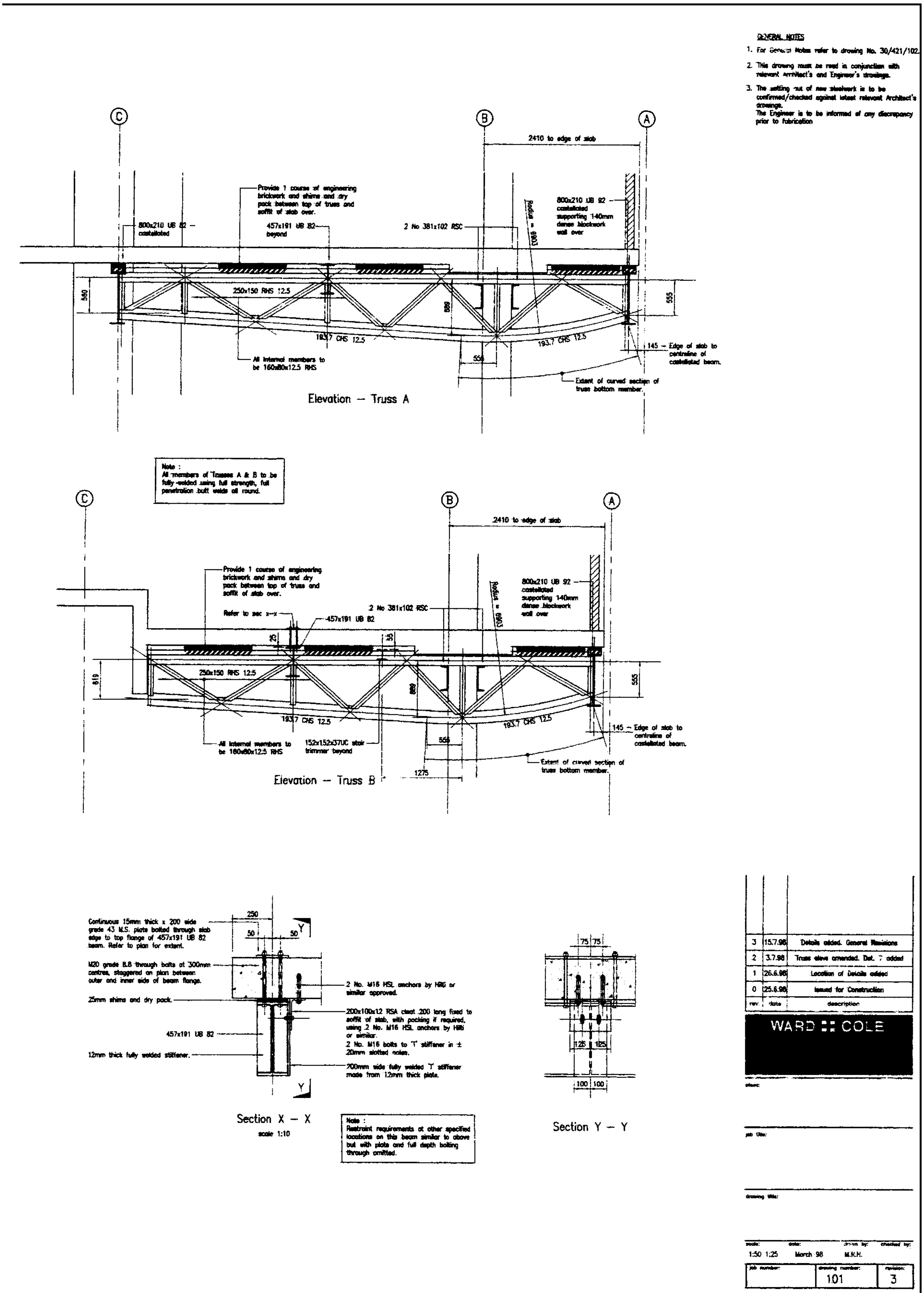


Fig. 7.1.6. Steel truss roof and supporting ancillary structures


GENERAL NOTES
1. For General Notes refer to drawing No. 30/421/102.
2. This drawing must be read in conjunction with relevant Architect's and Engineer's drawings.
3. The setting out of new steelwork is to be confirmed/checked against latest relevant Architect's drawings.
The Engineer is to be informed of any discrepancy prior to fabrication
2410 to edge of slab
Provide 1 course of engineering brickwork and shims and dry pack between top of truss and soffit of slab over.
800x210 UB 82 castellated
457x191 UB 82 beyond
2 No 381x102 RSC
800x210 UB 92 castellated supporting 140mm dense blockwork wall over
250x150 RHS 12.5
193.7 CHS 12.5
All internal members to be 160x80x12.5 RHS
145 – Edge of slab to centreline of castellated beam.
Extent of curved section of truss bottom member.
Elevation – Truss A
Note :
All members of Trusses A & B to be fully welded using full strength, full penetration butt welds all round.
Refer to sec x–x
457x191 UB 82
152x152x37UC stair trimmer beyond
Elevation – Truss B
Continuous 15mm thick x 200 wide grade 43 M.S. plate bolted through slab edge to top flange of 457x191 UB 82 beam. Refer to plan for extent.
M20 grade 8.8 through bolts at 300mm centres, staggered on plan between outer and inner side of beam flange.
25mm shims and dry pack.
457x191 UB 82
12mm thick fully welded stiffener.
2 No. M16 HSL anchors by Hilti or similar approved.
200x100x12 RSA cleat 200 long fixed to soffit of slab, with packing if required, using 2 No. M16 HSL anchors by Hilti or similar.
2 No. M16 bolts to 'T' stiffener in ± 20mm slotted holes.
200mm wide fully welded 'T' stiffener made from 12mm thick plate.
Section X – X
scale 1:10
Note :
Restraint requirements at other specified locations on this beam similar to above but with plate and full depth bolting through omitted.
Section Y – Y
3 15.7.98 Details added. General Revisions
2 3.7.98 Truss elevs amended. Det. 7 added
1 26.6.98 Location of Details added
0 25.6.98 Issued for Construction
rev. date description
WARD COLE
client:
job title:
drawing title:
scale: 1:50 1:25
date: March 98
drawn by: M.R.H.
checked by:
job number:
drawing number: 101
revision: 3

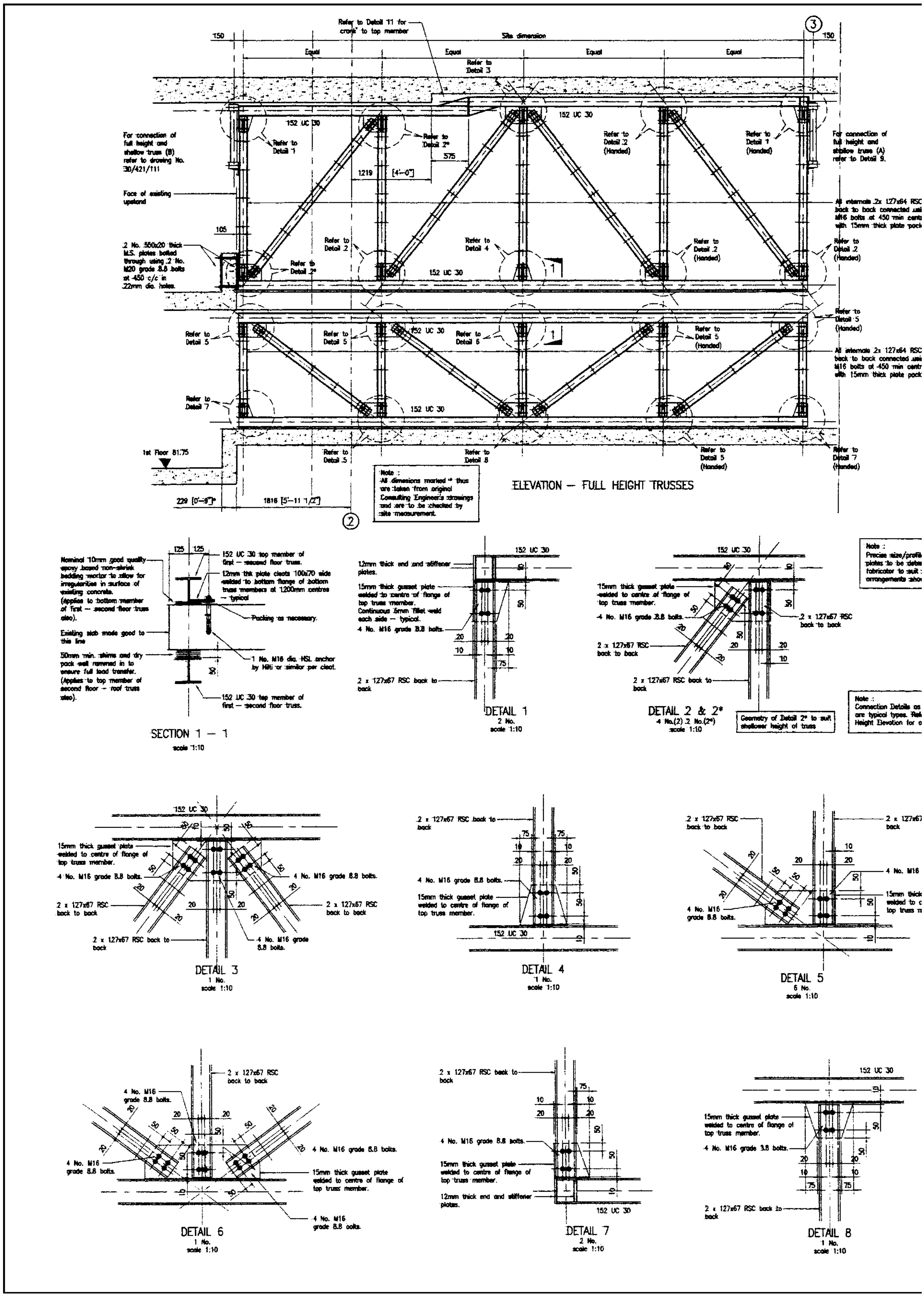
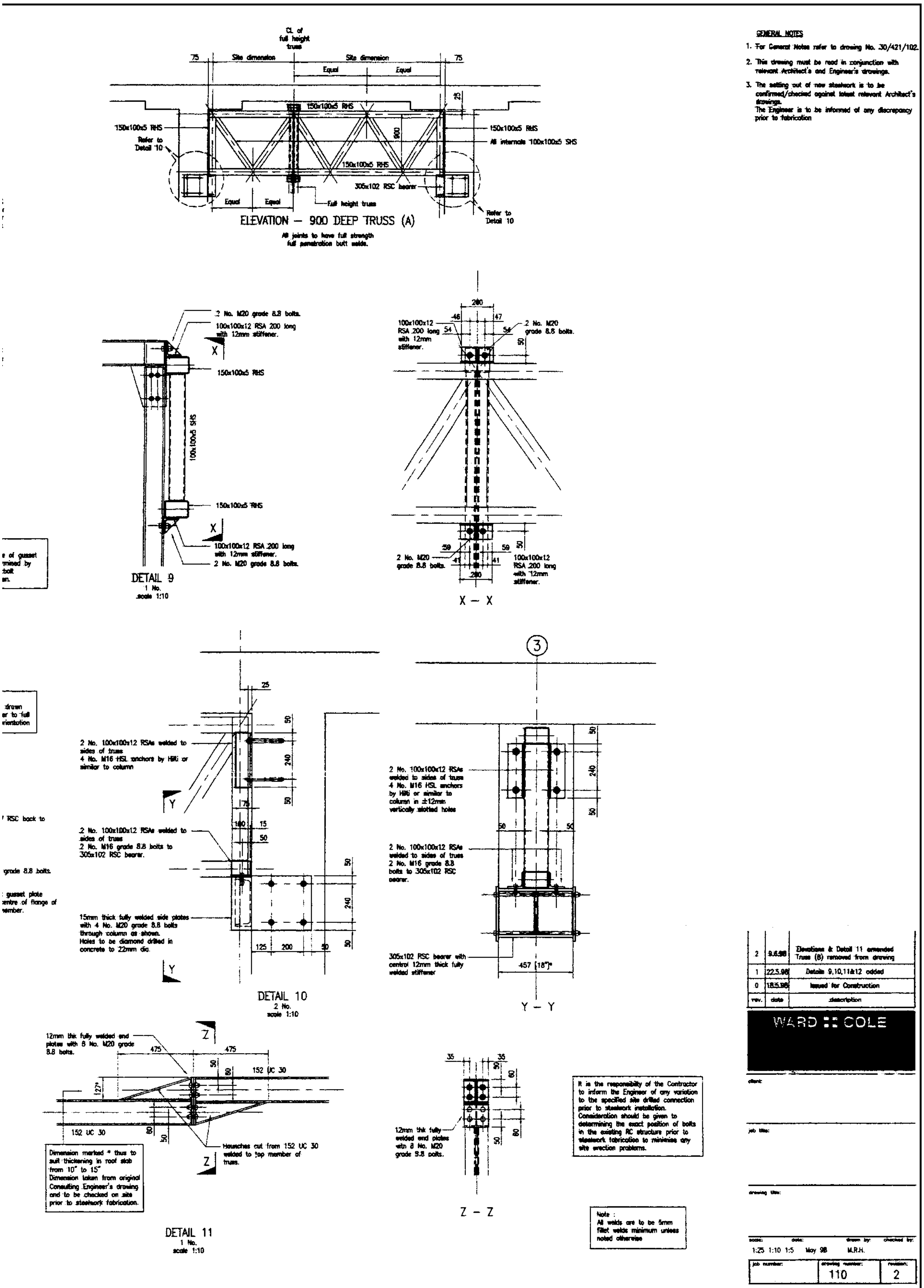


Fig. 7.1.7. Sectional elevation and structural details of a steel truss


GENERAL NOTES
1. For General Notes refer to drawing No. 30/421/102.
2. This drawing must be read in conjunction with relevant Architect's and Engineer's drawings.
3. The setting out of new steelwork is to be confirmed/checked against latest relevant Architect's drawings. The Engineer is to be informed of any discrepancy prior to fabrication
ELEVATION – 900 DEEP TRUSS (A)
All joints to have full strength full penetration butt welds.
DETAIL 9
1 No.
scale 1:10
X – X
DETAIL 10
2 No.
scale 1:10
Y – Y
DETAIL 11
1 No.
scale 1:10
Z – Z
It is the responsibility of the Contractor to inform the Engineer of any variation to the specified site drilled connection prior to steelwork installation. Consideration should be given to determining the exact position of bolts in the existing RC structure prior to steelwork fabrication to minimise any site erection problems.
Note : All welds are to be 5mm fillet welds minimum unless noted otherwise
2 | 9.6.98 | Elevations & Detail 11 amended Truss (B) removed from drawing
1 | 22.5.98 | Details 9,10,11&12 added
0 | 18.5.98 | Issued for Construction
rev. | date | description
WARD :: COLE
client:
job title:
drawing title:
scale: 1:25 1:10 1:5
date: May 98
drawn by: M.R.H.
checked by:
job number:
drawing number: 110
revision: 2

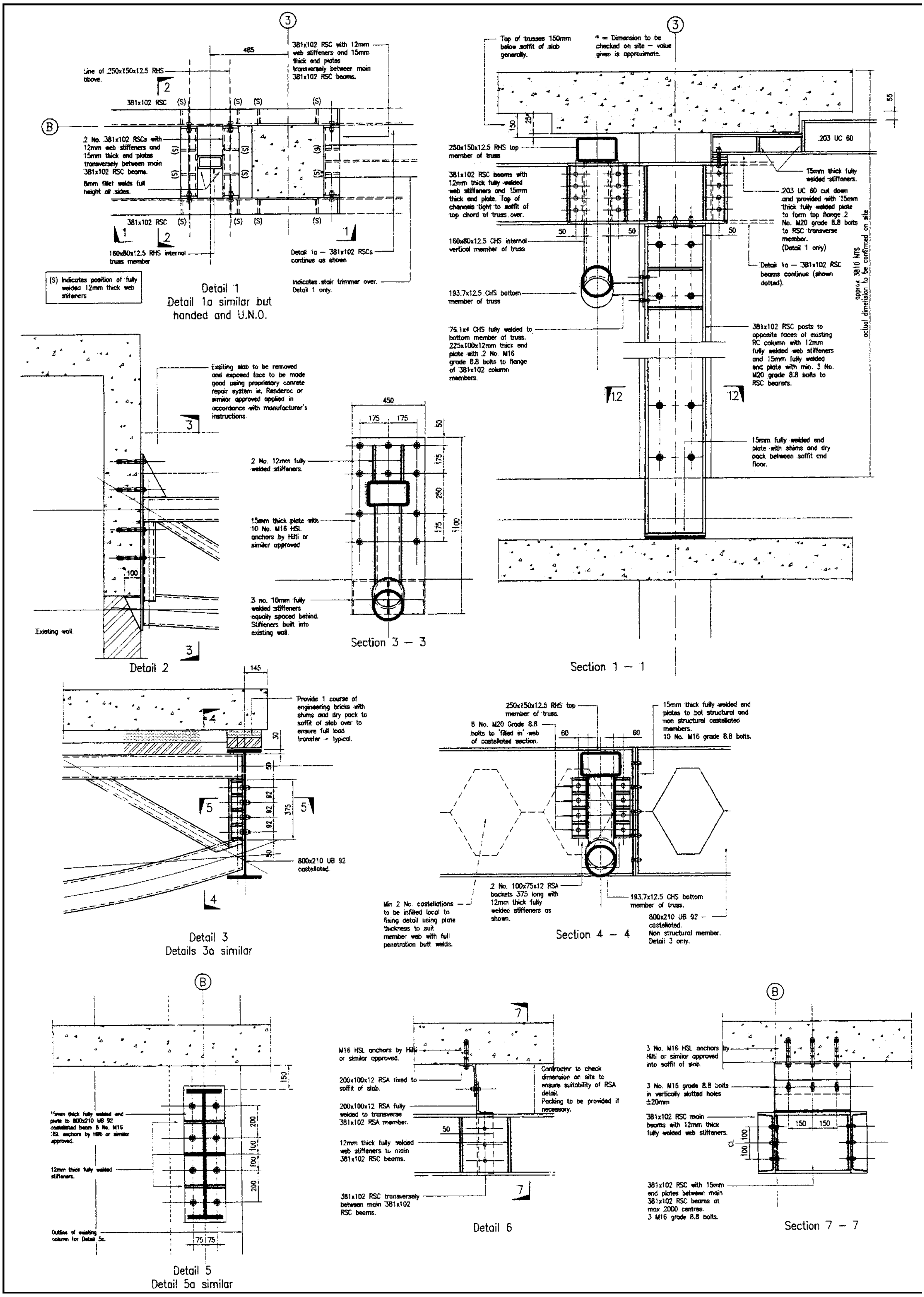
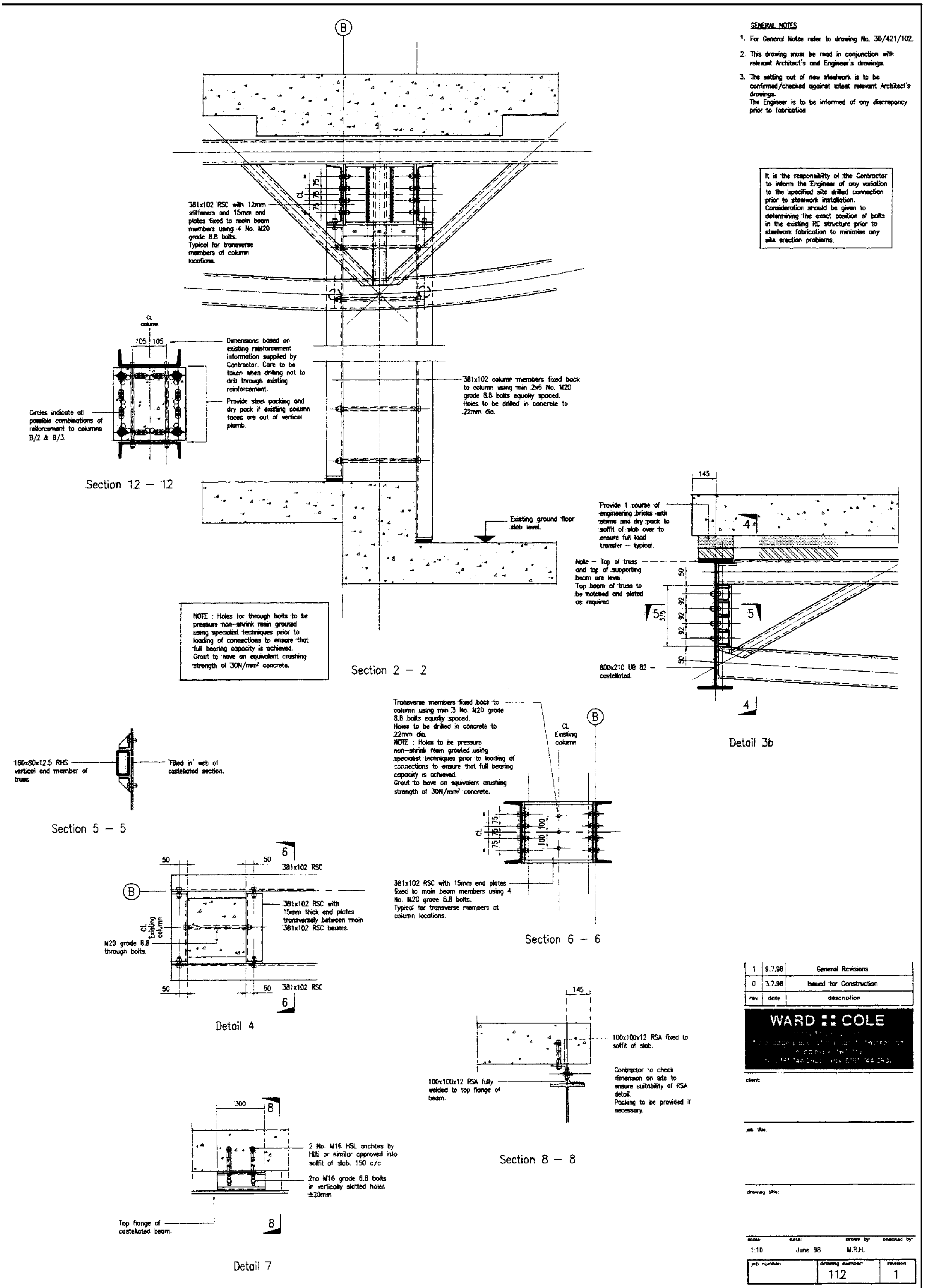


Fig. 7.1.8. A truss with a castellated beam and fastenings—construction drawing


GENERAL NOTES
1. For General Notes refer to drawing No. 30/421/102.
2. This drawing must be read in conjunction with relevant Architect's and Engineer's drawings.
3. The setting out of new steelwork is to be confirmed/checked against latest relevant Architect's drawings.
The Engineer is to be informed of any discrepancy prior to fabrication
It is the responsibilty of the Contractor to inform the Engineer of any variation to the specified site drilled connection prior to steelwork installation. Consideration should be given to determining the exact position of bolts in the existing RC structure prior to steelwork fabrication to minimise any site erection problems.
B
381x102 RSC with 12mm stiffeners and 15mm end plates fixed to main beam members using 4 No. M20 grade 8.8 bolts. Typical for transverse members at column locations.
CL column
105 105
Dimensions based on existing reinforcement information supplied by Contractor. Care to be taken when drilling not to drill through existing reinforcement.
Provide steel packing and dry pack if existing column faces are out of vertical plumb.
Circles indicate all possible combinations of reiforcement to columns B/2 & B/3.
Section 12 – 12
381x102 column members fixed back to column using min 2x6 No. M20 grade 8.8 bolts equally spaced. Holes to be drilled in concrete to 22mm dia.
Existing ground floor slab level.
NOTE : Holes for through bolts to be pressure non-shrink resin grouted using specialist techniques prior to loading of connections to ensure that full bearing capacity is achieved. Grout to have an equivalent crushing strength of 30N/mm² concrete.
Section 2 – 2
145
Provide 1 course of engineering bricks with shims and dry pack to soffit of slab over to ensure full load transfer – typical.
Note – Top of truss and top of supporting beam are level. Top boom of truss to be notched and plated as required
800x210 UB 82 – castellated.
Detail 3b
160x80x12.5 RHS vertical end member of truss.
'Filled in' web of castellated section.
Section 5 – 5
Transverse members fixed back to column using min 3 No. M20 grade 8.8 bolts equally spaced. Holes to be drilled in concrete to 22mm dia. NOTE : Holes to be pressure non-shrink resin grouted using specialist techniques prior to loading of connections to ensure that full bearing capacity is achieved. Grout to have an equivalent crushing strength of 30N/mm² concrete.
CL Existing column
381x102 RSC with 15mm end plates fixed to main beam members using 4 No. M20 grade 8.8 bolts. Typical for transverse members at column locations.
Section 6 – 6
381x102 RSC
381x102 RSC with 15mm thick end plates transversely between main 381x102 RSC beams.
M20 grade 8.8 through bolts.
Detail 4
100x100x12 RSA fixed to soffit of slab.
100x100x12 RSA fully welded to top flange of beam.
Contractor to check dimension on site to ensure suitability of RSA detail. Packing to be provided if necessary.
Section 8 – 8
2 No. M16 HSL anchors by Hilti or similar approved into soffit of slab. 150 c/c
2no M16 grade 8.8 bolts in vertically slotted holes ±20mm
Top flange of castellated beam.
Detail 7
1 | 9.7.98 | General Revisions
0 | 3.7.98 | Issued for Construction
rev. | date | description
WARD COLE
client:
job title:
drawing title:
scale: 1:10
date: June 98
drawn by: M.R.H.
checked by:
job number:
drawing number: 112
revision: 1

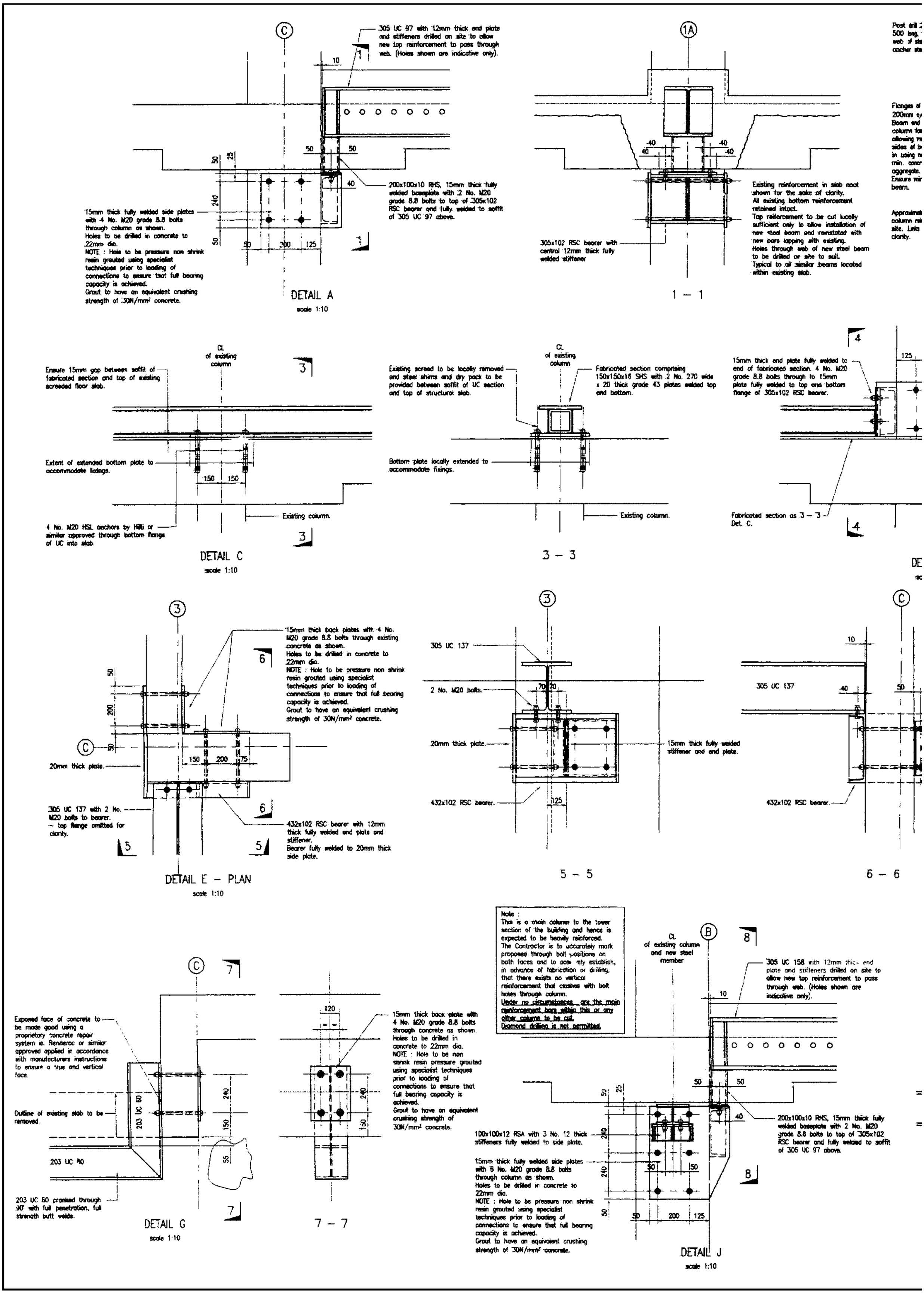
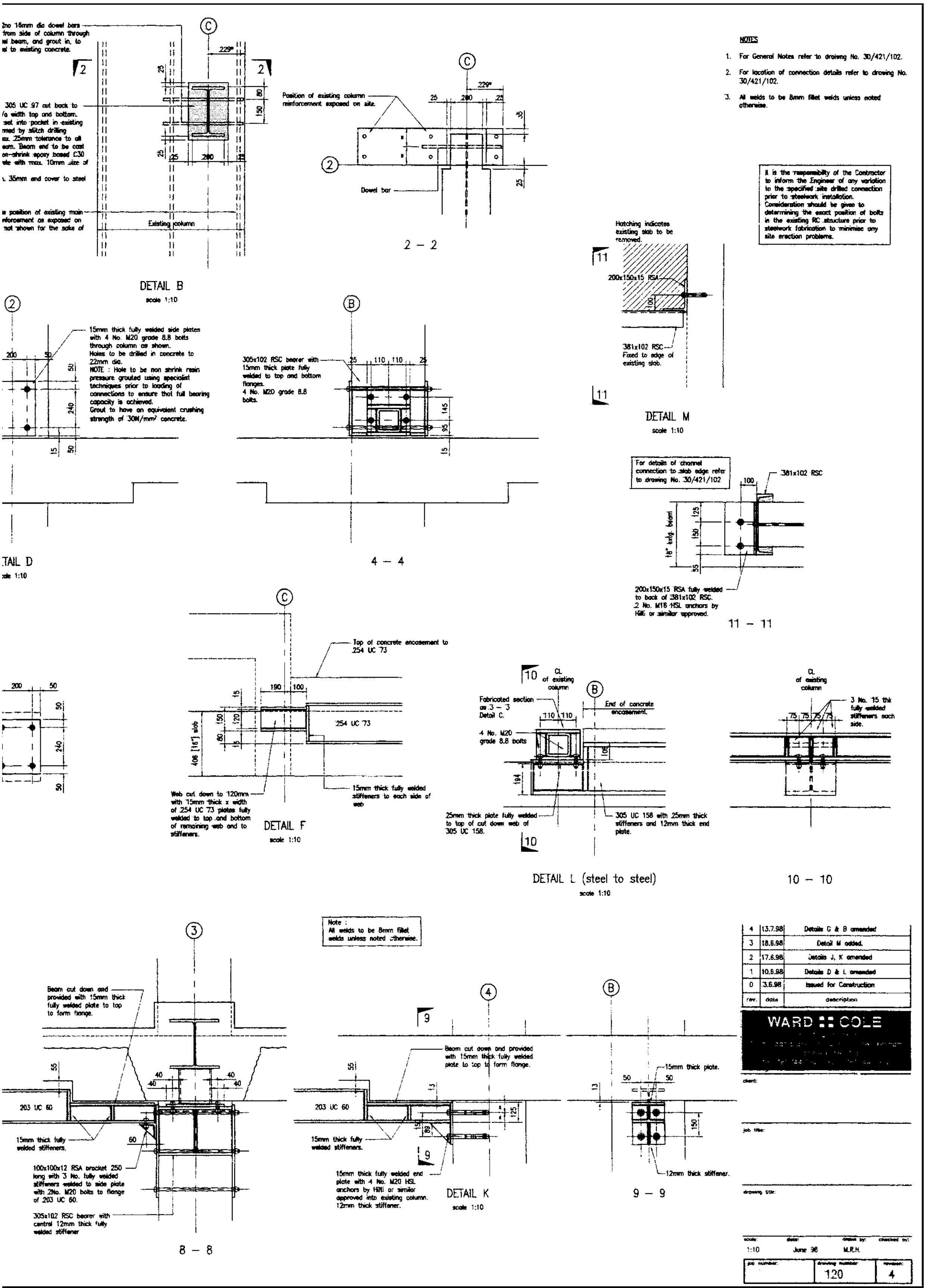


Fig. 7.1.9. Typical fastenings details—construction drawing 1


NOTES
1. For General Notes refer to drawing No. 30/421/102.
2. For location of connection details refer to drawing No. 30/421/102.
3. All welds to be 8mm fillet welds unless noted otherwise.
It is the responsibility of the Contractor to inform the Engineer of any variation to the specified site drilled connection prior to steelwork installation. Consideration should be given to determining the exact position of bolts in the existing RC structure prior to steelwork fabrication to minimise any site erection problems.
DETAIL B
scale 1:10
2 – 2
Position of existing column reinforcement exposed on site.
Dowel bar
Existing column
DETAIL M
scale 1:10
Hatching indicates existing slab to be removed.
200x150x15 RSA
381x102 RSC Fixed to edge of existing slab.
For details of channel connection to slab edge refer to drawing No. 30/421/102
381x102 RSC
200x150x15 RSA fully welded to back of 381x102 RSC. 2 No. M16 HSL anchors by Hilti or similar approved.
11 – 11
DETAIL D
scale 1:10
15mm thick fully welded side plates with 4 No. M20 grade 8.8 bolts through column as shown. Holes to be drilled in concrete to 22mm dia.
NOTE : Hole to be non shrink resin pressure grouted using specialist techniques prior to loading of connections to ensure that full bearing capacity is achieved. Grout to have an equivalent crushing strength of 30N/mm² concrete.
4 – 4
305x102 RSC bearer with 15mm thick plate fully welded to top and bottom flanges. 4 No. M20 grade 8.8 bolts.
DETAIL F
scale 1:10
Top of concrete encasement to 254 UC 73
254 UC 73
Web cut down to 120mm with 15mm thick x width of 254 UC 73 plates fully welded to top and bottom of remaining web and to stiffeners.
15mm thick fully welded stiffeners to each side of web
DETAIL L (steel to steel)
scale 1:10
Fabricated section as 3 – 3 Detail C.
4 No. M20 grade 8.8 bolts
End of concrete encasement.
25mm thick plate fully welded to top of cut down web of 305 UC 158.
305 UC 158 with 25mm thick stiffeners and 12mm thick end plate.
10 – 10
3 No. 15 thk fully welded stiffeners each side.
Note : All welds to be 8mm fillet welds unless noted otherwise.
8 – 8
Beam cut down and provided with 15mm thick fully welded plate to top to form flange.
203 UC 60
15mm thick fully welded stiffeners.
100x100x12 RSA bracket 250 long with 3 No. fully welded stiffeners welded to side plate with 2No. M20 bolts to flange of 203 UC 60.
305x102 RSC bearer with central 12mm thick fully welded stiffener
DETAIL K
scale 1:10
15mm thick fully welded end plate with 4 No. M20 HSL anchors by Hilti or similar approved into existing column. 12mm thick stiffener.
9 – 9
15mm thick plate.
12mm thick stiffener.
4 13.7.98 Details G & B amended
3 18.6.98 Detail M added.
2 17.6.98 Details J, K amended
1 10.6.98 Details D & L amended
0 3.6.98 Issued for Construction
rev. date description
WARD COLE
client:
job title:
drawing title:
scale: 1:10 date: June 98 drawn by: M.R.H. checked by:
job number: drawing number: 120 revision: 4

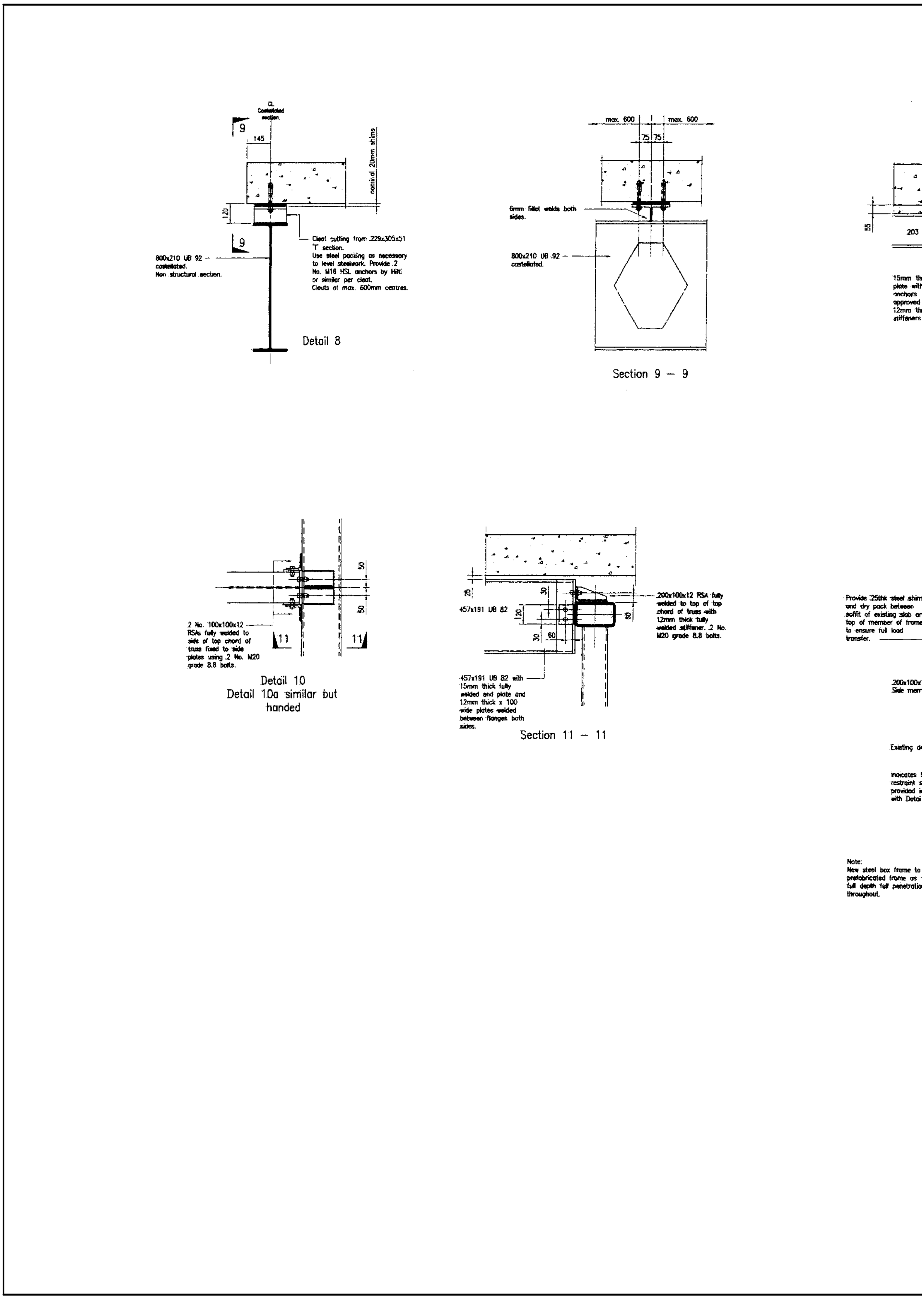
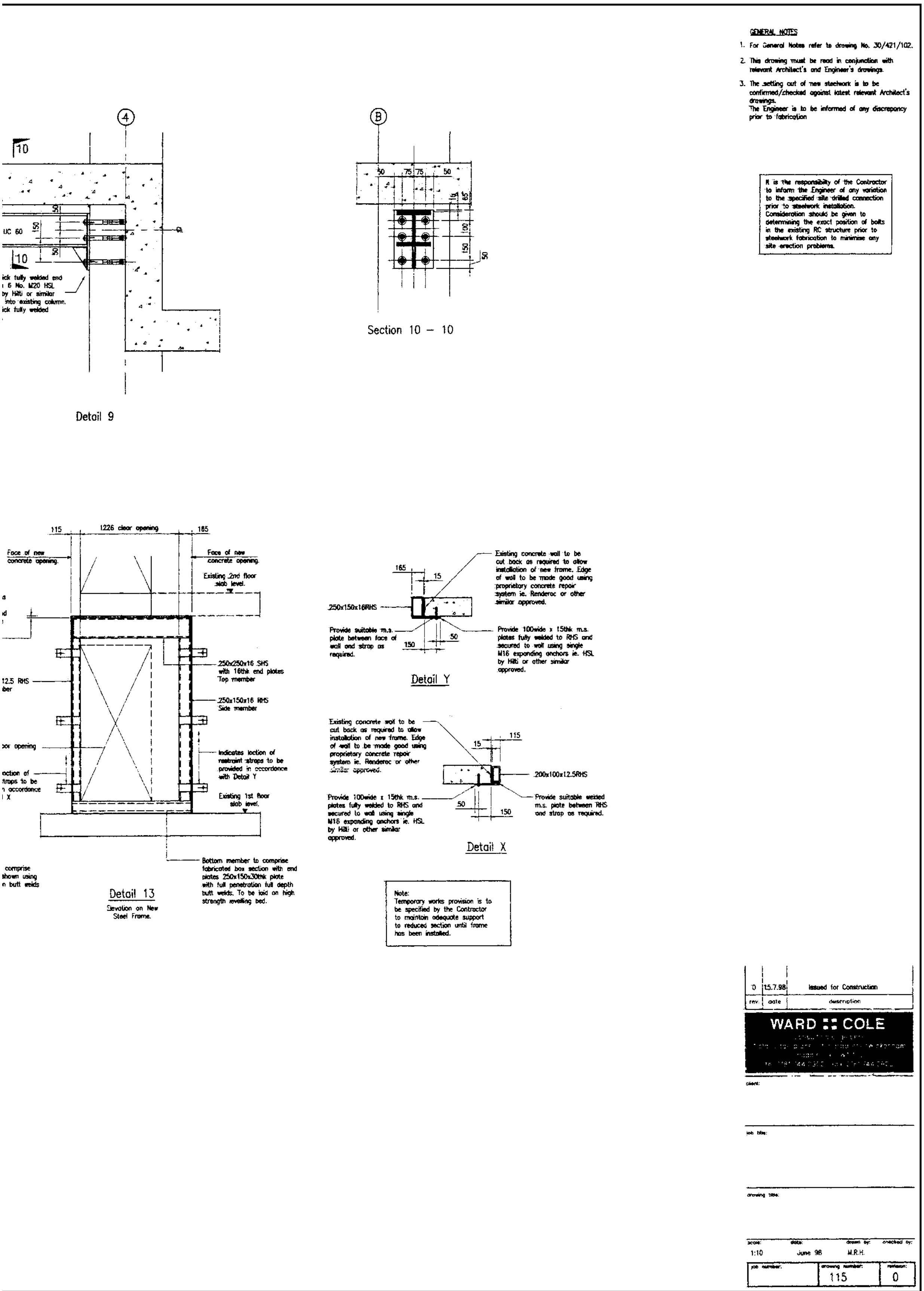


Fig. 7.1.10. Typical fastenings details—construction drawing 2


GENERAL NOTES
1. For General Notes refer to drawing No. 30/421/102.
2. This drawing must be read in conjunction with relevant Architect's and Engineer's drawings.
3. The setting out of new steelwork is to be confirmed/checked against latest relevant Architect's drawings.
The Engineer is to be informed of any discrepancy prior to fabrication
It is the responsibility of the Contractor to inform the Engineer of any variation to the specified site drilled connection prior to steelwork installation. Consideration should be given to determining the exact position of bolts in the existing RC structure prior to steelwork fabrication to minimise any site erection problems.
Detail 9
Section 10 – 10
115
1226 clear opening
185
Face of new concrete opening.
Face of new concrete opening.
Existing 2nd floor slab level.
250x250x16 SHS with 16thk end plates Top member
250x150x16 RHS Side member
Indicates loction of restraint straps to be provided in accordance with Detail Y
Existing 1st floor slab level.
Bottom member to comprise fabricated box section with end plates 250x150x30thk plate with full penetration full depth butt welds. To be laid on high strength levelling bed.
Detail 13
Elevation on New Steel Frame.
165
15
250x150x16RHS
Existing concrete wall to be cut back as required to allow installation of new frame. Edge of wall to be made good using proprietary concrete repair system ie. Renderoc or other similar approved.
Provide suitable m.s. plate between face of wall and strap as required.
150
50
Provide 100wide x 15thk m.s. plates fully welded to RHS and secured to wall using single M16 expanding anchors ie. HSL by Hilti or other similar approved.
Detail Y
Existing concrete wall to be cut back as required to allow installation of new frame. Edge of wall to be made good using proprietary concrete repair system ie. Renderoc or other similar approved.
115
15
200x100x12.5RHS
Provide 100wide x 15thk m.s. plates fully welded to RHS and secured to wall using single M16 expanding anchors ie. HSL by Hilti or other similar approved.
50
150
Provide suitable welded m.s. plate between RHS and strap as required.
Detail X
Note:
Temporary works provision is to be specified by the Contractor to maintain adequate support to reduced section until frame has been installed.
0 15.7.98 Issued for Construction
rev. date description
WARD :: COLE
scale: 1:10
date: June 98
drawn by: M.R.H.
drawing number: 115
revision: 0

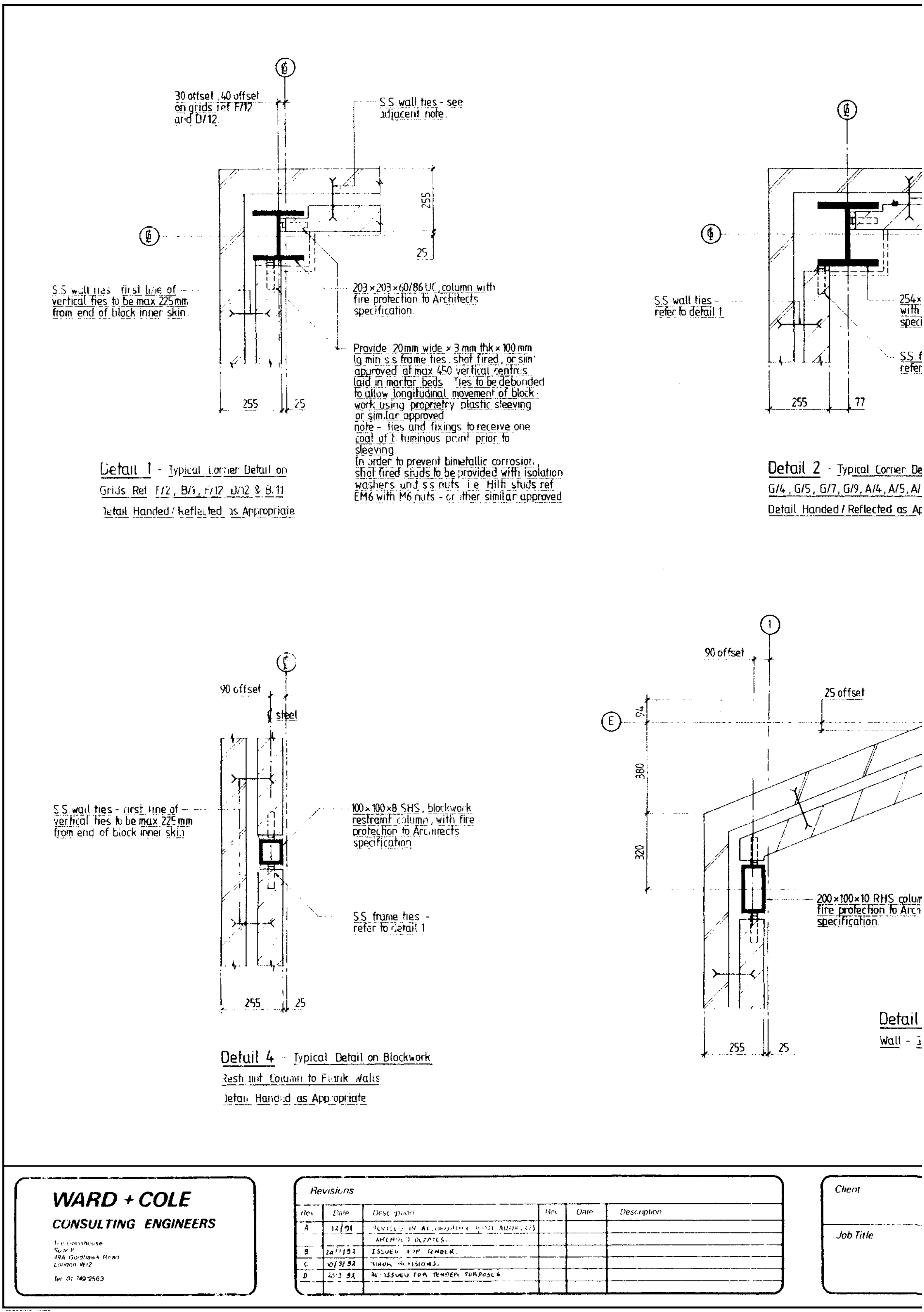
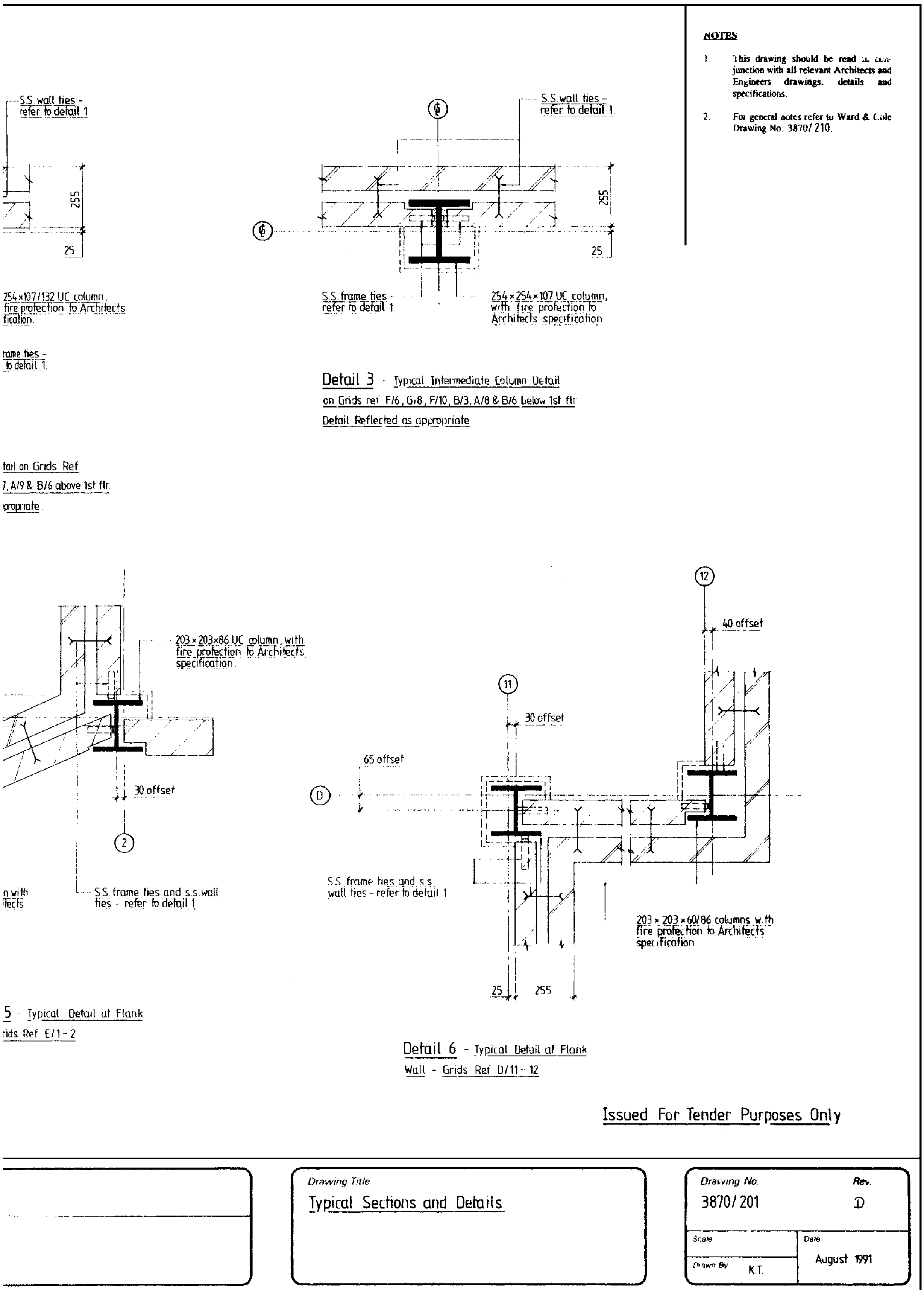


Fig. 7.1.11. Drawing issued for tender purposes—typical steel details at corner and flank


NOTES
1. This drawing should be read in conjunction with all relevant Architects and Engineers drawings, details and specifications.
2. For general notes refer to Ward & Cole Drawing No. 3870/ 210.
S.S. wall ties - refer to detail 1
255
25
254×107/132 UC column, fire protection to Architects fication
rame ties - to detail 1
tail on Grids Ref
7, A/9 & B/6 above 1st flr.
ppropriate
S.S. wall ties - refer to detail 1
255
25
S.S. frame ties - refer to detail 1
254×254×107 UC column, with fire protection to Architects specification
Detail 3 - Typical Intermediate Column Detail on Grids ref F/6, G/8, F/10, B/3, A/8 & B/6 below 1st flr Detail Reflected as appropriate
203×203×86 UC column, with fire protection to Architects specification
30 offset
2
n with itects
S.S. frame ties and s.s. wall ties - refer to detail 1
5 - Typical Detail at Flank
rids Ref E/1-2
12
40 offset
11
30 offset
65 offset
D
S.S. frame ties and s.s wall ties - refer to detail 1
203×203×60/86 columns with fire protection to Architects specification
25
255
Detail 6 - Typical Detail at Flank Wall - Grids Ref D/11-12
Issued For Tender Purposes Only
Drawing Title
Typical Sections and Details
Drawing No.
3870/ 201
Rev.
D
Scale
Date
August 1991
Drawn By
K.T.

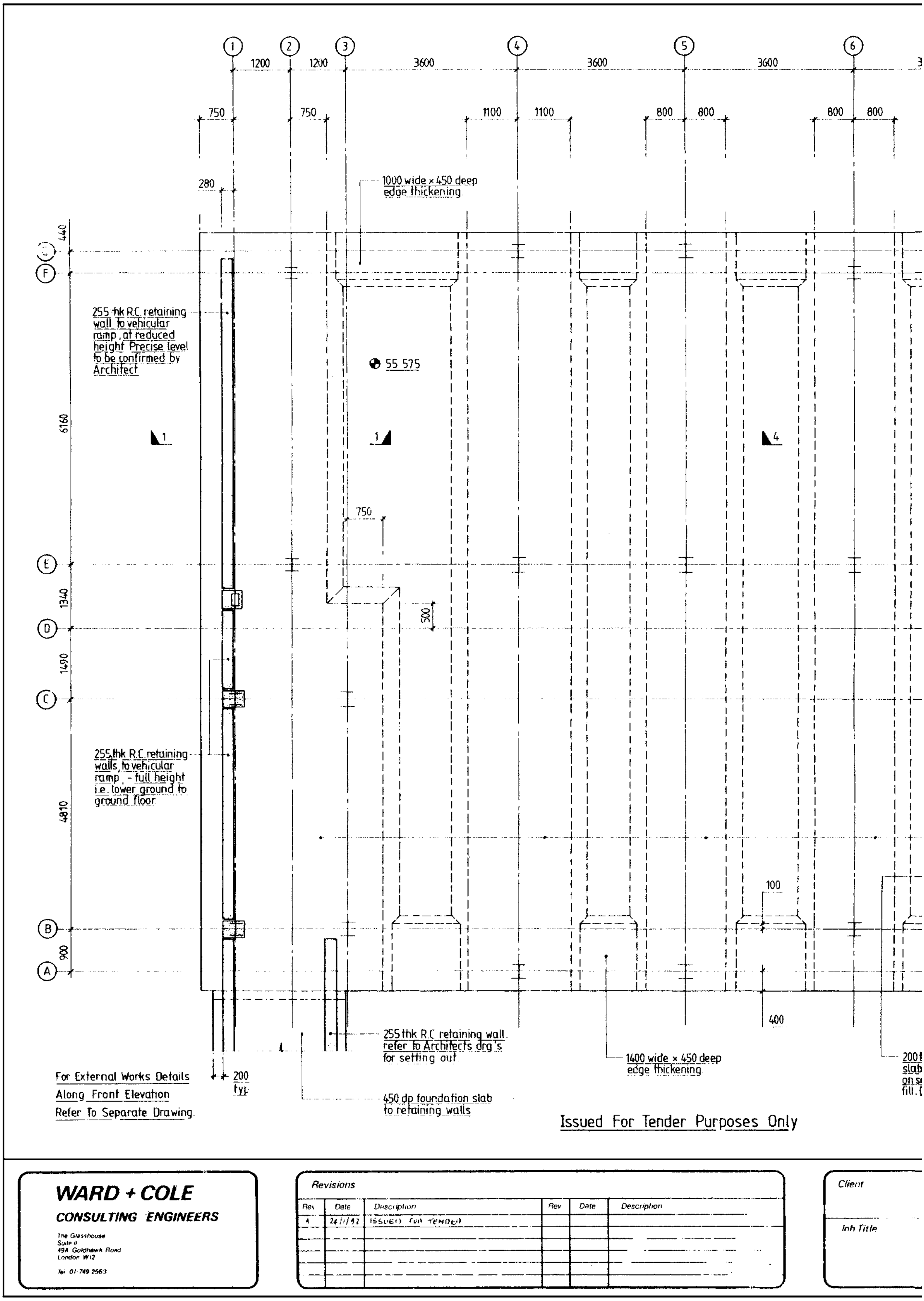
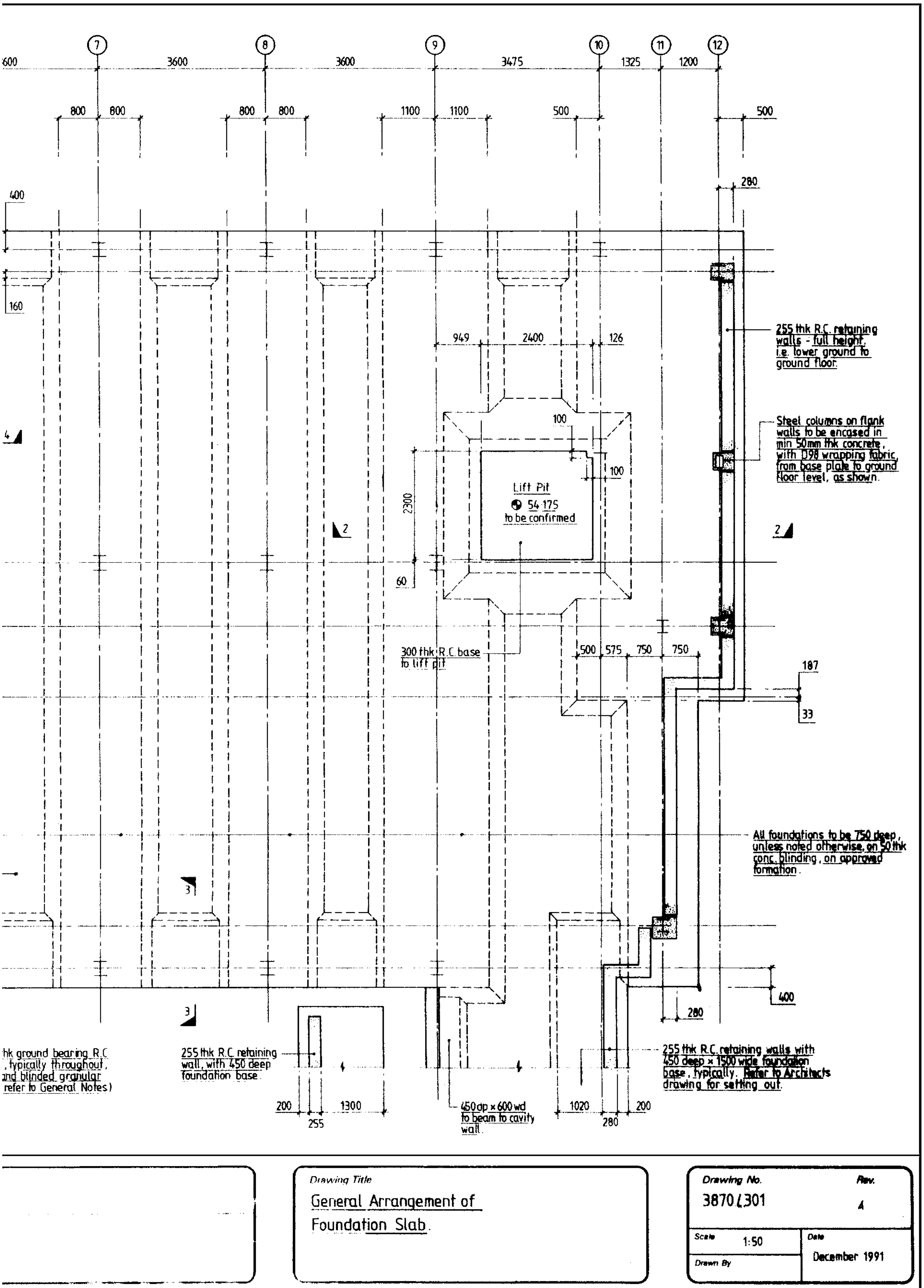


Fig. 7.1.12. Drawing issued for tender purposes—general arrangement for foundation slab


255 thk R.C. retaining walls - full height, i.e. lower ground to ground floor.
Steel columns on flank walls to be encased in min 50mm thk concrete, with D98 wrapping fabric, from base plate to ground floor level, as shown.
Lift Pit
54.175
to be confirmed
300 thk R.C base to lift pit
All foundations to be 750 deep, unless noted otherwise, on 50 thk conc. blinding, on approved formation.
255 thk R.C retaining wall, with 450 deep foundation base.
450dp x 600wd to beam to cavity wall.
255 thk R.C. retaining walls with 450 deep x 1500 wide foundation base, typically. Refer to Architects drawing for setting out.
Drawing Title
General Arrangement of
Foundation Slab.
Drawing No.
3870/301
Rev.
A
Scale
1:50
Date
December 1991
Drawn By

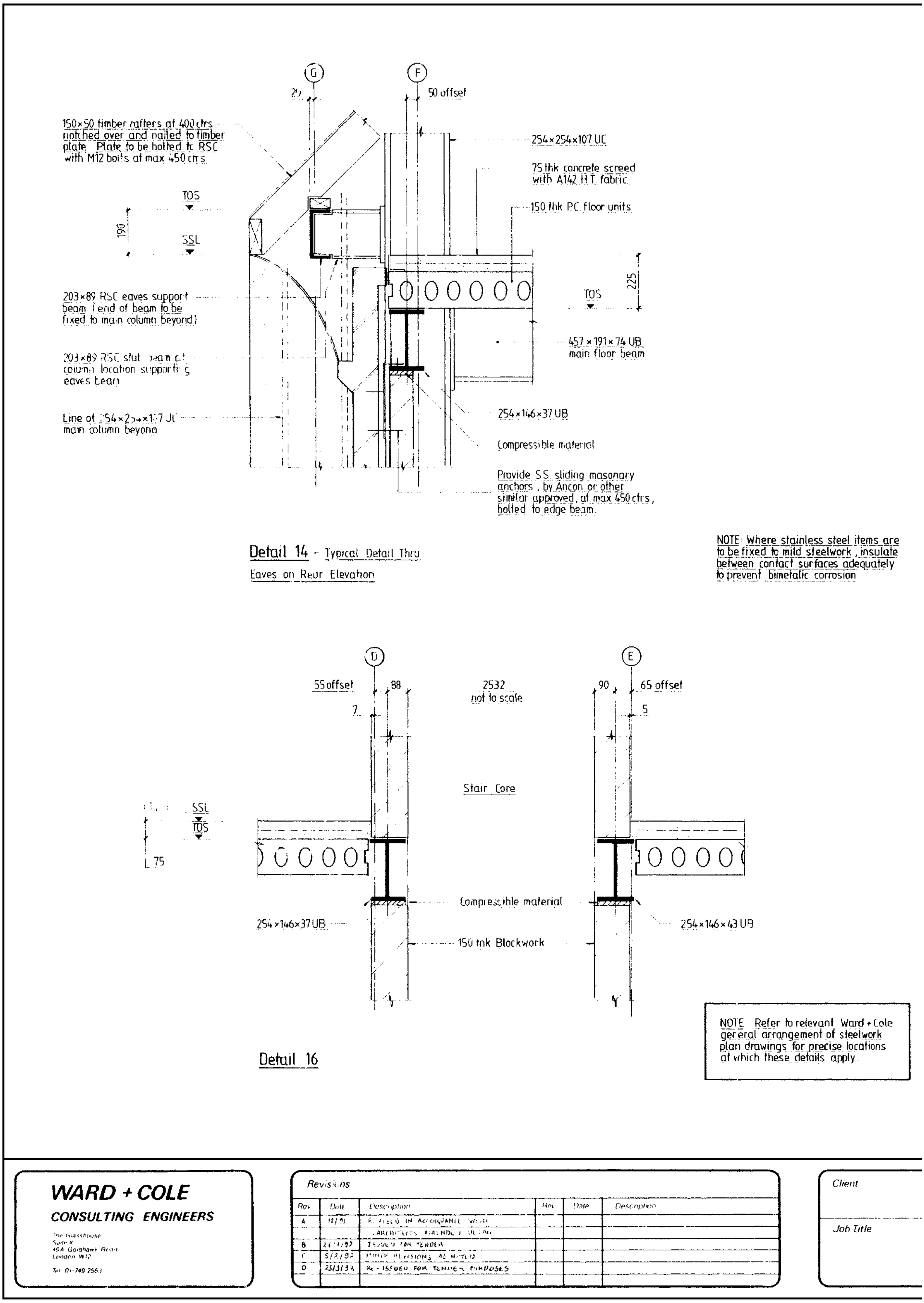
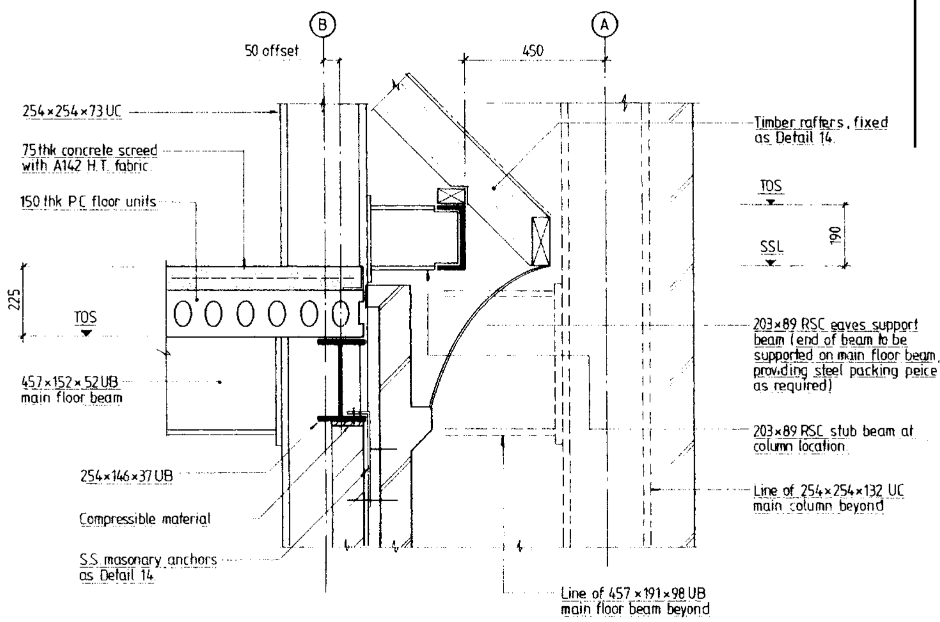


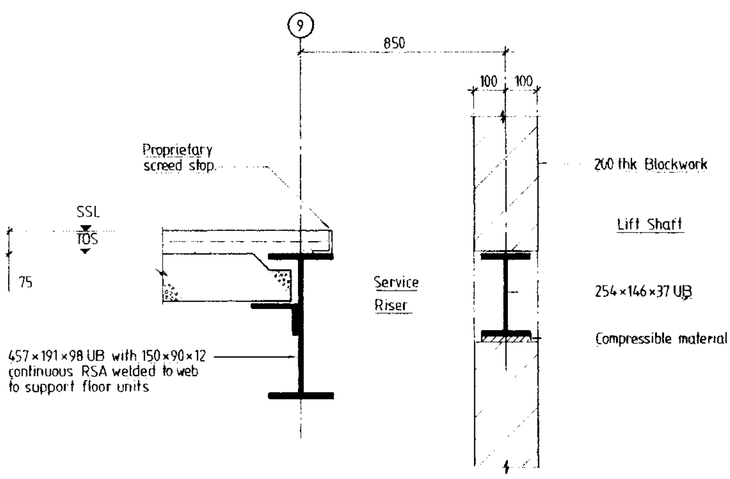
Fig. 7.1.13. Drawing issued for tender purposes—typical composite steel/concrete data

NOTES

1. This drawing should be read in conjunction with all relevant Architects and Engineers drawings, details and specifications.
2. For general notes refer to Ward & Cole Drawing No. 3870/210.



Detail 15 - Typical Detail Thru Eaves on Front Elevation



Detail 17

Issued For Tender Purposes Only

Drawing Title	Drawing No.	Rev.
Typical Sections and Details	3870/203	D

Scale	Date	Drawn By
1:10	Sept 1991	K.T.

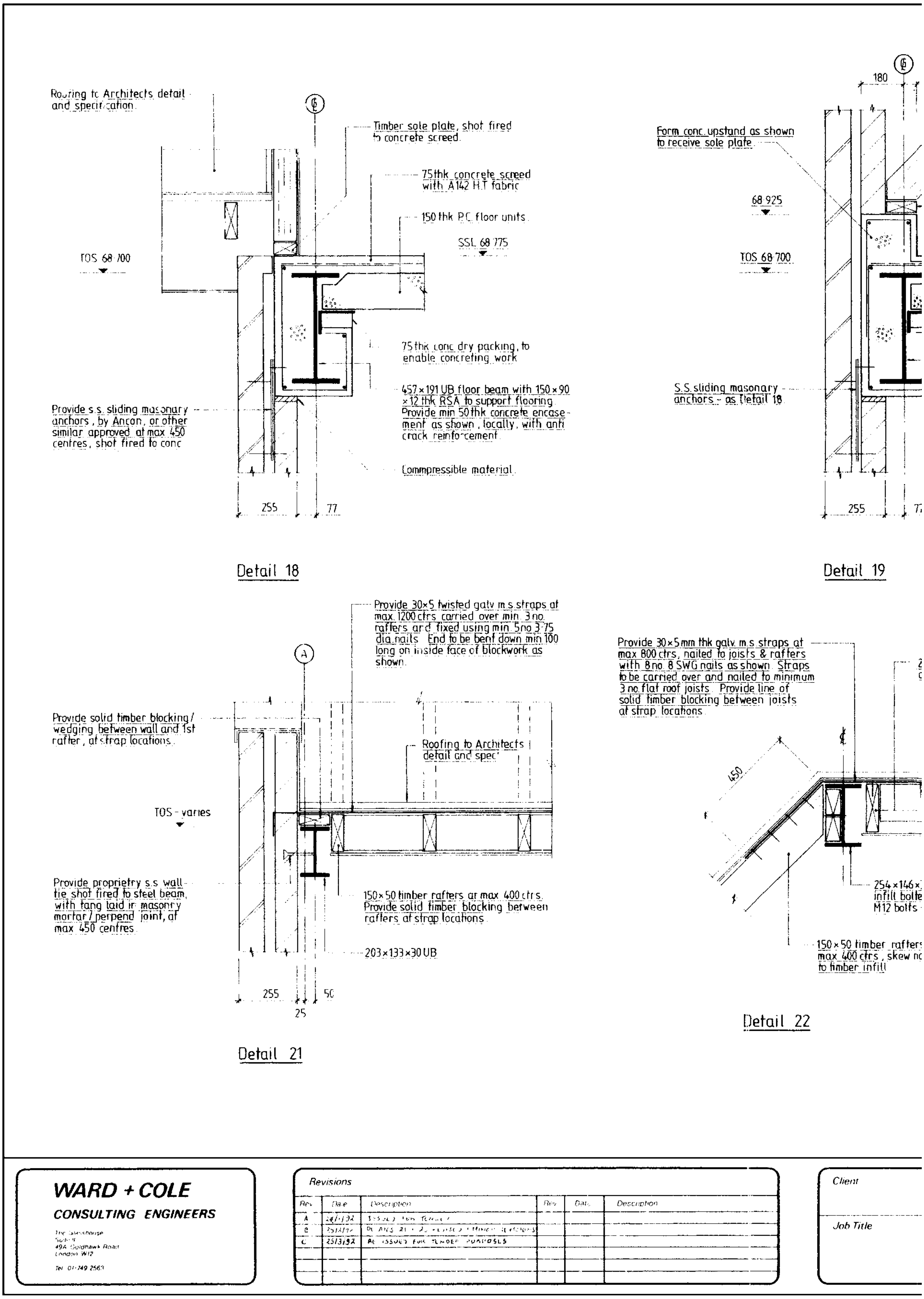
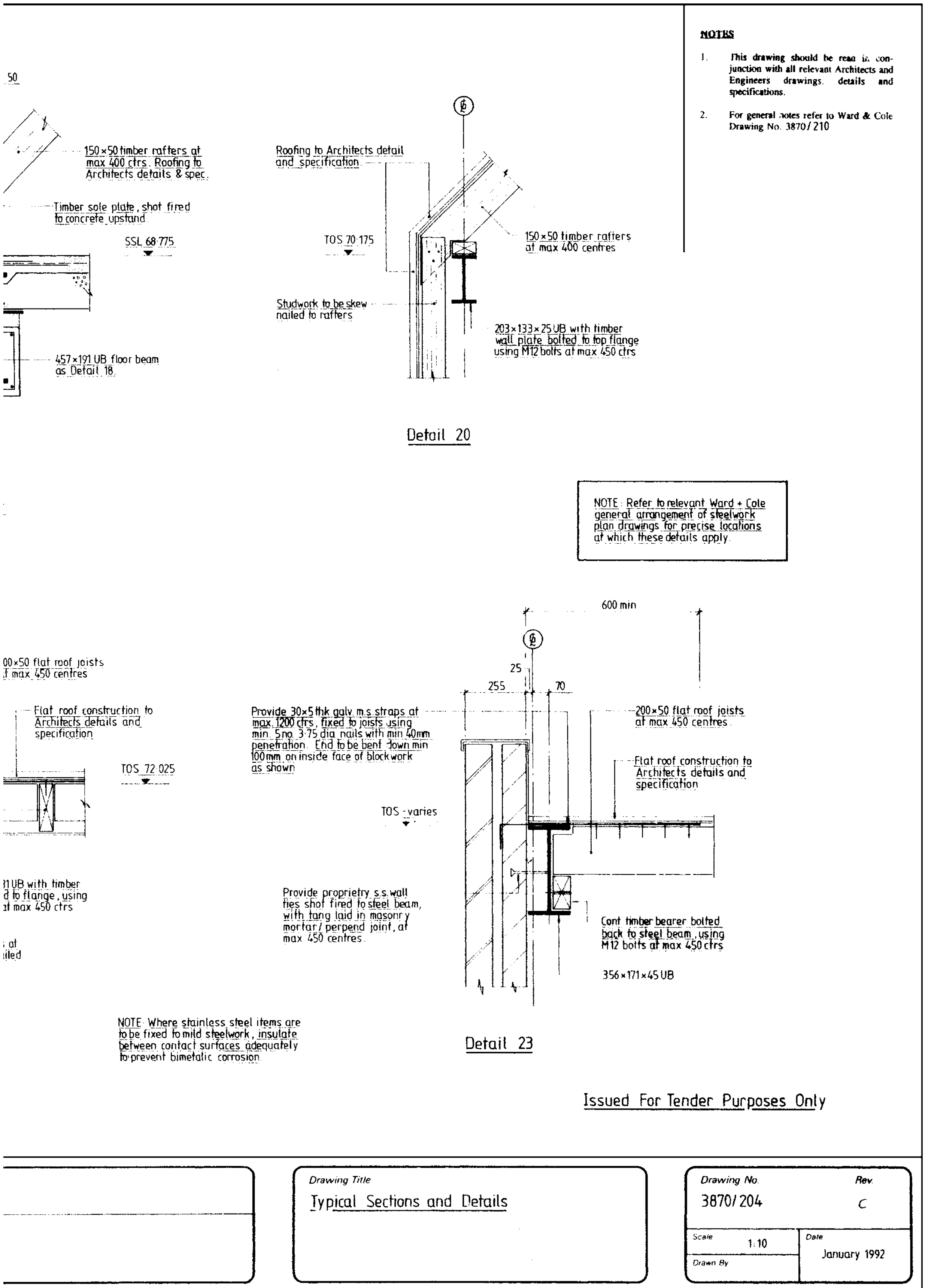


Fig. 7.1.14. *Drawing issued for tender purposes—typical sections, masonry wall, steel and timber details*


NOTES
1. This drawing should be read in conjunction with all relevant Architects and Engineers drawings, details and specifications.
2. For general notes refer to Ward & Cole Drawing No. 3870/210
150×50 timber rafters at max 400 ctrs. Roofing to Architects details & spec.
Timber sole plate, shot fired to concrete upstand
SSL 68.775
457×191 UB floor beam as Detail 18
Roofing to Architects detail and specification
TOS 70.175
Studwork to be skew nailed to rafters
150×50 timber rafters at max 400 centres
203×133×25 UB with timber wall plate bolted to top flange using M12 bolts at max 450 ctrs
Detail 20
NOTE: Refer to relevant Ward + Cole general arrangement of steelwork plan drawings for precise locations at which these details apply.
600 min
25
255
70
Flat roof construction to Architects details and specification
TOS 72.025
Provide 30×5 thk galv. m.s. straps at max. 1200 ctrs, fixed to joists using min. 5no. 3.75 dia nails with min 40mm penetration. End to be bent down min 100mm on inside face of blockwork as shown
TOS - varies
200×50 flat roof joists at max 450 centres.
Flat roof construction to Architects details and specification
Provide proprietry s.s. wall ties shot fired to steel beam, with tang laid in masonry mortar/perpend joint, at max 450 centres.
Cont timber bearer bolted back to steel beam, using M12 bolts at max 450 ctrs
356×171×45 UB
NOTE: Where stainless steel items are to be fixed to mild steelwork, insulate between contact surfaces adequately to prevent bimetalic corrosion
Detail 23
Issued For Tender Purposes Only
Drawing Title
Typical Sections and Details
Drawing No.
3870/204
Rev.
C
Scale
1:10
Date
January 1992
Drawn By

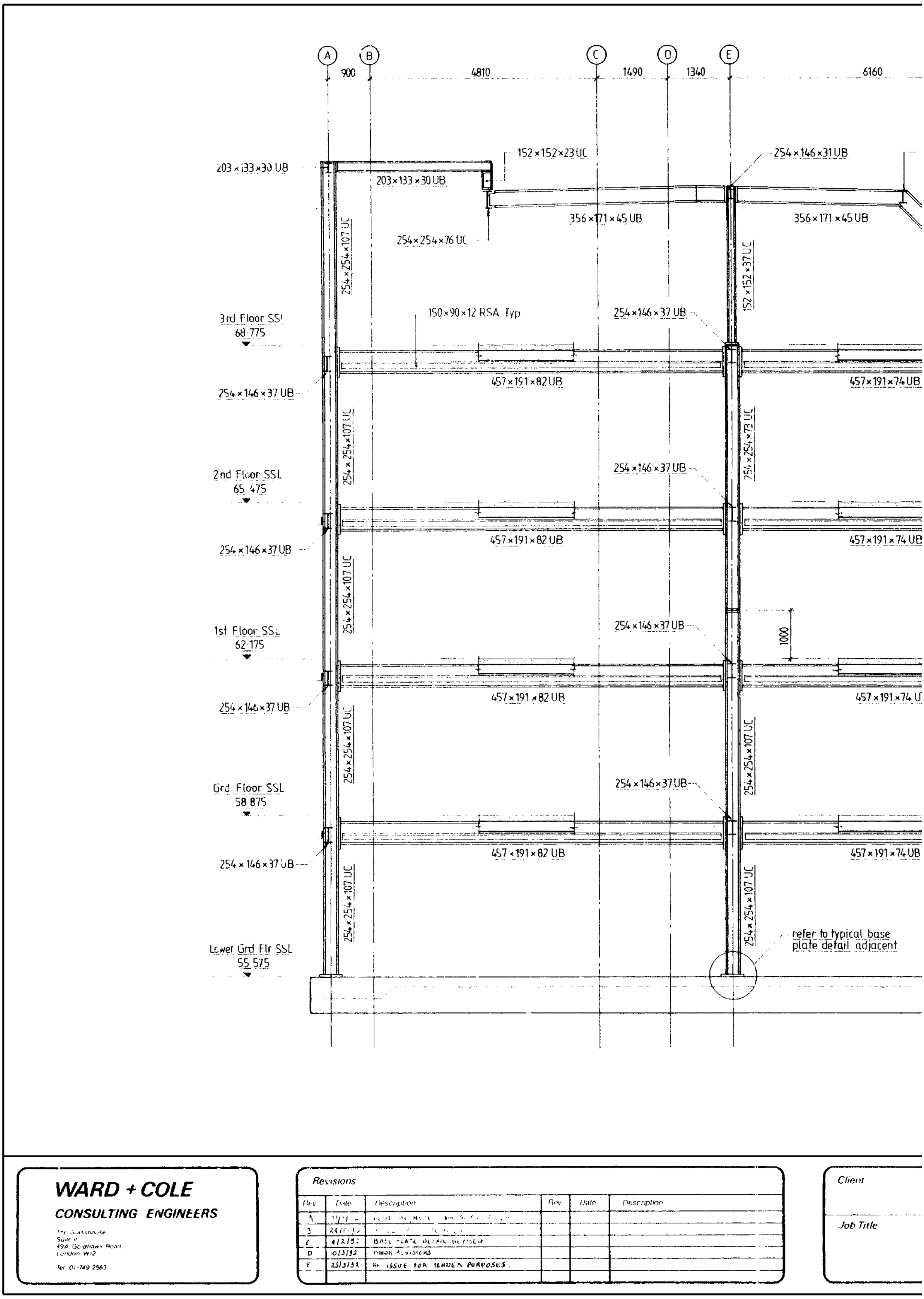
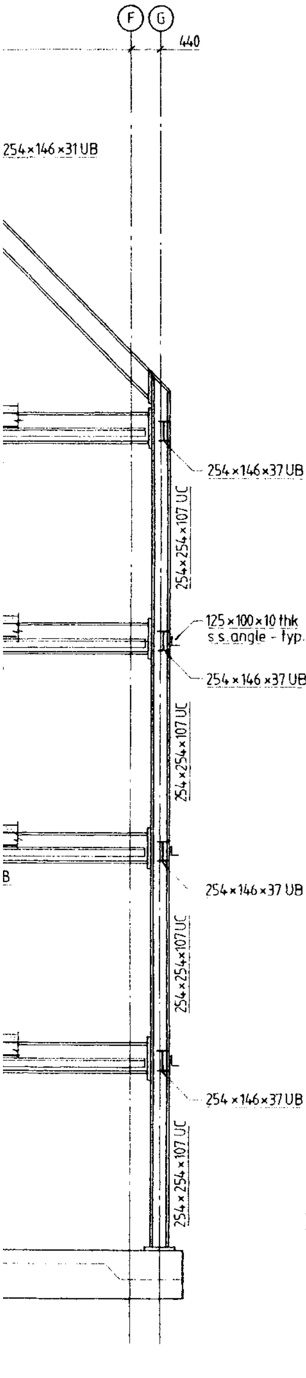


Fig. 7.1.15. Structural elevation and details of a typical steel building frame



Issued For Tender Purposes Only

GENERAL NOTES

1. This drawing is to be read in conjunction with all latest relevant Architects and Engineers drawings and specifications.

2. All dimensions to be obtained/checked against Architects drawings and by site measurement prior to the commencement of works or ordering of materials.
Do not scale this drawing.

3. The Contractor is responsible for the overall stability of the structure from the commencement of works, including the design and provision of all necessary temporary works.

4. All D.P.M.;s, D.P.C.'s and waterproofing/weathering details to be in accordance with Architects details.

5. Reinforced concrete to be Grade C35 with 20mm max. size of aggregate.
All concrete to be in accordance with B.S.8110.

6. Generally all steel columns to be grade 50 steel unless noted otherwise. All other steelwork to be grade 43 steel unless noted otherwise. All steelwork is to comply with B.S.5950. Steelwork which is not to be cased in concrete is to be supplied shot blasted in accordance with SA2.½ and painted with two coats of zinc rich primer. Any damage to be made good on site. Any steelwork which is to be cased in concrete is to be supplied free from loose mill scale and rust and is to remain unpainted.

7. All structural steelwork and fixings to be adequately protected against fire to the satisfaction of the Local Building Control Officer and in accordance with Architects details and specifications.

8. All bolts and washers to be mild steel. All bolts to be Grade 8.8 black bolts unless indicated otherwise.
All welds to be nominal 6mm fillet welds unless indicated otherwise.

9. The steelwork fabricator is to submit full working drawings to Ward + Cole at least two full weeks prior to fabrication.

10. All steelwork connections indicated 'simple' in nature to design/detail prepared by fabricators, using the beam reactions given. All other connections to be 'fixed' in nature to Ward & Cole design and details.

11. All buried steelwork to be encased with min. 50 mm concrete for corrosion protection, after erection, final setting out and plumbing of work.

12. All holding down bolts to be supplied ahead of main steelwork delivery for casting into bases by contractor.

13. All new timber to be Grade SC3 Timber is to be preservative treated in accordance with Architects specification, with cut ends thoroughly treated prior to building in. Materials and workmanship to be in accordance with B.S.5268.

14. High yield steel, prefixed 'T' on drawing and delivery tags, to be in accordance with B.S.4449 or B.S.4461.
Mild steel, prefixed 'R' on drawing and delivery tags, to be in accordance with B.S.4449.
High yield fabric to be in accordance with B.S.4483.

15. Setting out of walls to be in accordance with latest relevant Architects drawings.

16. Where delay occurs before placing of concrete, a min. 50 mm layer of blinding concrete is to be placed as soon as possible after excavation and exposure of the formation.

17. All foundations to be cast min. 1000 below ground level on an approved formation level to the satisfaction of the Local Building Control Officer. Provide mass concrete under R.C foundations to approved formation if required.
Foundations have been designed for an allowable ground bearing pressure of 150kN/m² in accordance with soils investigations report prepared by Herts & Essex Site Investigations.

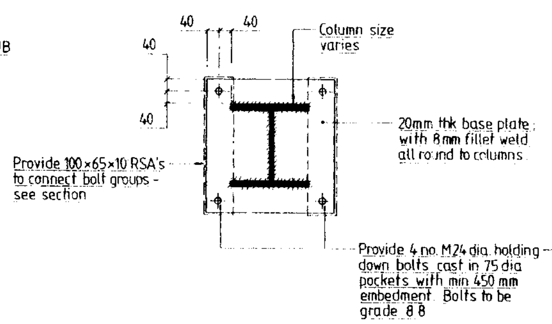
18. Any soft spots encountered under foundations to be removed and replaced with mass concrete.

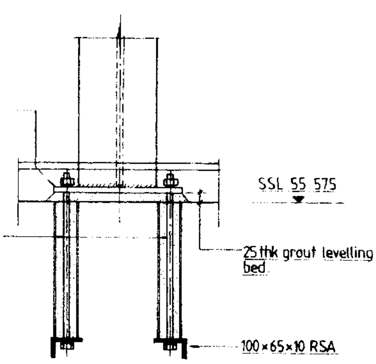
19. Hardcore / granular material to consist of selected broken stone, concrete, brick or other approved material clean of all organic material and to be chemically inert. The material is to be max. 75mm gauge with sufficient fines to ensure thorough compaction in max. 150 layers.
Any soft spots encountered underslab to be removed and replaced with granular material
Depth of underslab fill not to exceed 600mm.

20. The Contractor is responsible for the location of all underground services that may exist and to divert them if necessary prior to the commencement of works.

21. All blockwork used below ground level is to be of foundation quality with the relevant agreement certificates.

22. All structural works to be carried out strictly in accordance with the details given by Ward + Cole. The Engineer is to be advised of any significant variation prior to its implementation.





Typical Base Plate Details

Drawing Title Cross Section on Grid Line 8.	*Drawing No.* 3870/210	*Rev.* E
	Scale 1:50	*Date* December 1991
	Drawn By K.T.	

7.2. Computer-aided structural detailing—British practice solid modelling

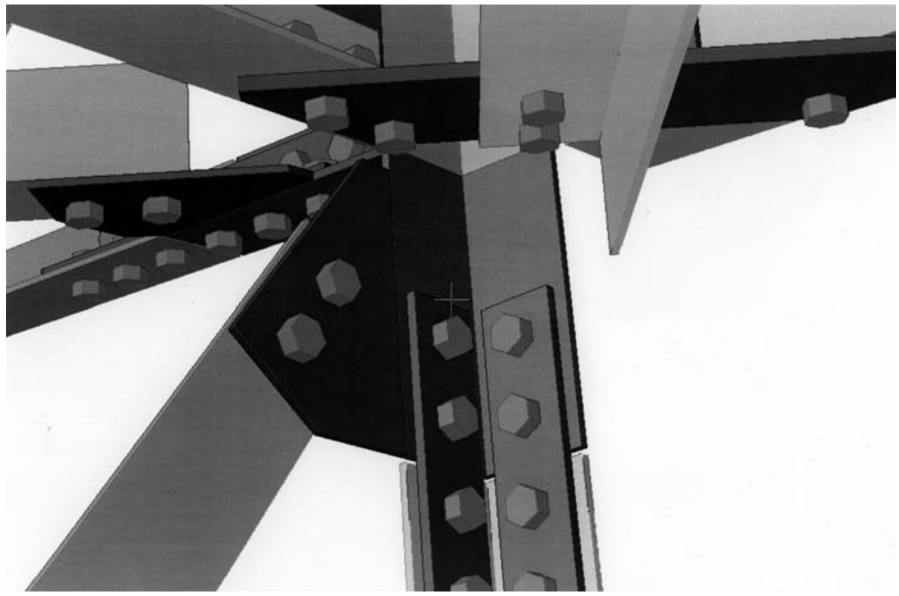


Fig. 7.2.1. Solid modelling of steel joints (Strucad, Derby, UK)

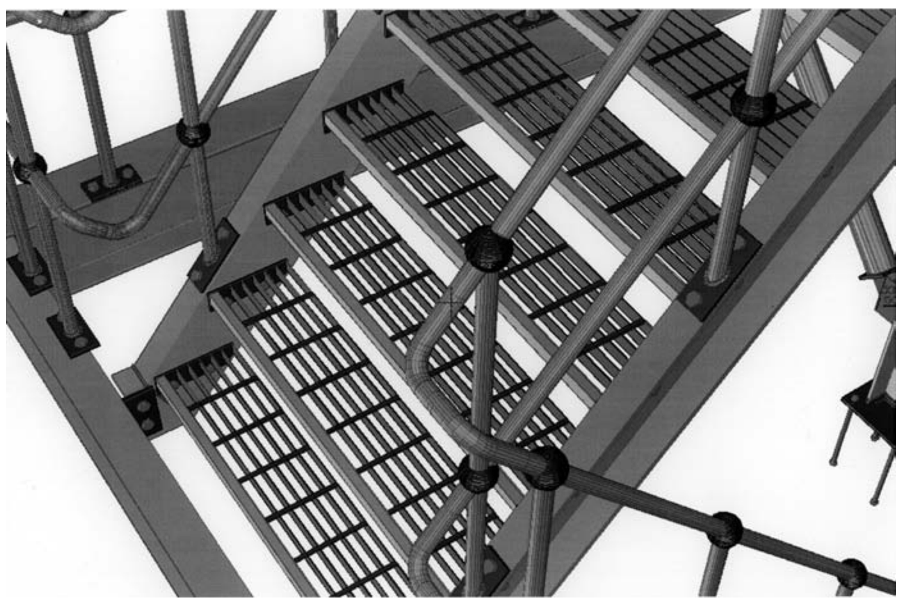


Fig. 7.2.2. Solid modelling of typical steel stairs (Strucad, Derby, UK)

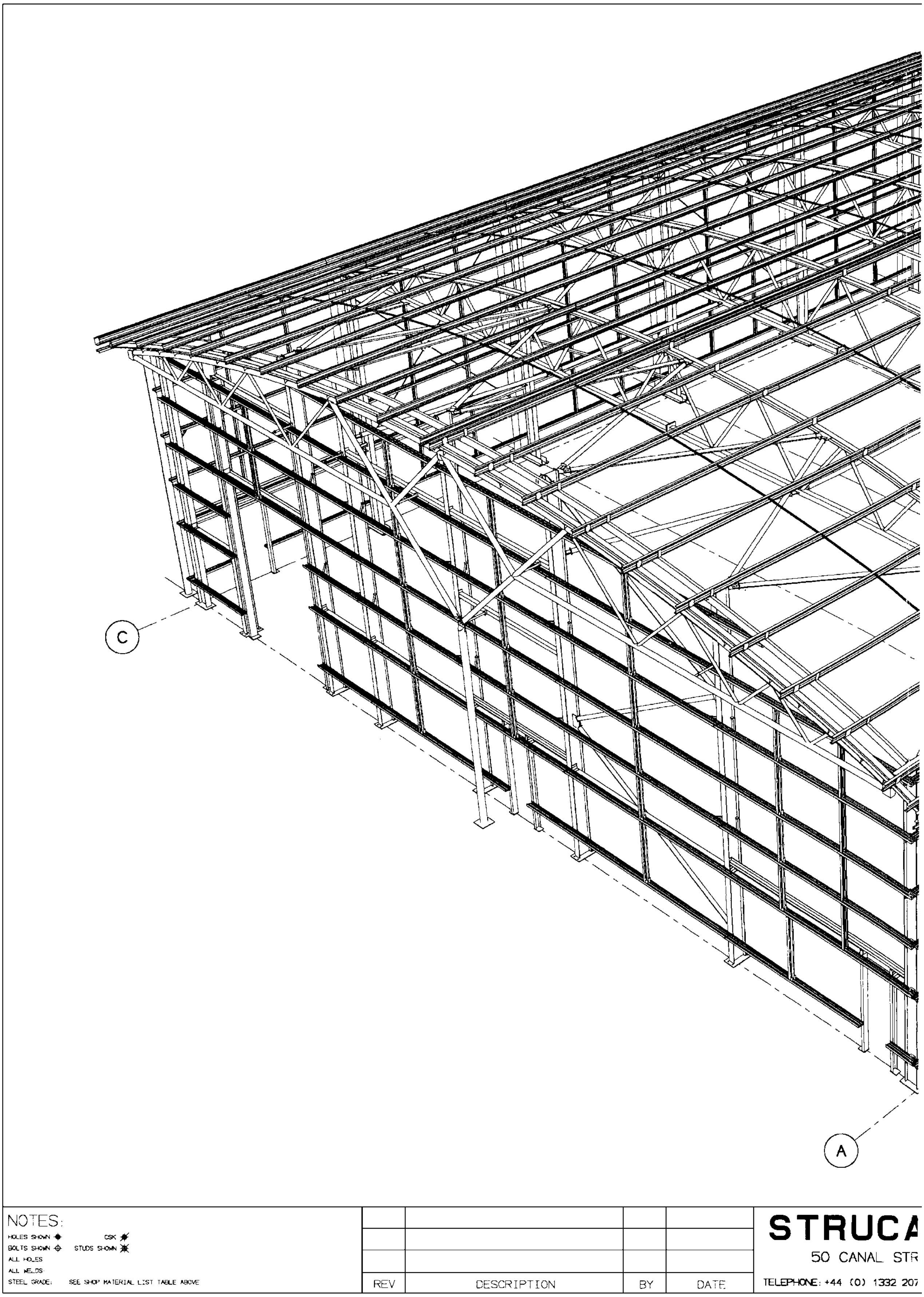
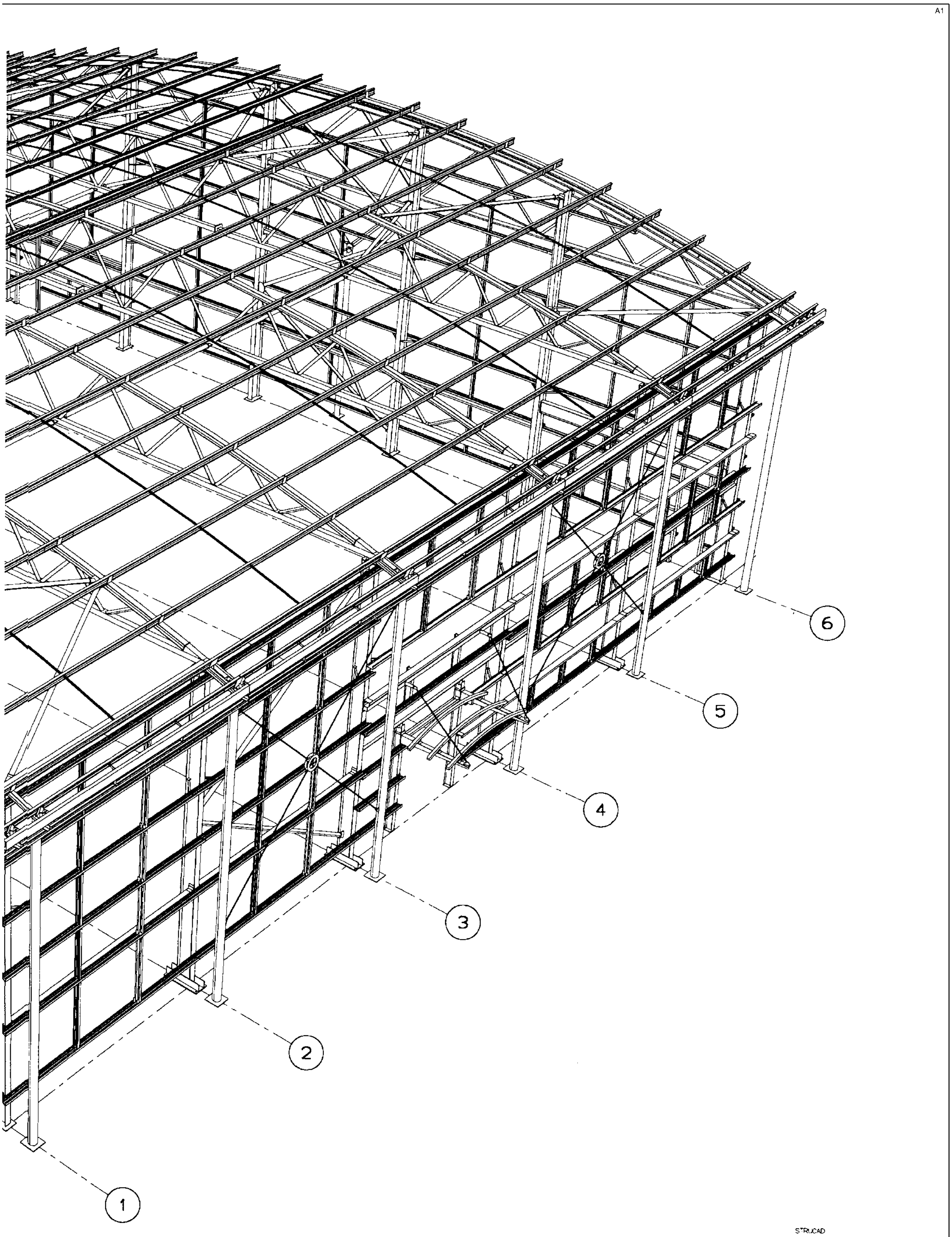


Fig. 7.2.3. 3D steel building infrastructure (Strucad, Derby, UK)



AD (UK) LTD	TITLE	CONT. NUMBER	R1067	DRAWN	CHECKED
REET, DERBY. DE1 2RJ	UNIT 7	SCALE	N. T. S.	BY AR/SB	BY
7344 FAXSIMILE: +44 (0) 1332 207355	CIRCLE SOUTH	REMARKS		DATE 07/05/98	DATE
				DRG. No. 3d	REV

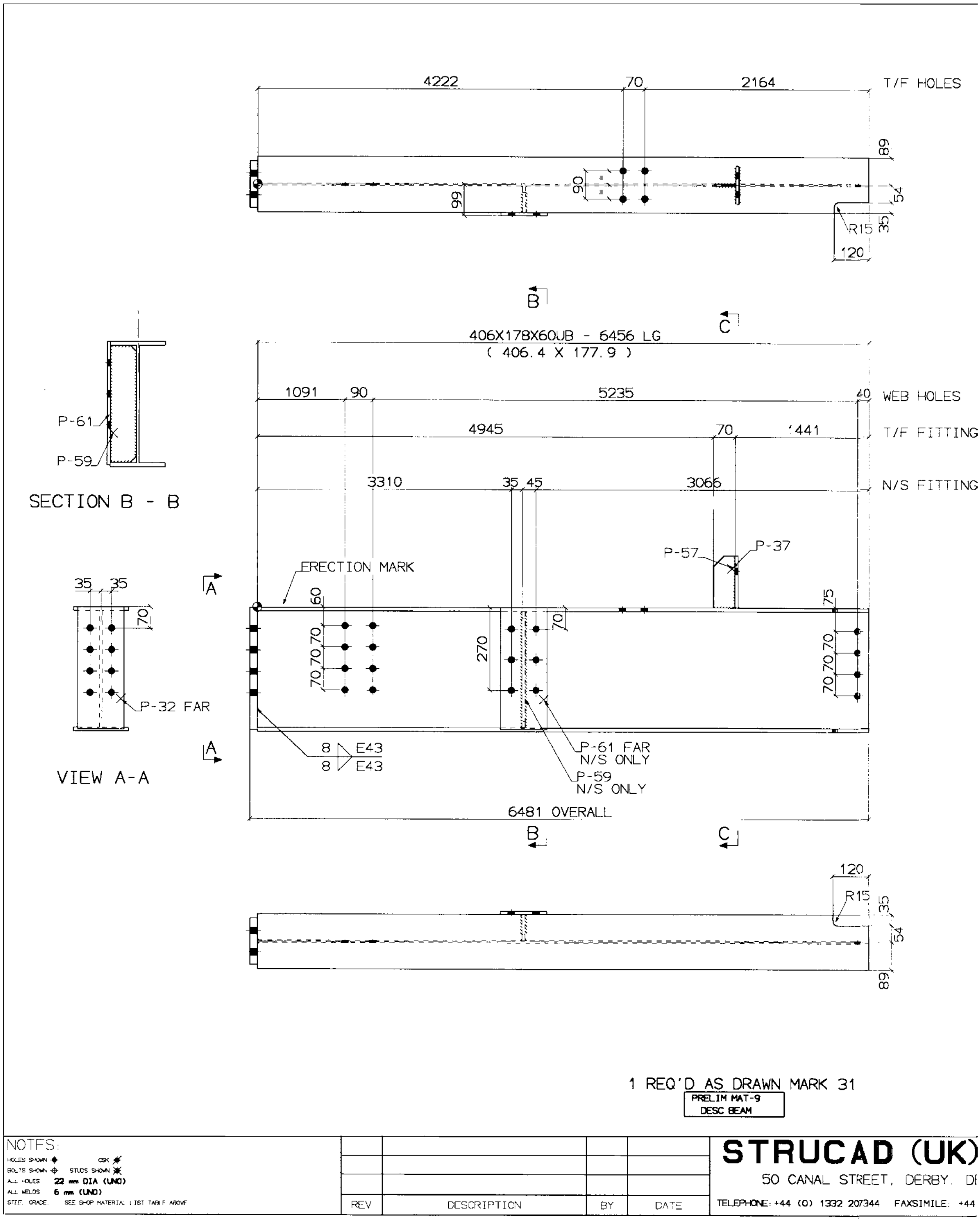
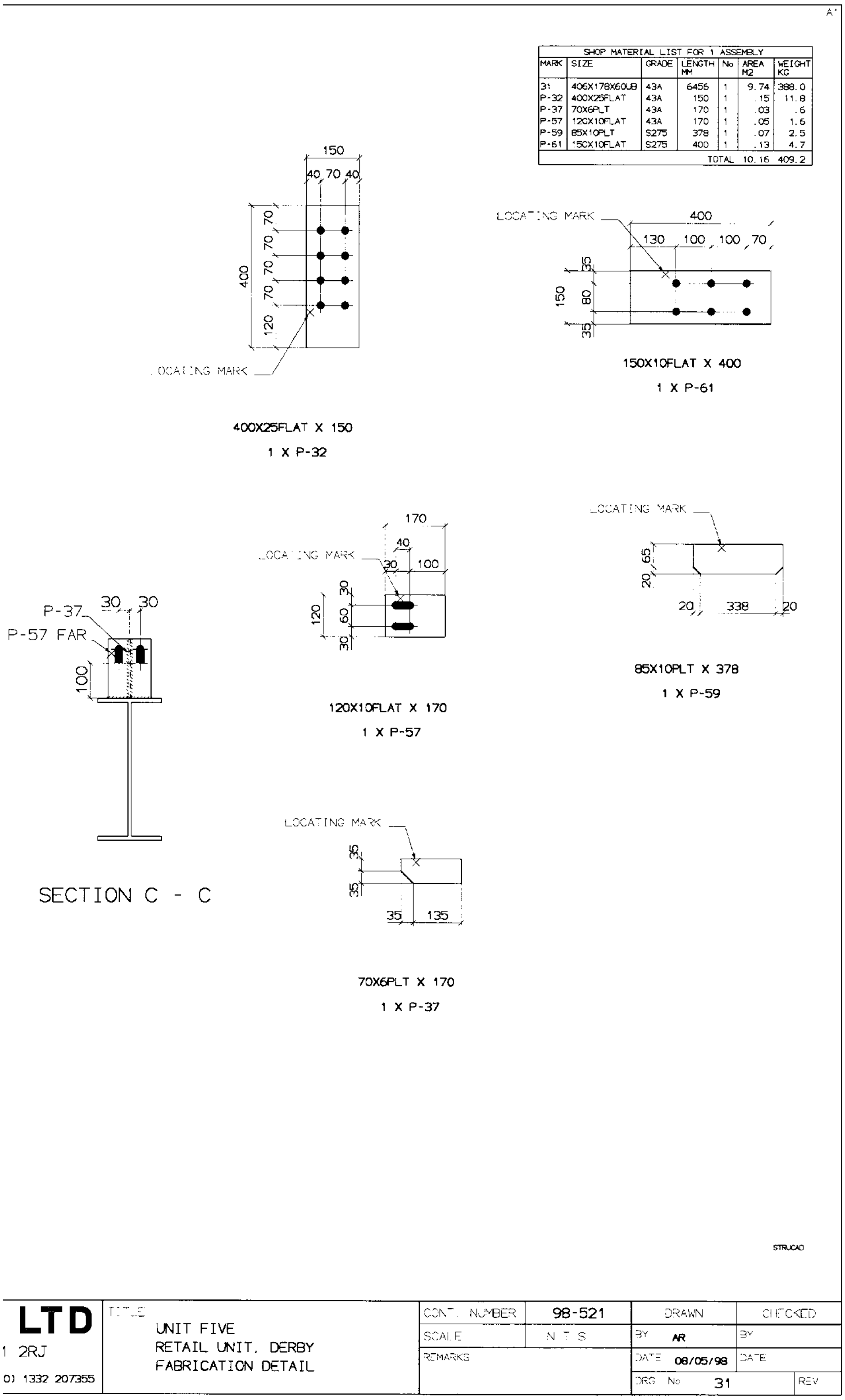


Fig. 7.2.4. Typical fabrication details for a beam (Strucad, Derby, UK)



SHOP MATERIAL LIST FOR 1 ASSEMBLY						
MARK	SIZE	GRADE	LENGTH MM	No	AREA M2	WEIGHT KG
31	406X178X60UB	43A	6456	1	9.74	388.0
P-32	400X25FLAT	43A	150	1	.15	11.8
P-37	70X6PLT	43A	170	1	.03	.6
P-57	120X10FLAT	43A	170	1	.05	1.6
P-59	85X10PLT	S275	378	1	.07	2.5
P-61	150X10FLAT	S275	400	1	.13	4.7
				TOTAL	10.16	409.2

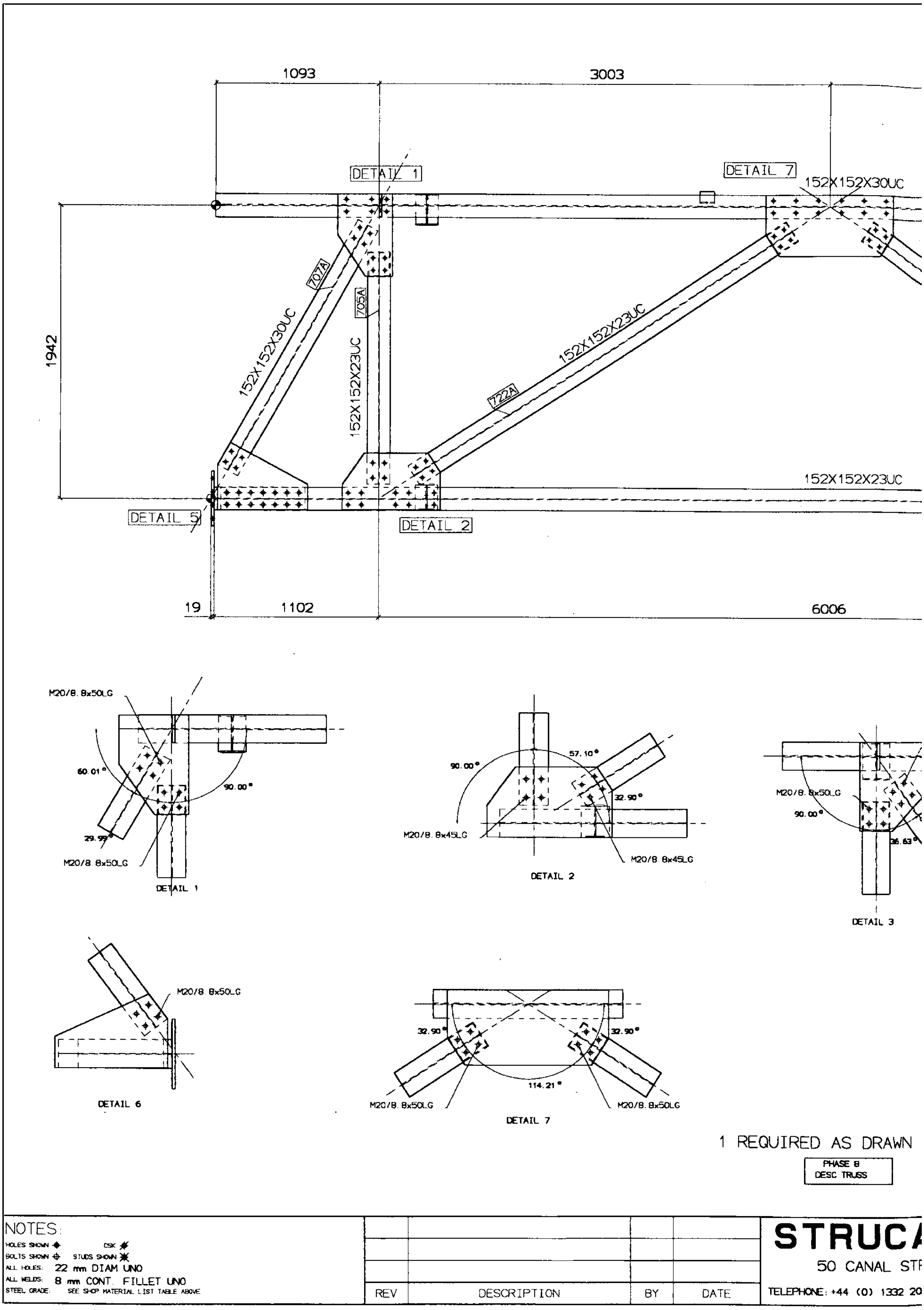
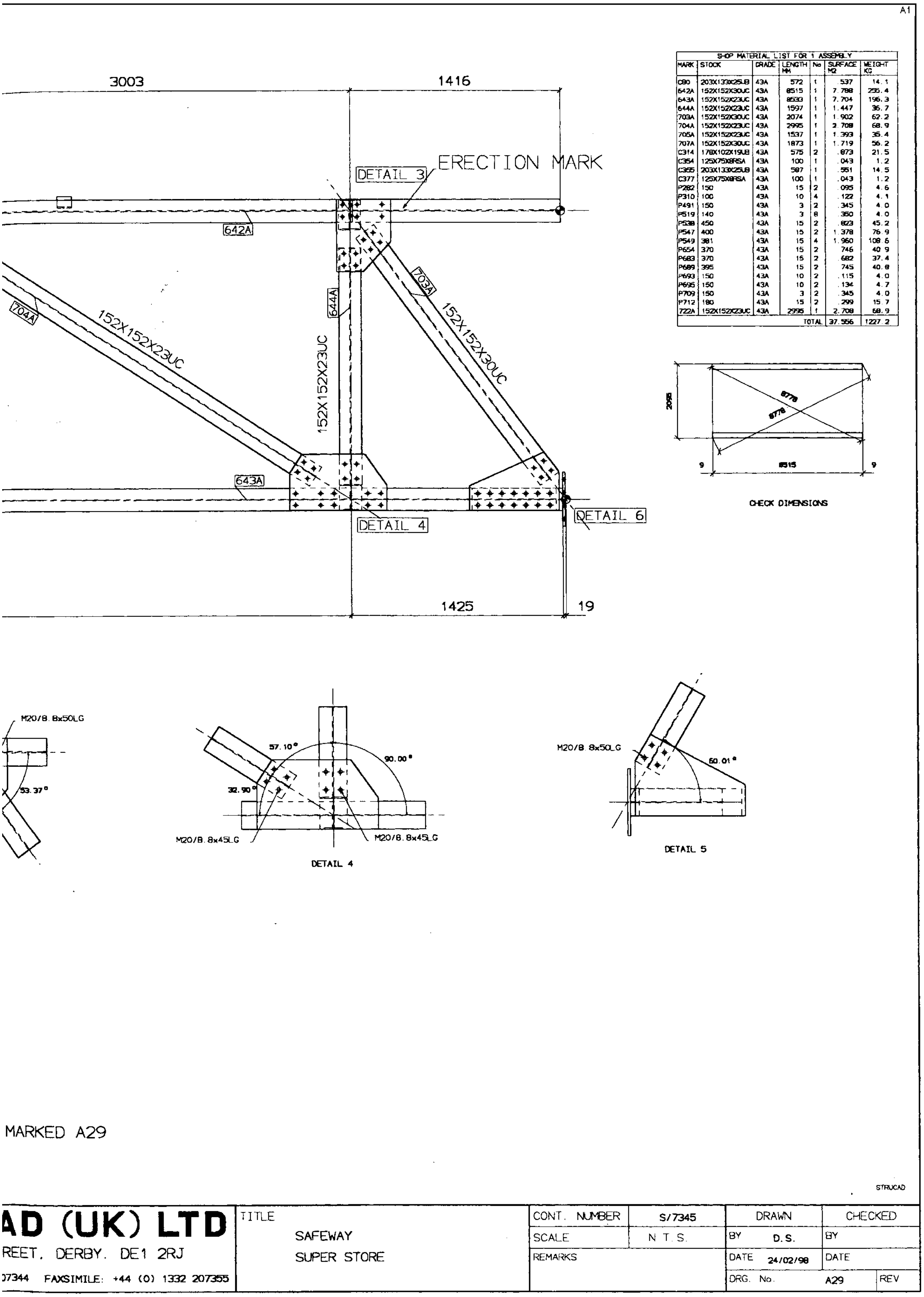


Fig. 7.2.5. Typical truss details in steel bolted section (Strucad, Derby, UK)



SHOP MATERIAL LIST FOR 1 ASSEMBLY

MARK	STOCK	GRADE	LENGTH MM	No	SURFACE M2	WEIGHT KG
C80	203X133X25UB	43A	572	1	.537	14.1
642A	152X152X30UC	43A	8515	1	7.788	255.4
643A	152X152X23UC	43A	8533	1	7.704	196.3
644A	152X152X23UC	43A	1597	1	1.447	36.7
703A	152X152X30UC	43A	2074	1	1.902	62.2
704A	152X152X23UC	43A	2995	1	2.708	68.9
705A	152X152X23UC	43A	1537	1	1.393	35.4
707A	152X152X30UC	43A	1873	1	1.719	56.2
C314	178X102X19UB	43A	575	2	.873	21.5
C354	125X75X8RSA	43A	100	1	.043	1.2
C365	203X133X25UB	43A	587	1	.551	14.5
C377	125X75X8RSA	43A	100	1	.043	1.2
P282	150	43A	15	2	.095	4.6
P310	100	43A	10	4	.122	4.1
P491	150	43A	3	2	.345	4.0
P519	140	43A	3	8	.350	4.0
P538	450	43A	15	2	.823	45.2
P547	400	43A	15	2	1.378	76.9
P549	381	43A	15	4	1.960	108.6
P654	370	43A	15	2	746	40 9
P683	370	43A	15	2	.682	37.4
P689	395	43A	15	2	745	40.8
P693	150	43A	10	2	.115	4.0
P696	150	43A	10	2	.134	4.7
P709	150	43A	3	2	.345	4.0
P712	180	43A	15	2	.299	15.7
722A	152X152X23UC	43A	2995	1	2.708	68.9
				TOTAL	37.556	1227.2

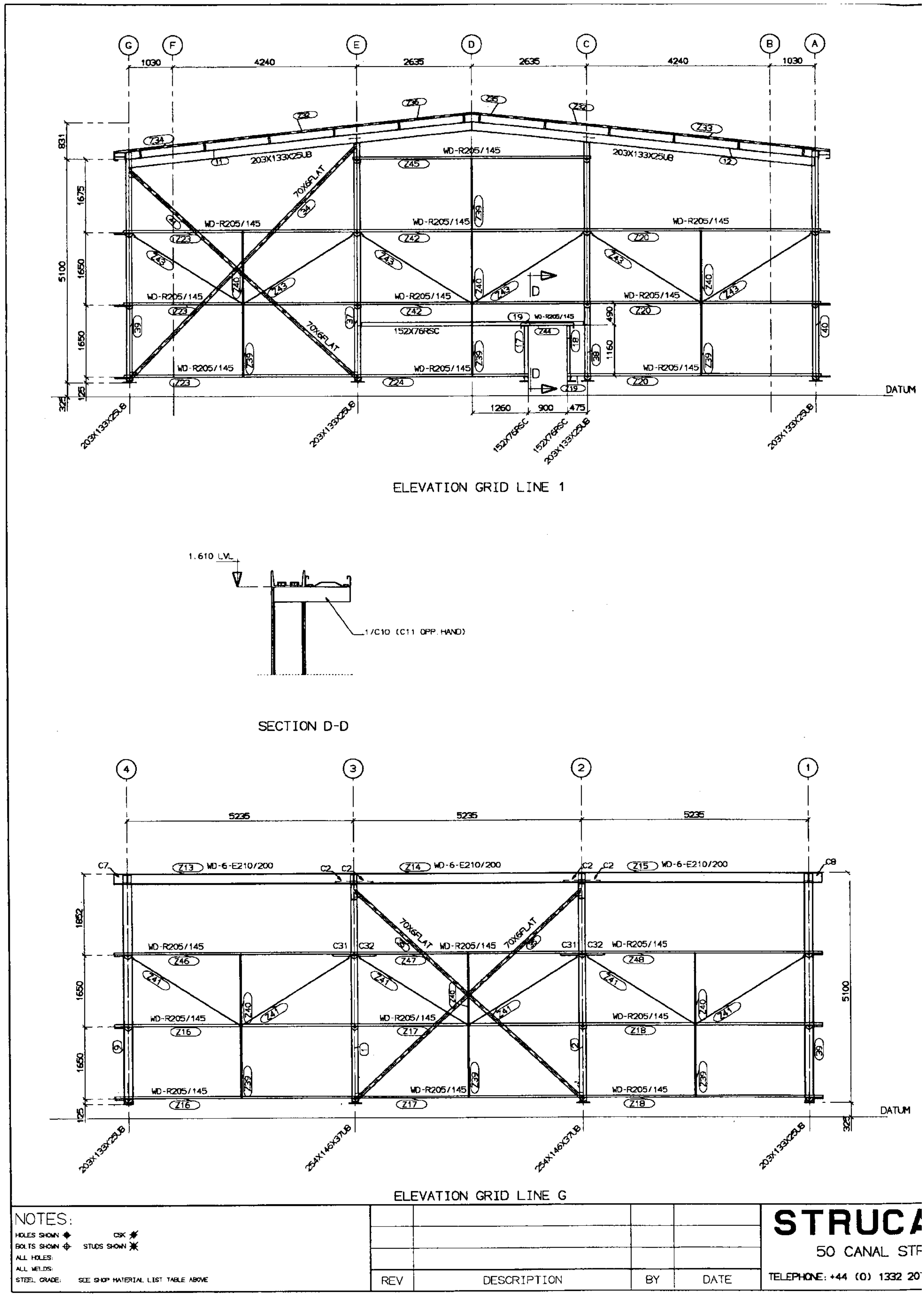
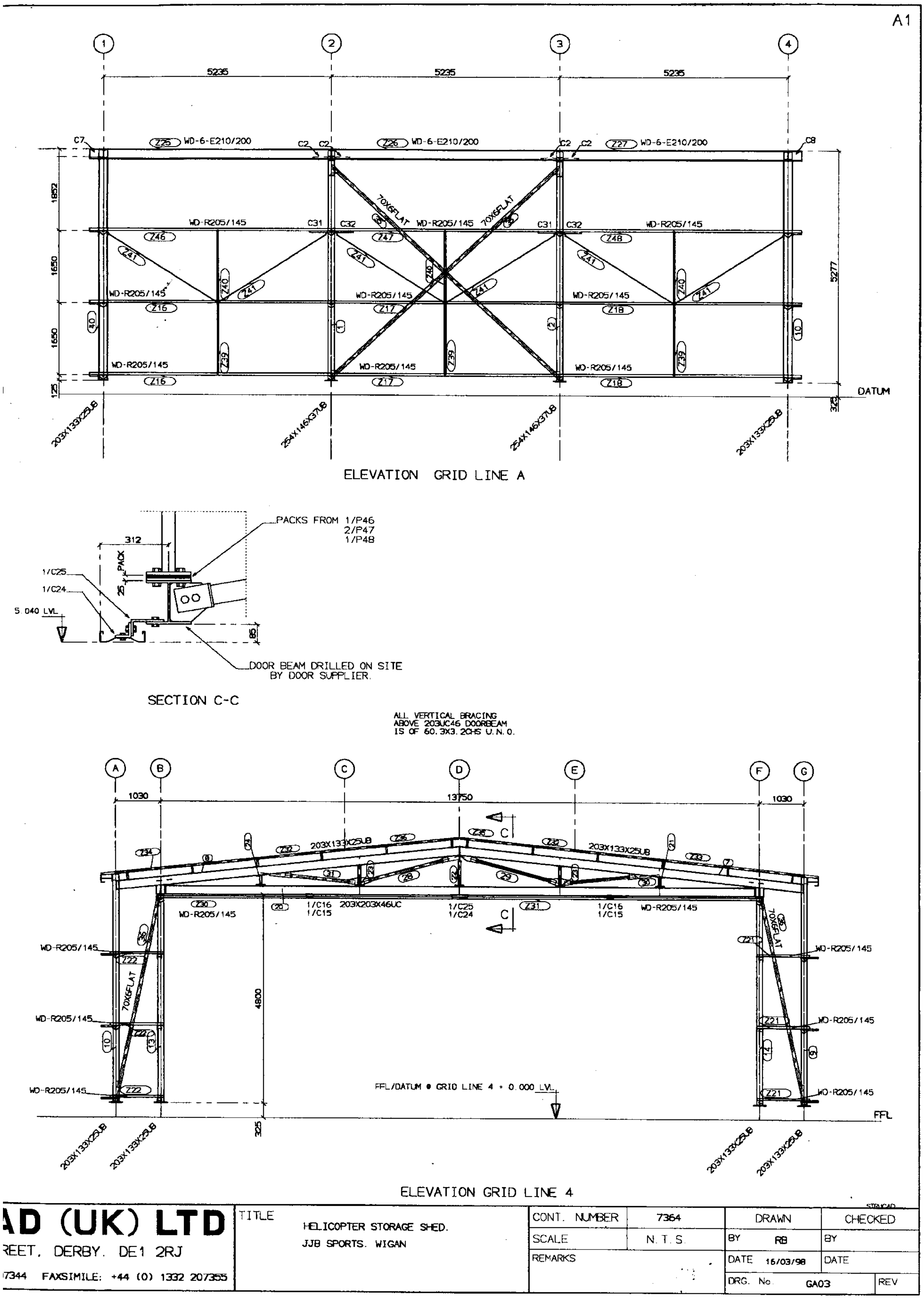


Fig. 7.2.6. Typical helicopter storage shed made with trussed frame in steel (Strucad, Derby, UK)


A1
ELEVATION GRID LINE A
PACKS FROM 1/P46
2/P47
1/P48
DOOR BEAM DRILLED ON SITE
BY DOOR SUPPLIER.
SECTION C-C
ALL VERTICAL BRACING
ABOVE 203UC46 DOORBEAM
IS OF 60.3X3.2CHS U.N.O.
FFL/DATUM @ GRID LINE 4 = 0.000 LVL.
ELEVATION GRID LINE 4
AD (UK) LTD
REET, DERBY. DE1 2RJ
7344 FAXSIMILE: +44 (0) 1332 207355
TITLE
HELICOPTER STORAGE SHED.
JJB SPORTS. WIGAN
CONT. NUMBER 7364
SCALE N.T.S.
REMARKS
DRAWN
BY RB
DATE 15/03/98
CHECKED
BY
DATE
DRG. No. GA03
REV

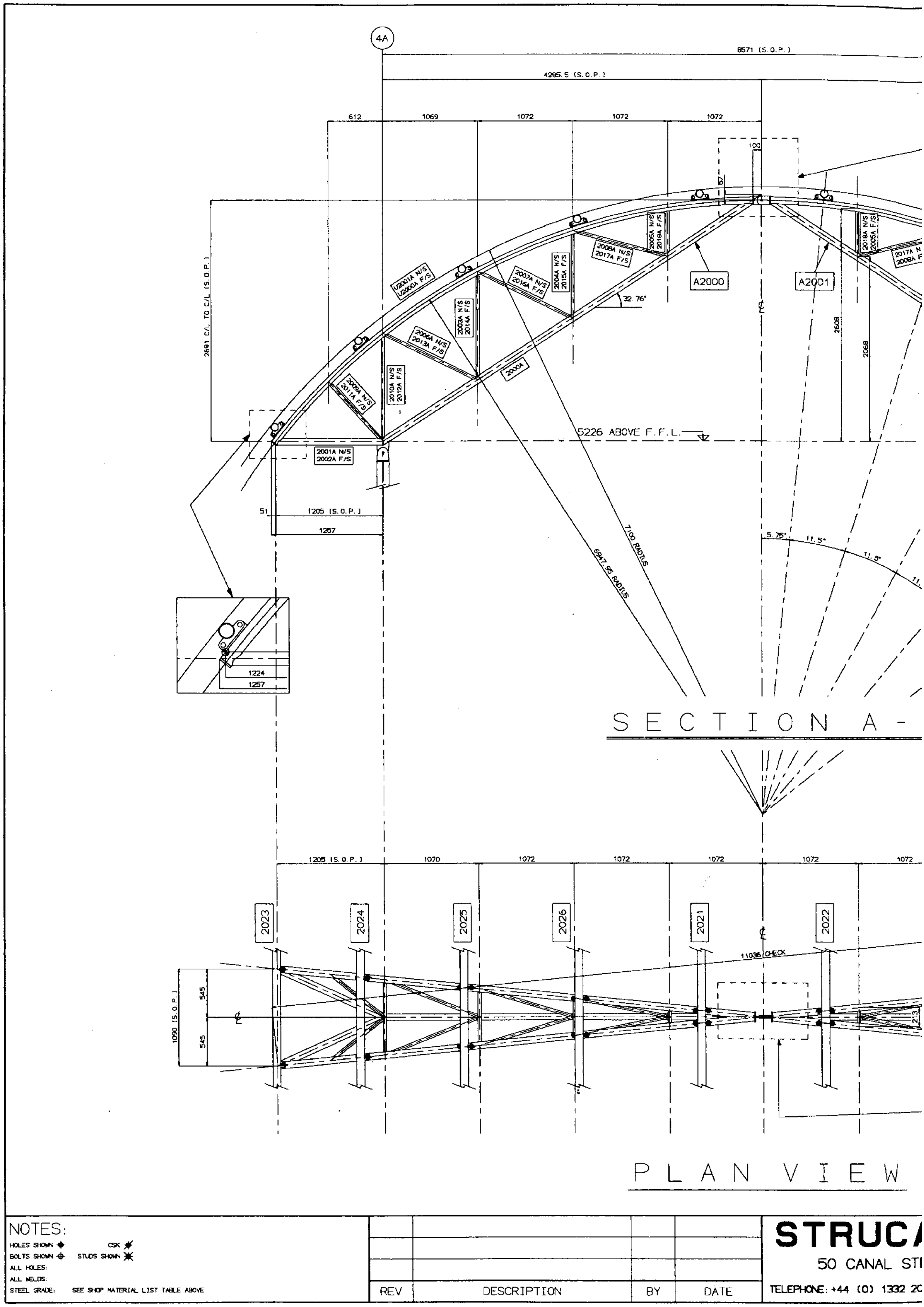
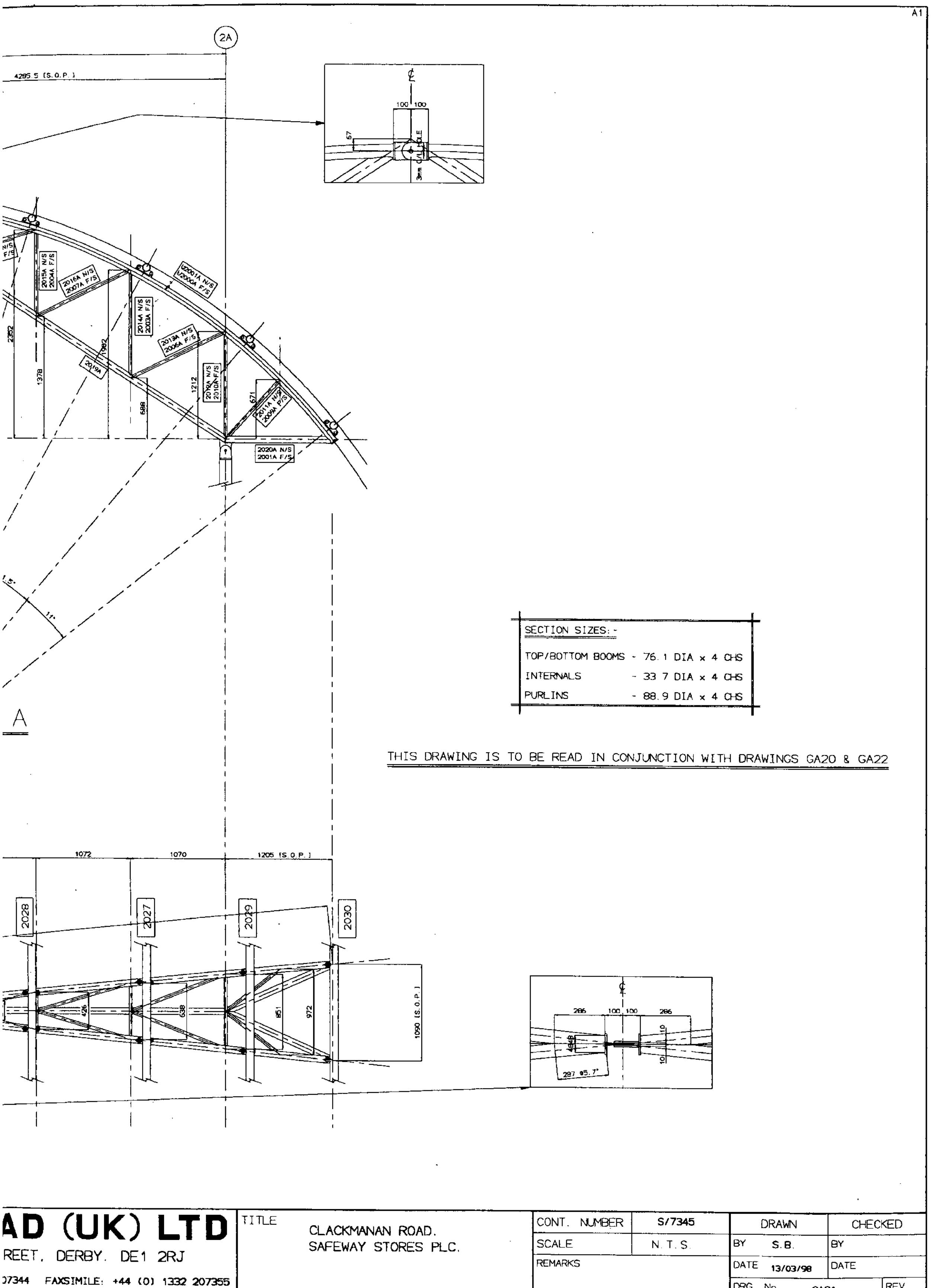


Fig. 7.2.7. Trussed arched roof section and plan for a store (Strucad, Derby, UK)


A1
2A
SECTION SIZES:-
TOP/BOTTOM BOOMS - 76.1 DIA x 4 CHS
INTERNALS - 33.7 DIA x 4 CHS
PURLINS - 88.9 DIA x 4 CHS
THIS DRAWING IS TO BE READ IN CONJUNCTION WITH DRAWINGS GA20 & GA22
A
2028
2027
2029
2030
AD (UK) LTD
REET. DERBY. DE1 2RJ
FAXSIMILE: +44 (0) 1332 207355
TITLE
CLACKMANAN ROAD.
SAFEWAY STORES PLC.
CONT. NUMBER S/7345
SCALE N.T.S.
REMARKS
DRAWN
BY S.B.
DATE 13/03/98
CHECKED
BY
DATE
DRG. No. GA21
REV

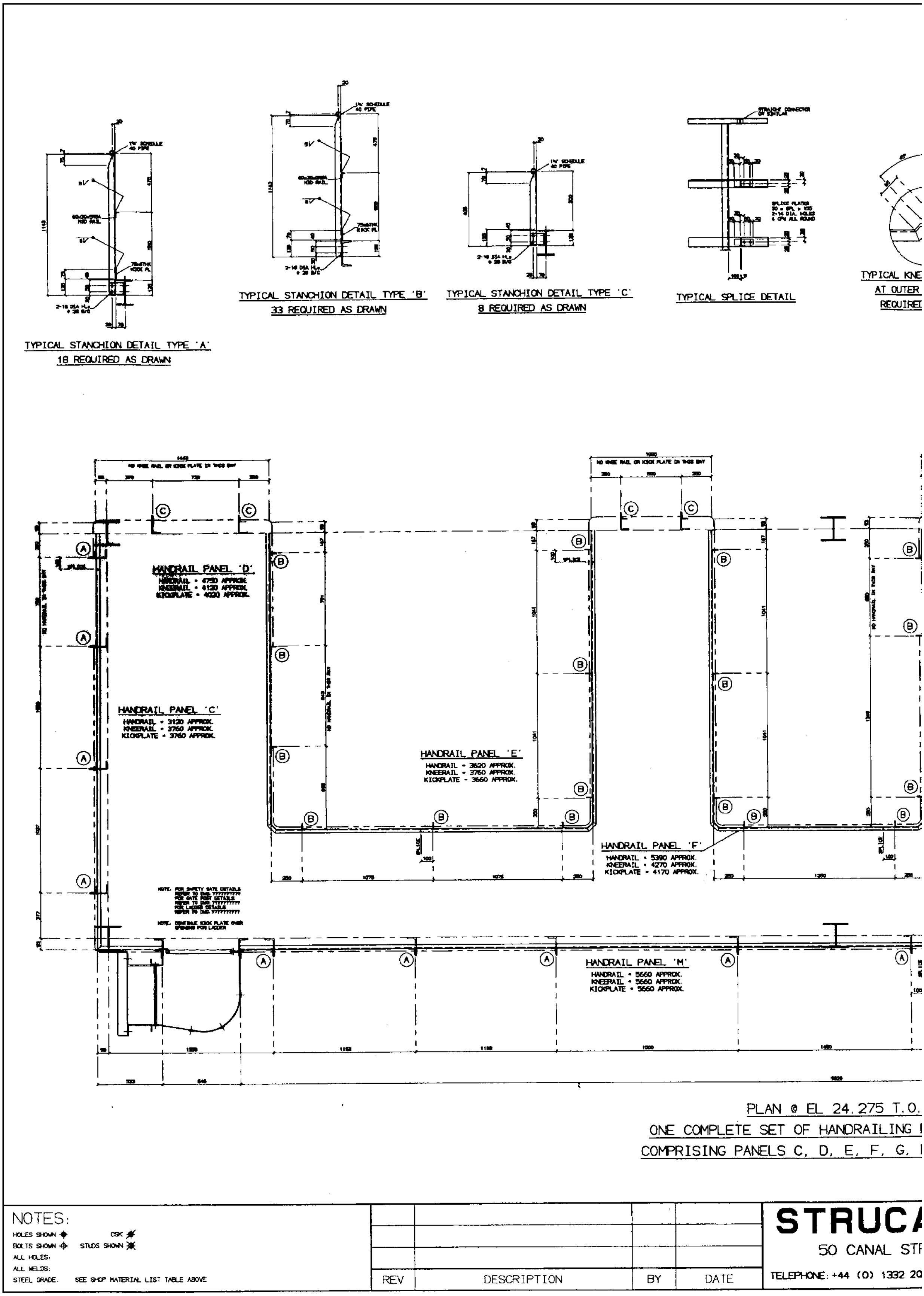
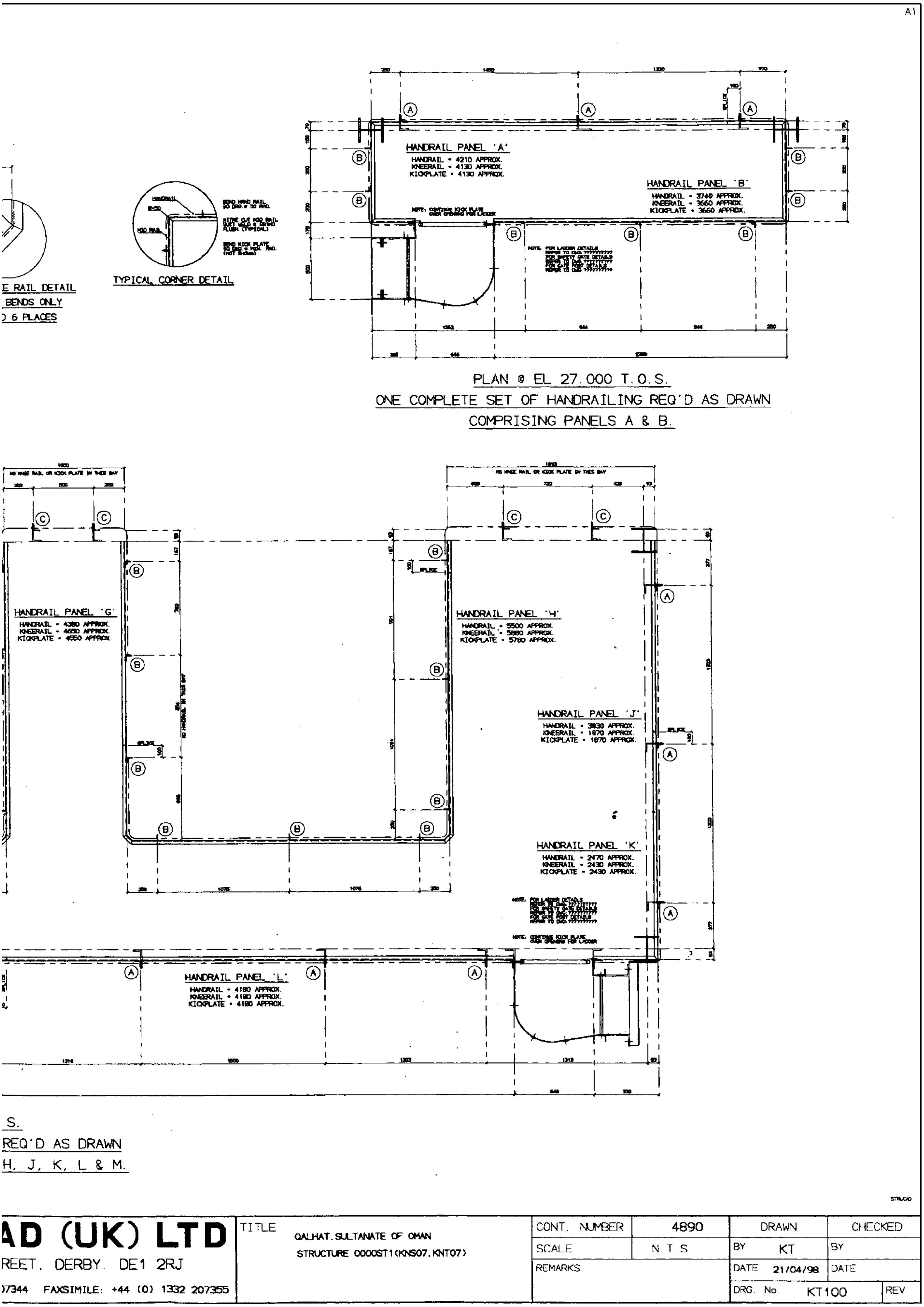


Fig. 7.2.8. Handrail details in steel (Strucad, Derby, UK)


A1
HANDRAIL PANEL 'A'
HANDRAIL = 4210 APPROX.
KNEERAIL = 4130 APPROX.
KICKPLATE = 4130 APPROX.
HANDRAIL PANEL 'B'
HANDRAIL = 3740 APPROX.
KNEERAIL = 3660 APPROX.
KICKPLATE = 3660 APPROX.
TYPICAL CORNER DETAIL
E RAIL DETAIL
BENDS ONLY
) 6 PLACES
PLAN @ EL 27.000 T.O.S.
ONE COMPLETE SET OF HANDRAILING REQ'D AS DRAWN
COMPRISING PANELS A & B.
HANDRAIL PANEL 'G'
HANDRAIL = 4380 APPROX.
KNEERAIL = 4650 APPROX.
KICKPLATE = 4550 APPROX.
HANDRAIL PANEL 'H'
HANDRAIL = 5500 APPROX.
KNEERAIL = 5880 APPROX.
KICKPLATE = 5780 APPROX.
HANDRAIL PANEL 'J'
HANDRAIL = 3830 APPROX.
KNEERAIL = 1870 APPROX.
KICKPLATE = 1870 APPROX.
HANDRAIL PANEL 'K'
HANDRAIL = 2470 APPROX.
KNEERAIL = 2430 APPROX.
KICKPLATE = 2430 APPROX.
HANDRAIL PANEL 'L'
HANDRAIL = 4180 APPROX.
KNEERAIL = 4180 APPROX.
KICKPLATE = 4180 APPROX.
S.
REQ'D AS DRAWN
H, J, K, L & M.
AD (UK) LTD
REET, DERBY. DE1 2RJ
)7344 FAXSIMILE: +44 (0) 1332 207355
TITLE
QALHAT, SULTANATE OF OMAN
STRUCTURE 0000ST1(KNS07, KNT07)
CONT. NUMBER 4890
SCALE N.T.S.
REMARKS
DRAWN
BY KT
DATE 21/04/98
CHECKED
BY
DATE
DRG. No. KT100
REV

7.3. Structural details in steel — American practice

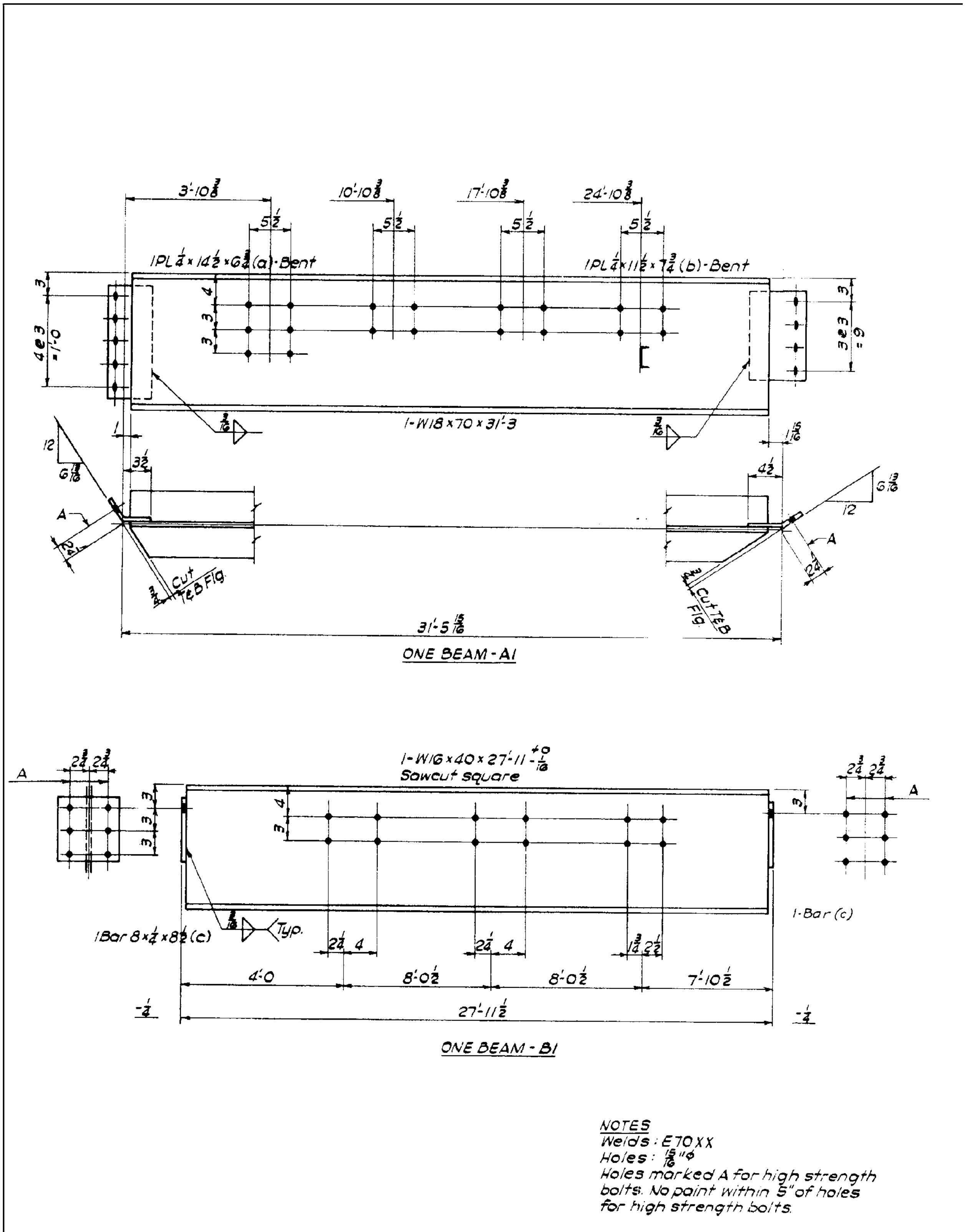
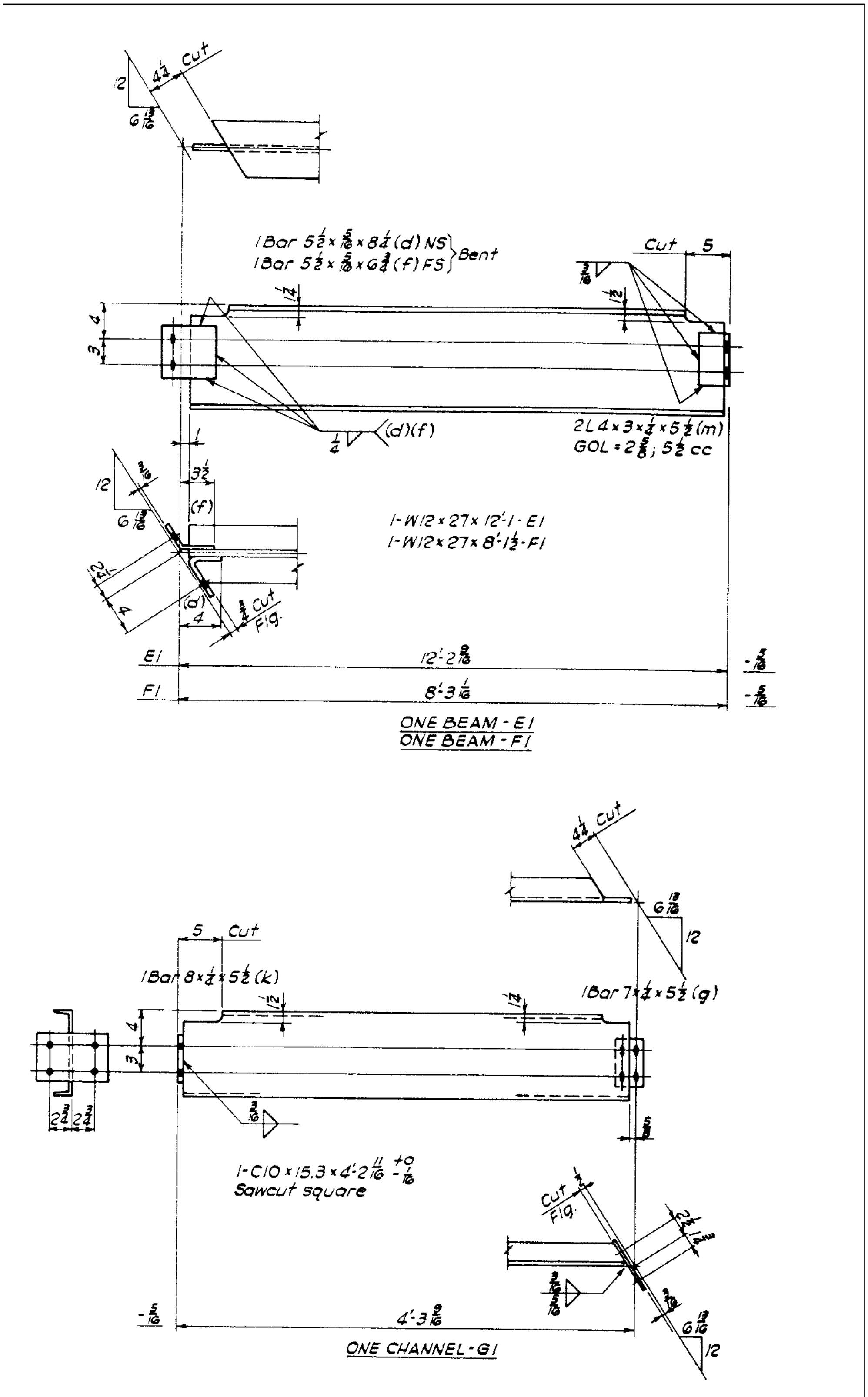


Fig. 7.3.1. Fabrication for steel beams — LRFD approach. Copyright: American Institute of Steel Construction, Inc. Reprinted with permission. All rights reserved



Cut
1Bar 5½ x 5/16 x 8¼ (d) NS
1Bar 5½ x 5/16 x 6¾ (f) FS
Bent
2L 4 x 3 x ¼ x 5½ (m)
GOL = 2⅝ ; 5½ cc
1-W12 x 27 x 12'-1 - E1
1-W12 x 27 x 8'-1½ - F1
Cut Flg.
E1
F1
12'-2 9/16
8'-3 1/16
ONE BEAM - E1
ONE BEAM - F1
1Bar 8 x ¼ x 5½ (k)
1Bar 7 x ¼ x 5½ (g)
1-C10 x 15.3 x 4'-2 11/16 +0 -1/16
Sawcut square
4'-3 9/16
ONE CHANNEL - G1

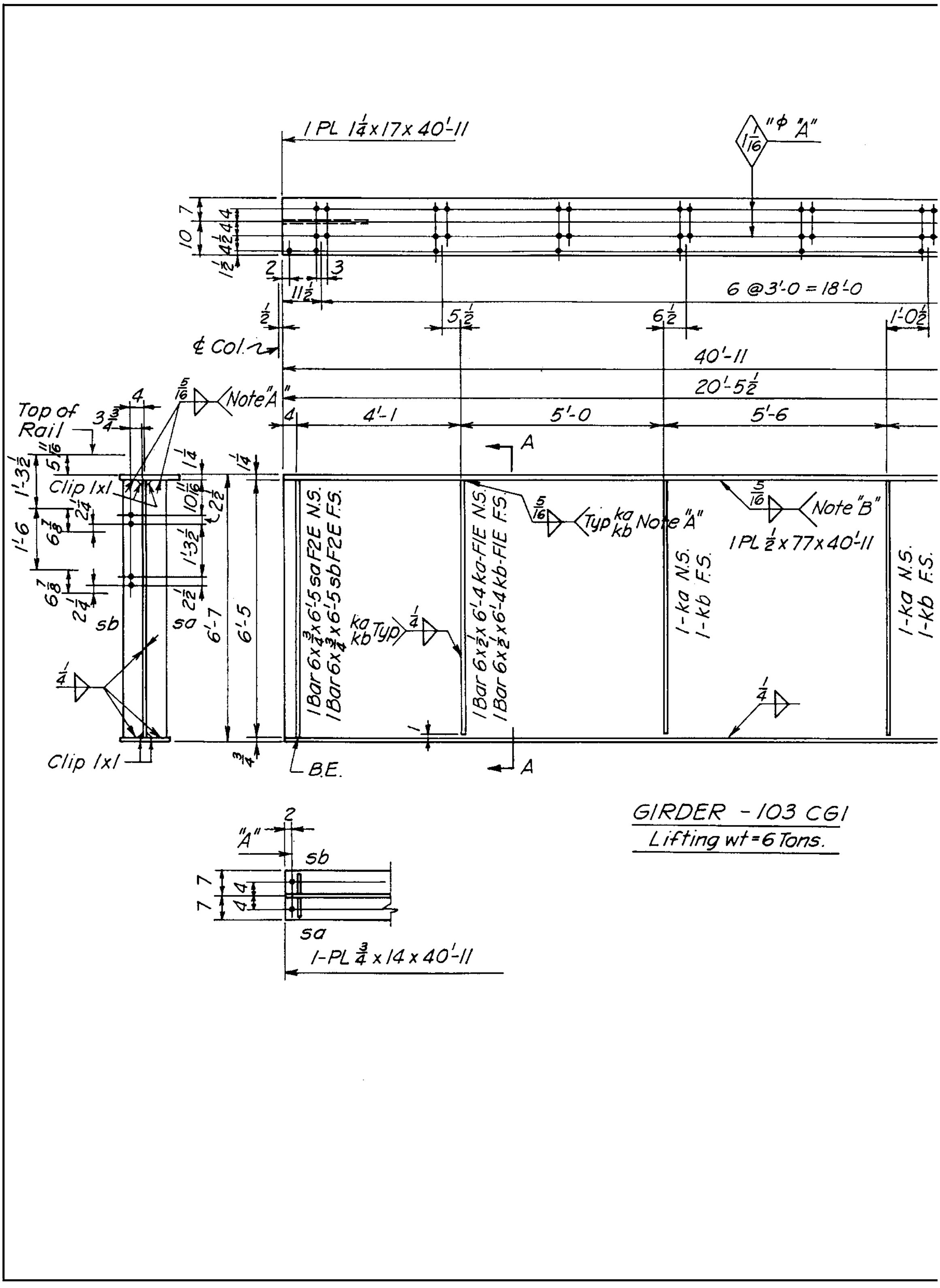
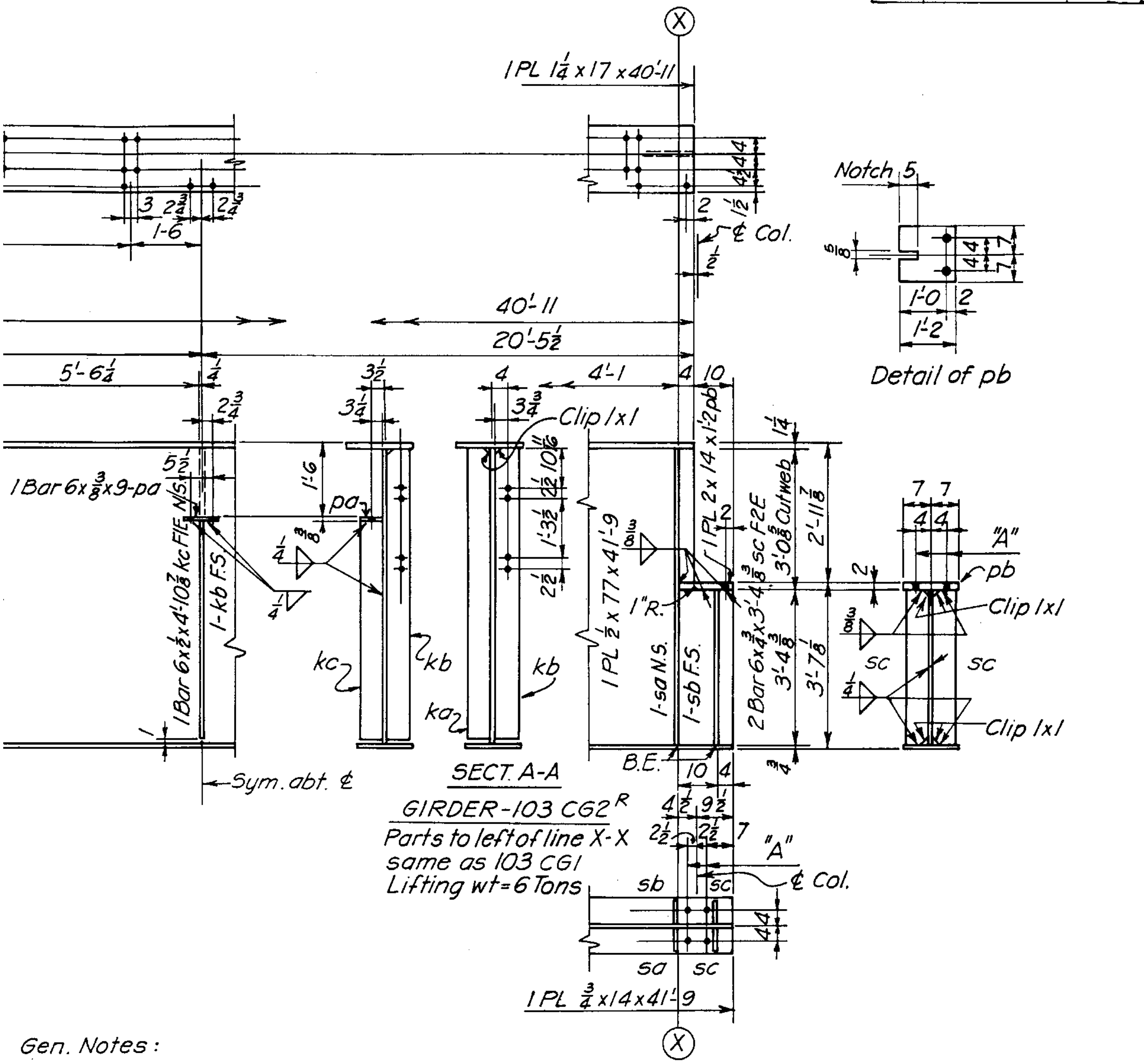


Fig. 7.3.2. Welded steel girder details. Copyright: American Institute of Steel Construction, Inc. Reprinted with permission. All rights reserved

REQUIRED		
No	Description	Mark
3	Girders	103 CG1
2	Girders	103 CG2R



Gen. Notes:

Spec: AISC latest edition
Matl. : ASTM A36
Holes : $\frac{15}{16}$" diam. unless noted
Welding : E70XX or F7XEXX
Paint : One coat SSPC-Paint 13-64 (Brown)
No paint on shop in contact surfaces.
Holes marked "A" are for high strength structural bolts. NO PAINT within 5" of these holes.
Note "A": Fit stiffeners tight before welding
B.E. denotes bearing end of stiffeners.
Note "B": Web must be in tight contact with the flange over its full length before welding.

TITLE BLOCK

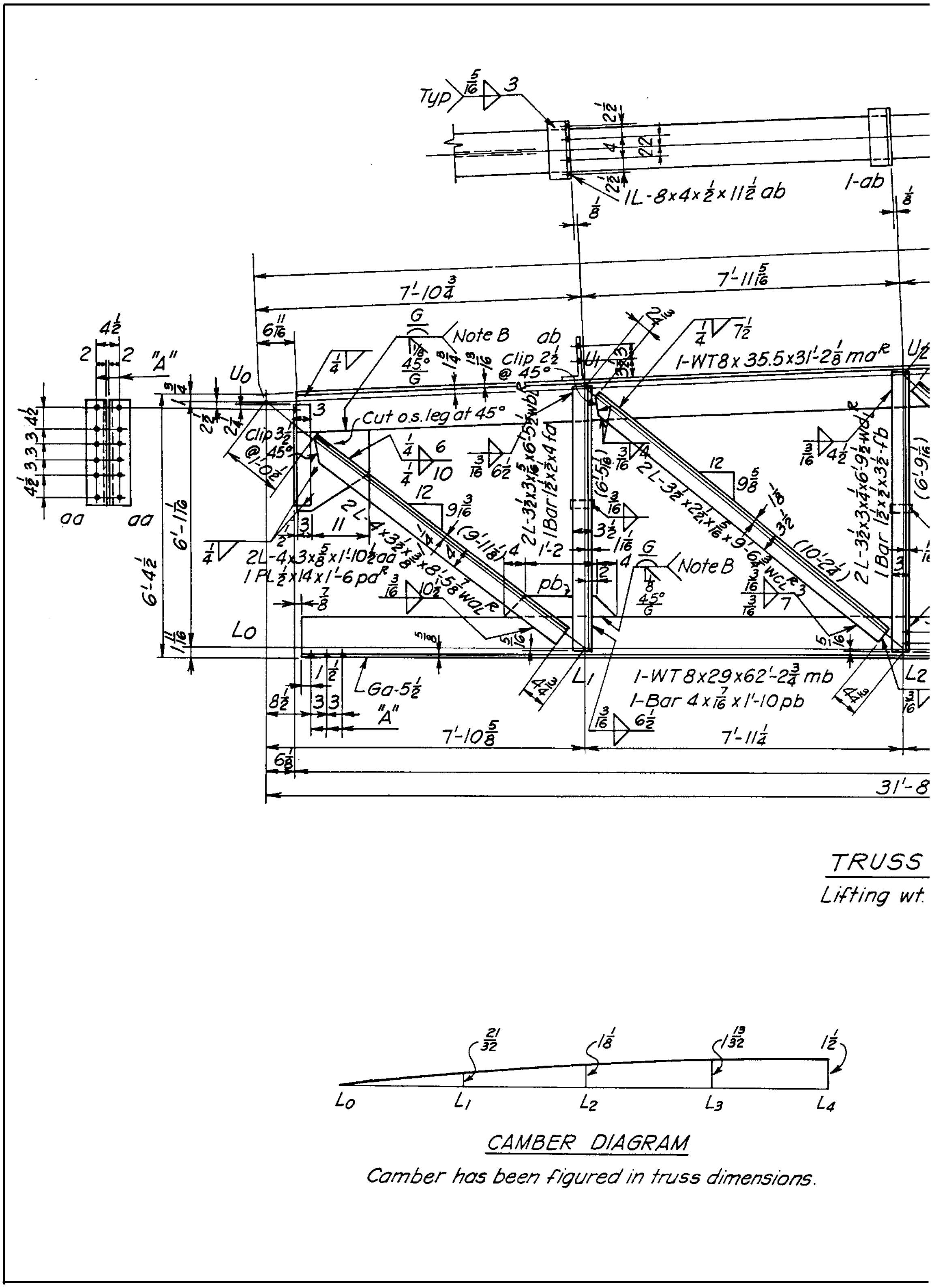
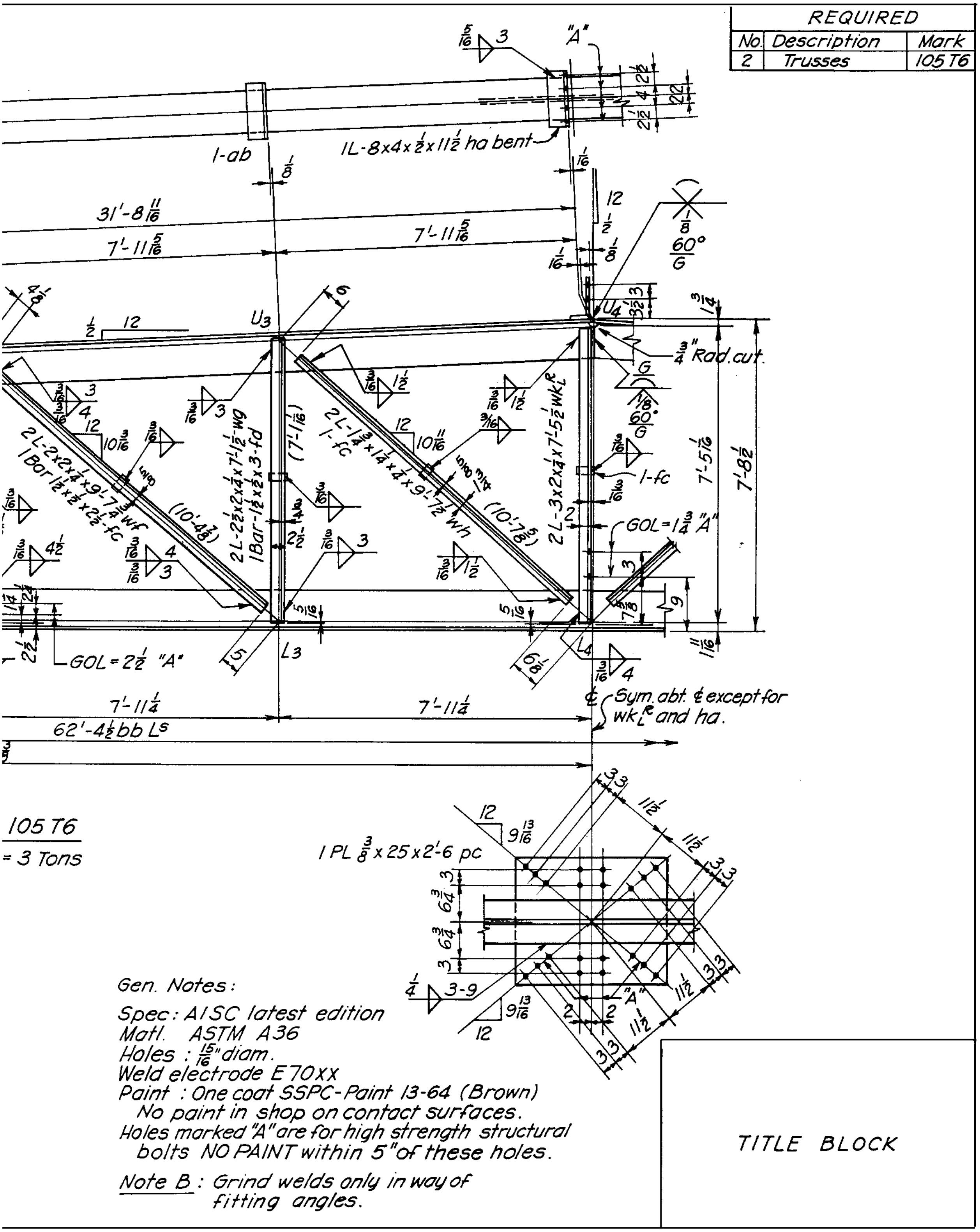


Fig. 7.3.3. Trussed steel frame details. Copyright: American Institute of Steel Construction, Inc.


REQUIRED
No. | Description | Mark
2 | Trusses | 105 T6
"A"
1-ab
1L-8x4x½x11½ ha bent
31'-8 11/16
7'-11 5/16
7'-11 5/16
U3
U4
¾" Rad. cut
2L-2x2x¼x9'-7¾ wf
1 Bar 1½x½x2½-fc
(10'-4⅞)
2L-2½x2x¼x7'-1½ wg
1 Bar-1½x½x3-fd
(7'-1 1/16)
2L-1¾x1¾x¼x9'-7½ wh
1-fc
(10'-7 5/8)
2L-3x2x¼x7'-5½ wk_L^R
1-fc
GOL = 1¾ "A"
7'-5 1/16
7'-8½
GOL = 2½ "A"
L3
L4
7'-11¼
7'-11¼
62'-4½ bb L^s
℄ Sym. abt. ℄ except for wk_L^R and ha.
105 T6
= 3 Tons
1 PL ⅜ x 25 x 2'-6 pc
Gen. Notes:
Spec: AISC latest edition
Matl. ASTM A36
Holes: 15/16" diam.
Weld electrode E70XX
Paint: One coat SSPC-Paint 13-64 (Brown)
No paint in shop on contact surfaces.
Holes marked "A" are for high strength structural bolts NO PAINT within 5" of these holes.
Note B: Grind welds only in way of fitting angles.
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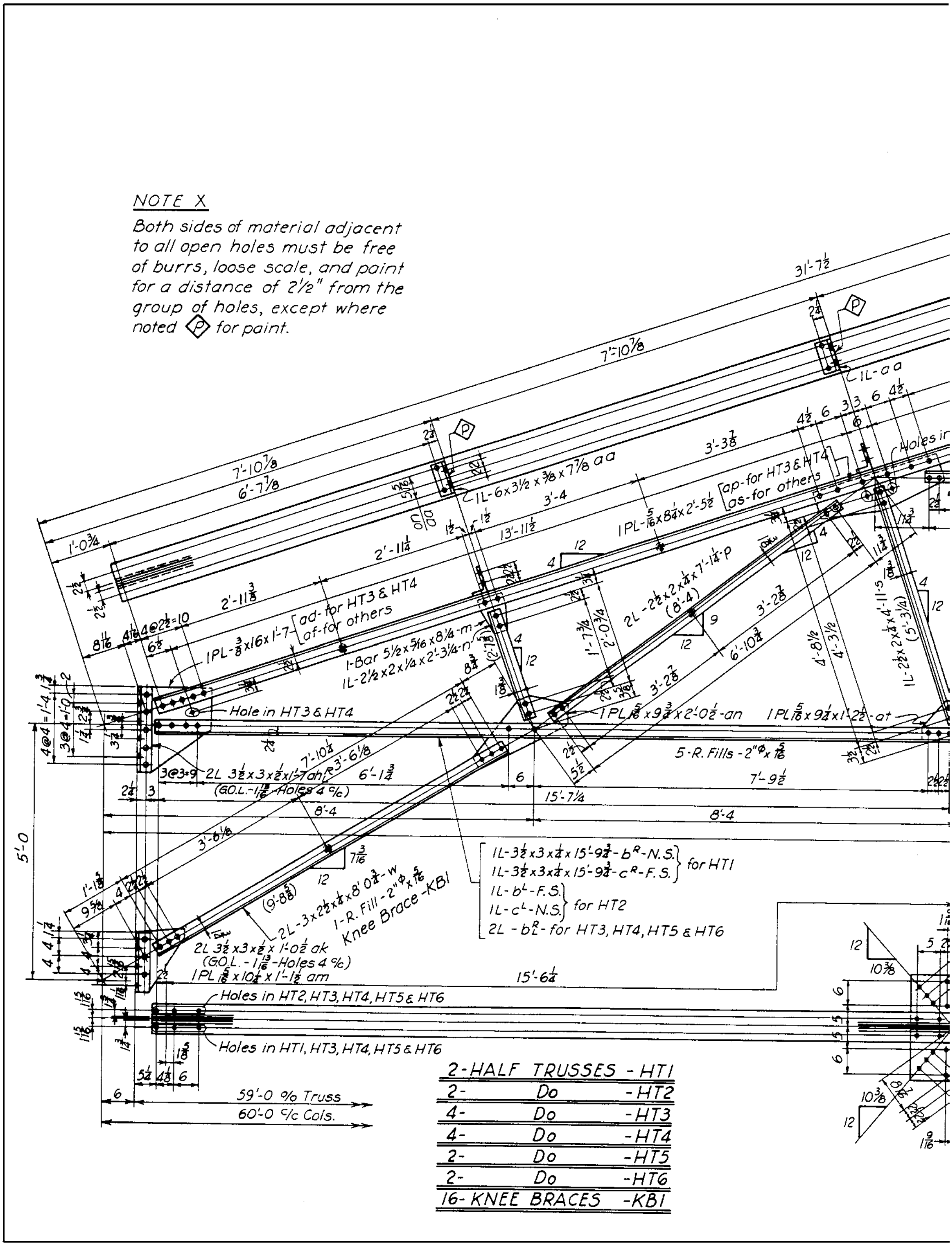
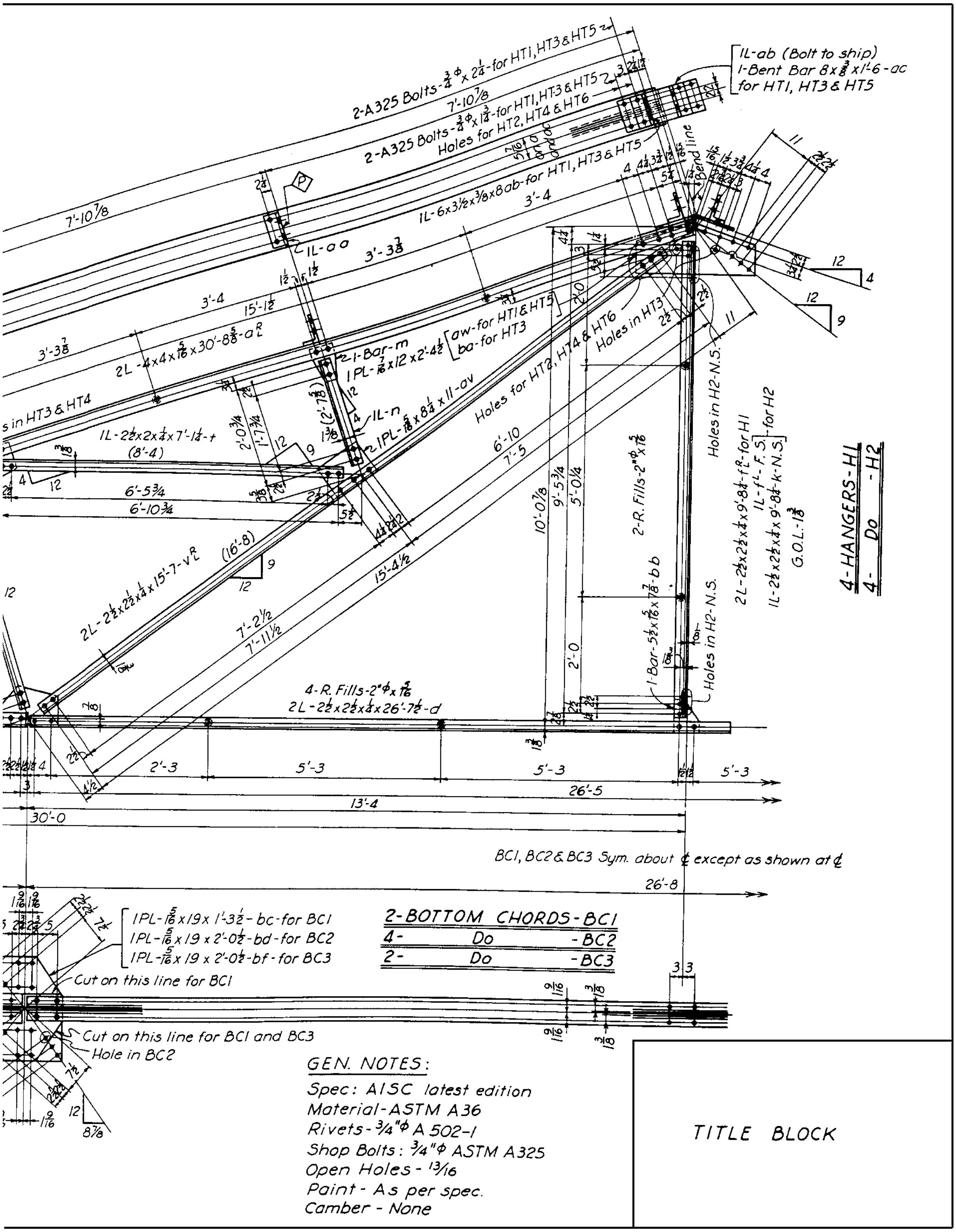


Fig. 7.3.4. Detailing of a steel roof truss. Copyright: American Institute of Steel Construction, Inc. Reprinted with permission. All rights reserved


1L-ab (Bolt to ship)
1-Bent Bar 8x3/8x1'-6-ac for HT1, HT3 & HT5
2-A325 Bolts-3/4φx2 1/4-for HT1, HT3 & HT5
2-A325 Bolts-3/4φx1 3/4-for HT1, HT3 & HT5
Holes for HT2, HT4 & HT6
1L-6x3 1/2x3/8x8ab-for HT1, HT3 & HT5
1L-aa
2L-4x4x5/16x30'-8 5/8-a R/L
1-Bar-m
1PL-7/16x12x2'-4 1/2
aw-for HT1 & HT5
ba-for HT3
1L-n
1PL-5/16x8 1/4x11-av
Holes for HT2, HT4 & HT6
Holes in HT3
1L-2 1/2x2x1/4x7'-1 1/4-t
(8'-4)
2L-2 1/2x2 1/2x1/4x15'-7-v R/L
(16'-8)
4-R. Fills-2"φx5/16
2L-2 1/2x2 1/2x1/4x26'-7 1/2-d
2-R. Fills-2"φx5/16
1-Bar-5 1/2x5/16x7 7/8-bb
Holes in H2-N.S.
2L-2 1/2x2 1/2x1/4x9'-8 1/4-f R/L-for H1
1L-f L-F.S.
1L-2 1/2x2 1/2x1/4x9'-8 1/4-k-N.S.
-for H2
G.O.L.-1 3/8
4-HANGERS-H1
4- Do -H2
BC1, BC2 & BC3 Sym. about ℄ except as shown at ℄
1PL-5/16x19x1'-3 1/2-bc-for BC1
1PL-5/16x19x2'-0 1/2-bd-for BC2
1PL-5/16x19x2'-0 1/2-bf-for BC3
Cut on this line for BC1
Cut on this line for BC1 and BC3
Hole in BC2
2-BOTTOM CHORDS-BC1
4- Do -BC2
2- Do -BC3
GEN. NOTES:
Spec: AISC latest edition
Material-ASTM A36
Rivets-3/4"φ A 502-1
Shop Bolts: 3/4"φ ASTM A325
Open Holes-13/16
Paint-As per spec.
Camber-None
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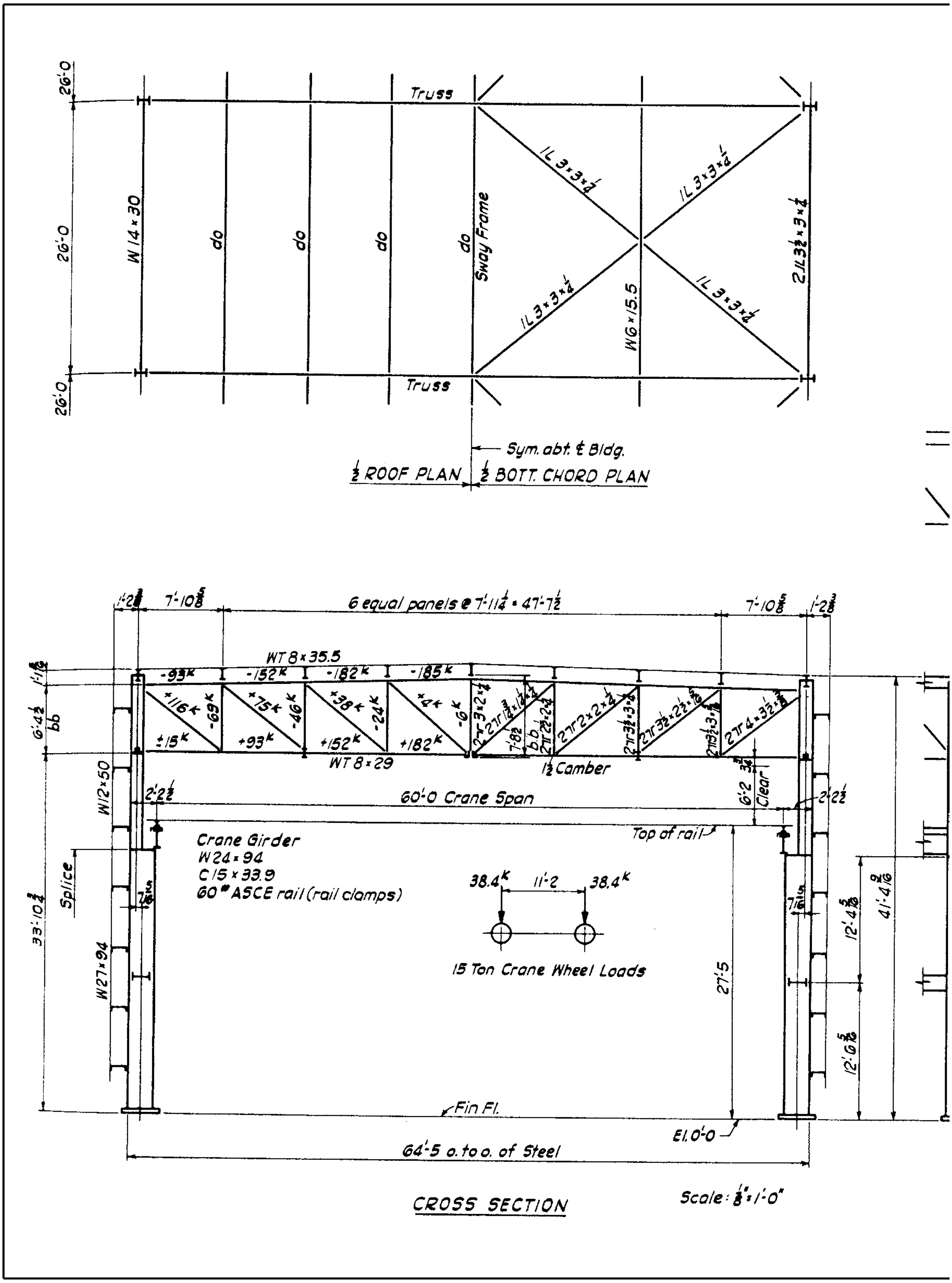
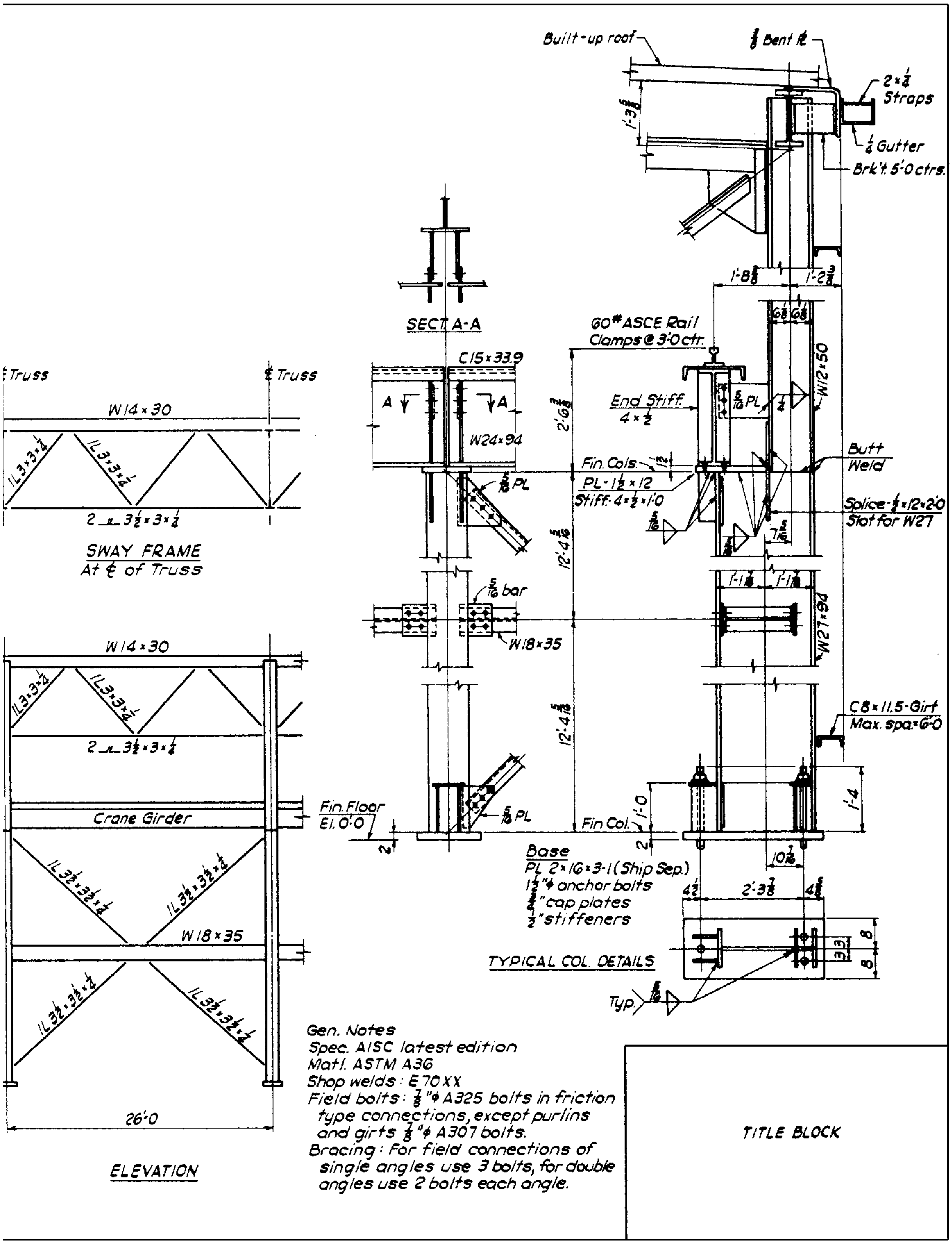


Fig. 7.3.5. Detailing of a trussed portal frame


Built-up roof
Bent PL
2×1/4 Straps
1/4 Gutter
Brk't 5'-0 ctrs.
1'-3 5/8
1'-8 3/8
1'-2 3/4
6 3/8 6 3/8
SECT A-A
60# ASCE Rail
Clamps @ 3'-0 ctr.
C15×33.9
W12×50
℄ Truss
℄ Truss
W14×30
1L3×3×1/4
1L3×3×1/4
2 ⅃⅂ 3 1/2×3×1/4
SWAY FRAME
At ℄ of Truss
A
A
W24×94
2'-6 3/8
End Stiff.
4×1/2
5/16 PL
Fin. Cols.
PL-1 1/2×12
Stiff. 4×1/2×1'-0
5/16 PL
Butt
Weld
Splice-1/2×12×2'-0
Slot for W27
12'-4 5/16
7/16
1'-1 7/8
1'-1 7/8
5/16 bar
W18×35
W27×94
W14×30
1L3×3×1/4
1L3×3×1/4
2 ⅃⅂ 3 1/2×3×1/4
12'-4 5/16
C8×11.5 Girt
Max. spa=6'-0
Crane Girder
Fin. Floor
El. 0'-0
5/16 PL
Fin. Col.
1'-0
1'-4
2
2
1L3 1/2×3 1/2×1/4
1L3 1/2×3 1/2×1/4
W18×35
1L3 1/2×3 1/2×1/4
1L3 1/2×3 1/2×1/4
Base
PL 2×16×3-1 (Ship Sep.)
1 1/2"φ anchor bolts
3/4" cap plates
1/2" stiffeners
10 7/16
4 1/2
2'-3 7/8
4 5/8
8
3 3
8
TYPICAL COL. DETAILS
Typ.
5/16
26'-0
ELEVATION
Gen. Notes
Spec. AISC latest edition
Mat'l. ASTM A36
Shop welds: E70XX
Field bolts: 7/8"φ A325 bolts in friction type connections, except purlins and girts 5/8"φ A307 bolts.
Bracing: For field connections of single angles use 3 bolts, for double angles use 2 bolts each angle.
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8. Steel bridges — case studies

This chapter contains the relevant specifications of the British, European and American codes on the design/detailing of steel bridges and their important components. In some cases the practices are self-explanatory and need no additional text to clarify them. For thorough explanations of theory, design analysis and structural detailing refer to *Prototype bridge structures: analysis and design* by the author, published by Thomas Telford, London, 1999.

8.1. Bridge loadings and specifications

8.1.1. Highway bridge live loads based on British practice

General Standard highway loading consists of HA and HB loading. HA loading is a formula loading representing normal traffic in Great Britain. HB loading is an abnormal vehicle unit loading. Both loadings include impact.

Loads to be considered The structure and its elements shall be designed to resist the more severe effects of either:

- design HA loading (see Fig. 8.1)
- design HA loading combined with design HB loading.

Notional lanes, hard shoulders, etc. The width and number of notional lanes, and the presence of hard shoulders, hard strips, verges and central reserves are integral to the disposition of HA and HB loading. Requirements for deriving the width and number of notional lanes for design purposes are specified in 8.1.2. Requirements for reducing HA loading for certain lane widths and loaded length are specified.

Distribution analysis of structure The effects of the design standard loadings shall, where appropriate, be distributed in accordance with a rigorous distribution analysis or from data derived from suitable tests. In the latter case, the use of such data shall be subject to the approval of the appropriate authority.

Type HA loading Type HA loading consists of a uniformly distributed load (see Clause 8.1.2 of the code) and a knife edge load combined, or of a single wheel load.

Table 8.1. Factors for limit state for combination of loads (HA type)

Design HA loading – for design HA load considered alone, VFL shall be taken as follows:

	For the ultimate limit state	For the serviceability limit state
For combination 1	1.50	1.20
For combinations 2 and 3	1.25	1.00

Where HA loading is coexisting with HB loading (see Clause 6.4.2) VFL, as specified in Clause 6.3.4, shall be applied to HA loading (BS 5950).

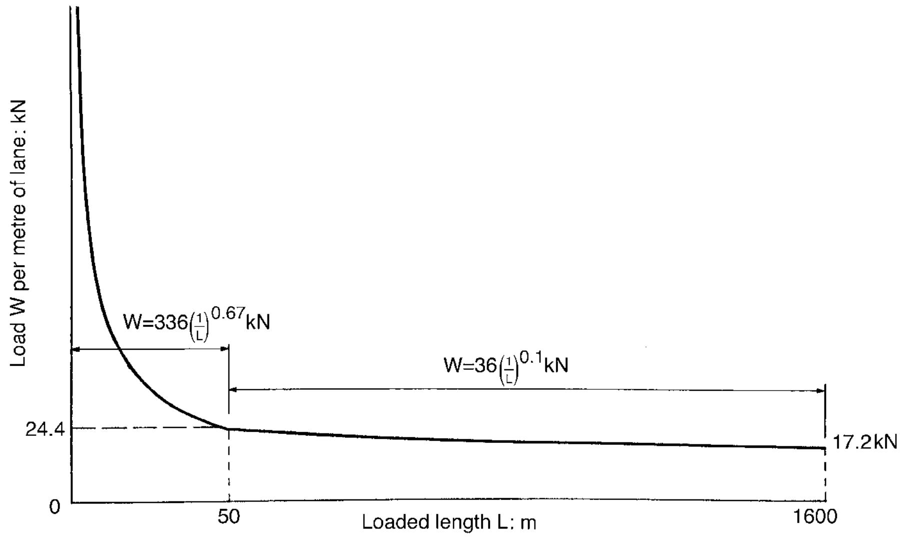


Fig. 8.1. HA loading

Nominal uniformly distributed load (UDL) For loaded lengths up to and including 50 m, the UDL, expressed in kN per linear metre of notional lane, shall be derived from the equation

$$W = 336\left(\frac{1}{L}\right)^{0{\cdot}67} \qquad (8.1)$$

and for loaded lengths in excess of 50 m but less than 1600 m the UDL shall be derived from the equation

$$W = 36\left(\frac{1}{L}\right)^{0{\cdot}1} \qquad (8.2)$$

where L is the loaded length (in m) and W is the load per metre of notional lane (in kN). For loaded lengths above 1600 m, the UDL shall be agreed with the appropriate authority.

Nominal knife edge load (KEL) The KEL per notional lane shall be taken as 120 kN.

Distribution The UDL and KEL shall be taken to occupy one notional lane, uniformly distributed over the full width of the lane and applied as specified in Clause 6.4.1 of the code.

Dispersal No allowance for the dispersal of the UDL and KEL shall be made.

Nominal HB loading

Type HB loading For all public highway bridges in Great Britain, the minimum number of units of type HB loading that shall normally be considered is 30, but this number may be increased up to 45 if so directed by the appropriate authority.

The overall length of the HB vehicle shall be taken as 10, 15, 20, 25 or 30 m for inner axle spacings of 6, 11, 16, 21 or 26 m respectively, and the effects of

Table 8.2. Type HA uniformly distributed load

Loaded length: m	Load: kN/m	Loaded length: m	Load: kN/m	Loaded length: m	Load: kN/m
2	211·2	55	24·1	370	19·9
4	132·7	60	23·9	410	19·7
6	101·2	65	23·7	450	19·5
8	83·4	70	23·5	490	19·4
10	71·8	75	23·4	530	19·2
12	63·6	80	23·2	570	19·1
14	57·3	85	23·1	620	18·9
16	52·4	90	23·0	670	18·8
18	48·5	100	22·7	730	18·6
20	45·1	110	22·5	790	18·5
23	41·1	120	22·3	850	18·3
26	37·9	130	22·1	910	18·2
29	35·2	150	21·8	980	18·1
32	33·0	170	21·5	1050	18·0
35	31·0	190	21·3	1130	17·8
38	29·4	220	21·0	1210	17·7
41	27·9	250	20·7	1300	17·6
44	26·6	280	20·5	1400	17·4
47	25·5	310	20·3	1500	17·3
50	24·4	340	20·1	1600	17·2

the most severe of these cases shall be adopted. The overall width shall be taken as 3·5 m. The longitudinal axis of the HB vehicle shall be taken as parallel with the lane markings.

Contact area Nominal HB wheel loads shall be assumed to be uniformly distributed over a circular contact area, assuming an effective pressure of 1·1 N/mm^2.

Design HB loading For design HB load, y_{fL} shall be taken as shown in Table 8.3.

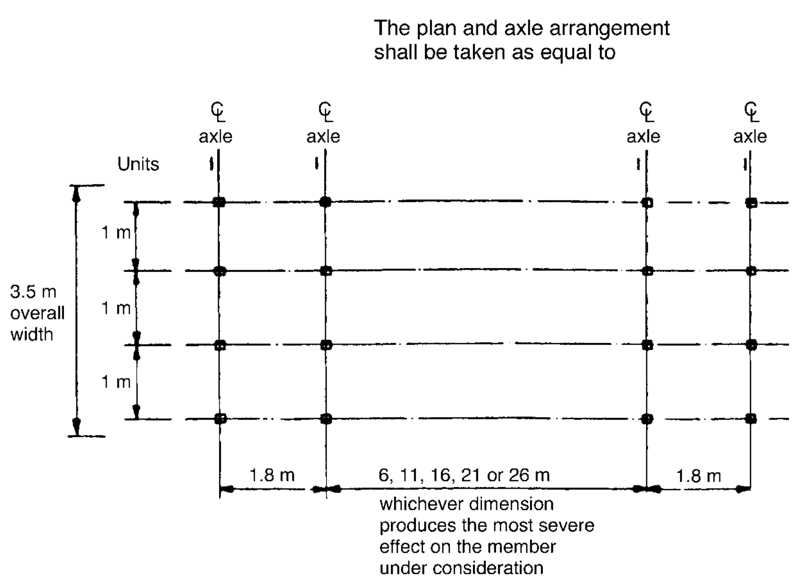


Fig. 8.2. Dimensions of HB vehicle for 1 unit of nominal loading (1 unit = 10 kN per axle—i.e. 2·5 kN per wheel)

Table 8.3. Factors for limit state for combination of loads (HB type)

	For the ultimate limit state	For the serviceability limit state
For combination 1	1·30	1·10
For combinations 2 and 3	1·10	1·00

Railway bridge live load

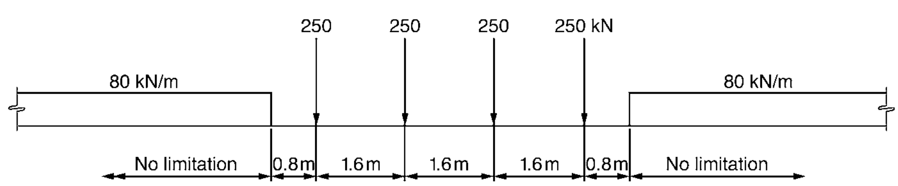
General Standard railway loading consists of two types, RU and RL. RU loading allows for all combinations of vehicles currently running or projected to run on railways in Europe, including the UK, and is to be adopted for the design of bridges carrying main line railways of 1·4 m gauge and above.

RL loading is a reduced loading for use only on passenger rapid transit railway systems on lines where main line locomotives and rolling stock do not operate.

Type RU loading Nominal type RU loading consists of four 250 kN concentrated loads preceded, and followed, by a uniformly distributed load of 80 kN/m. The arrangement of this loading is as shown in Fig. 8.3.

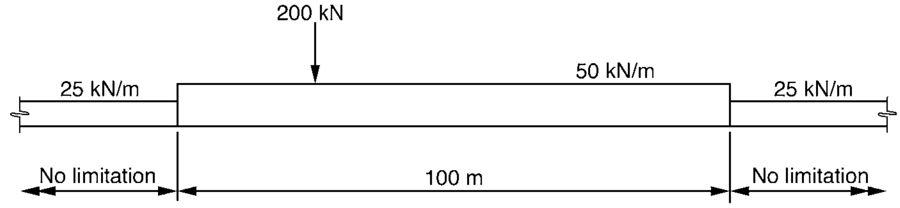
Type RL loading Nominal type RL loading consists of a single 200 kN concentrated load coupled with a uniformly distributed load of 50 kN/m for loaded lengths up to 100 m. For loaded lengths in excess of 100 m the distributed nominal load shall be 50 kN/m for the first 100 m and shall be reduced to 25 kN/m for lengths in excess of 100 m, as shown in Fig. 8.4.

Alternatively, two concentrated nominal loads, one of 300 kN and the other of 150 kN, spaced at 2·4 m intervals along the track, shall be used on deck elements where this gives a more severe condition. These two concentrated loads shall be deemed to include dynamic effects.



Note: see Dynamic effects, below, for effect of additions to this loading.

Fig. 8.3. Type RU loading



Note: see Dynamic effects, below, for effect of additions to this loading.

Fig. 8.4. Type RL loading

Dynamic effects

The standard railway loadings specified above (except the 300 kN and 150 kN concentrated alternative RL loading) are equivalent static loadings and shall be multiplied by appropriate dynamic factors to allow for impact, oscillation and other dynamic effects including those caused by track and wheel irregularities.

Type RU loading The dynamic factor for RU loading applied to all types of track and shall be as given in Table 8.4.

In deriving the dynamic factor, L is taken as the length (in m) of the influence line for deflection of the element under consideration. For unsymmetrical influence lines, L is twice the distance between the point at which the greatest ordinate occurs and the nearest end point of the influence line. In the case of floor members, 3 m should be added to the length of the influence line as an allowance for load distribution through track.

Type RL loading The dynamic factor for RL loading, when evaluating moments and shears, shall be taken as 1·20, except for unballasted tracks where, for rail bearers and single-track cross girders, the dynamic factor shall be increased to 1·40.

Road traffic actions and other actions specifically for road bridges—ENV 1991–3: 1995

Models of road traffic loads Loads due to the road traffic, consisting of cars, lorries and special vehicles (e.g. for industrial transport), give rise to vertical and horizontal, static and dynamic forces. The load models defined in this section do not describe actual loads. They have been selected so that their effects (with dynamic amplification included unless otherwise specified) represent the effects of the actual traffic. Where traffic outside the scope of the load models specified in this section needs to be considered, then complementary load models, with associated combination rules, should be defined or agreed by the client.

Separate models are defined below for vertical, horizontal, accidental and fatigue loads.

Loading classes The actual loads on road bridges result from various categories of vehicles and from pedestrians. Vehicle traffic may differ between bridges depending on traffic composition (e.g. percentages of lorries), density (e.g. average number of vehicles per year), conditions (e.g. jam frequency), the extreme likely weights of vehicles and their axle loads, and, if relevant, the influence of road signs restricting carrying capacity.

These differences justify the use of load models suited to the location of a bridge. Some classifications are defined in this section (e.g. classes of special vehicles). Others are only suggested for further consideration (e.g. choice of

Table 8.4. Dynamic factor for type RU loading

Dimension L: m	Dynamic factor for evaluating bending moment	Dynamic factor for evaluating shear
Up to 3·6	2·00	1·67
From 3·6 to 67	$0{\cdot}73+\dfrac{2{\cdot}16}{\sqrt{(L-0{\cdot}2)}}$	$0{\cdot}82+\dfrac{1{\cdot}44}{\sqrt{(L-0{\cdot}2)}}$
Over 67	1·00	1·00

adjustment factors α and β defined in Clause 4.3.2(7) of the code for the main model and in Clause 4.3.3 for the single axle model) and may be presented as loading classes (or traffic classes).

Divisions of the carriageway into notional lanes The widths w_l of notional lanes on a carriageway and the greatest possible whole (integer) number n_l of such lanes on this carriageway are shown in Table 8.5.

8.1.2. Highways loads based on EC3 loadings

Location and numbering of the lanes for design (EC3) (ENV 1995)

The location and numbering of the lanes should be determined in accordance with the following rules:

(*a*) the locations of notional lanes are not necessarily related to their numbering
(*b*) for each individual verification (e.g. for a verification of the ultimate limit states of resistance of a cross-section to bending), the number of lanes to be taken into account as loaded, their location on the carriageway and their numbering should be so chosen that the effects from the load models are the most adverse.

Vertical loads—characteristic values

General and associated design situations Characteristic loads are intended for the determination of road traffic effects associated with ultimate limit-state verifications and with particular serviceability verifications (see ENV 1991-1, 9.4.2 and 9.5.2, and ENV 1992 to 1995). The load models for vertical loads represent the following traffic effects.

(*a*) Load model 1: concentrated and uniformly distributed loads, which cover most of the effects of the traffic of lorries and cars. This model is intended for general and local verifications.
(*b*) Load model 2: a single axle load applied on specific tyre contact areas which covers the dynamic effects of normal traffic on very short structural elements. This model should be separately considered and is only intended for local verifications.
(*c*) Load model 3: a set of assemblies of axle loads representing special vehicles (e.g. for industrial transport) which may travel on routes permitted for abnormal loads. This model is intended to be used only when, and as far as required by the client, for general and local verifications.

Table 8.5. Number and width of lanes

Carriageway width w	Number of notional lanes	Width of a notional lane	Width of the remaining area
$w < 5{\cdot}4$ m	$n_l = 1$	3 m	$w - 3$ m
$5{\cdot}4\ \text{m} \leqslant w < 6$ m	$n_l = 2$	$\frac{w}{2}$	0
$6\ \text{m} \leqslant w$	$n_l = \text{Int}\left(\frac{w}{3}\right)$	3 m	$w - 3 \times n_l$

Note: for example, for a carriageway width of 11 m, $n_l = \text{Int}\left(\frac{w}{3}\right) = 3$, and the width of the remaining area is $11 - 3 \times 3 = 2$ m.

(*d*) Load model 4: a crowd loading. This model should be considered only when required by the client. It is intended only for general verifications. However, crowd loading may be usefully specified by the relevant authority for bridges located in or near towns if its effects are not obviously covered by load model 1.

Load models 1 and 2 are defined numerically for persistent situations and are to be considered for any type of design situation (e.g. for transient situations during repair works). Load models 3 and 4 are defined only for some transient design situations. Design situations are specified as far as necessary in design Eurocodes and/or in particular projects, in accordance with definitions and principles given in ENV 1991-1. Combinations for persistent and transient situations may be numerically different.

Main loading system (load model 1)

The main loading system consists of two partial systems as detailed below.

Double-axle concentrated loads (tandem system: TS), each axle having a weight:

$$\alpha_Q Q_k$$

where:

α_Q are adjustment factors.

No more than one tandem system should be considered per lane; only complete tandem systems shall be considered. Each tandem system should be located in the most adverse position in its lane (see, however, below and Fig. 8.5. Each axle of the tandem model has two identical wheels, the load per wheel being therefore equal to $0{\cdot}5\alpha_Q Q_k$. The contact surface of each wheel is to be taken as square and of side 0·40 m.

Uniformly distributed loads (UDL system), having a weight density per square metre:

$$\alpha_q q_k \qquad (8.3)$$

where

α_q are adjustment factors.

These loads should be applied only in the unfavourable parts of the influence surface, longitudinally and transversally.

Load model 1 should be applied on each notional lane and on the remaining areas. On notional lane number 1, the load magnitudes are referred to as $\alpha_{Qi} Q_{ik}$ and $\alpha_{qi} q_{ik}$ (Table 8.6). On the remaining areas, the load magnitude is referred to as $\alpha_{qr}\, q_{rk}$.

Unless otherwise specified, the dynamic amplification is included in the values for Q_{ik} and q_{ik}, the values of which are given in Table 8.6.

For the assessment of general effects, the tandem systems may be assumed to travel along the axes of the notional lanes.

Where general and local effects can be calculated separately, and unless otherwise specified by the client, the general effects may be calculated:

(*a*) by replacing the second and third tandem systems by a second tandem system with axle weight equal to

$(200\alpha_{Q2} + 100\alpha_{Q3})$ kN (although relevant authorities may restrict the application of this simplification) or

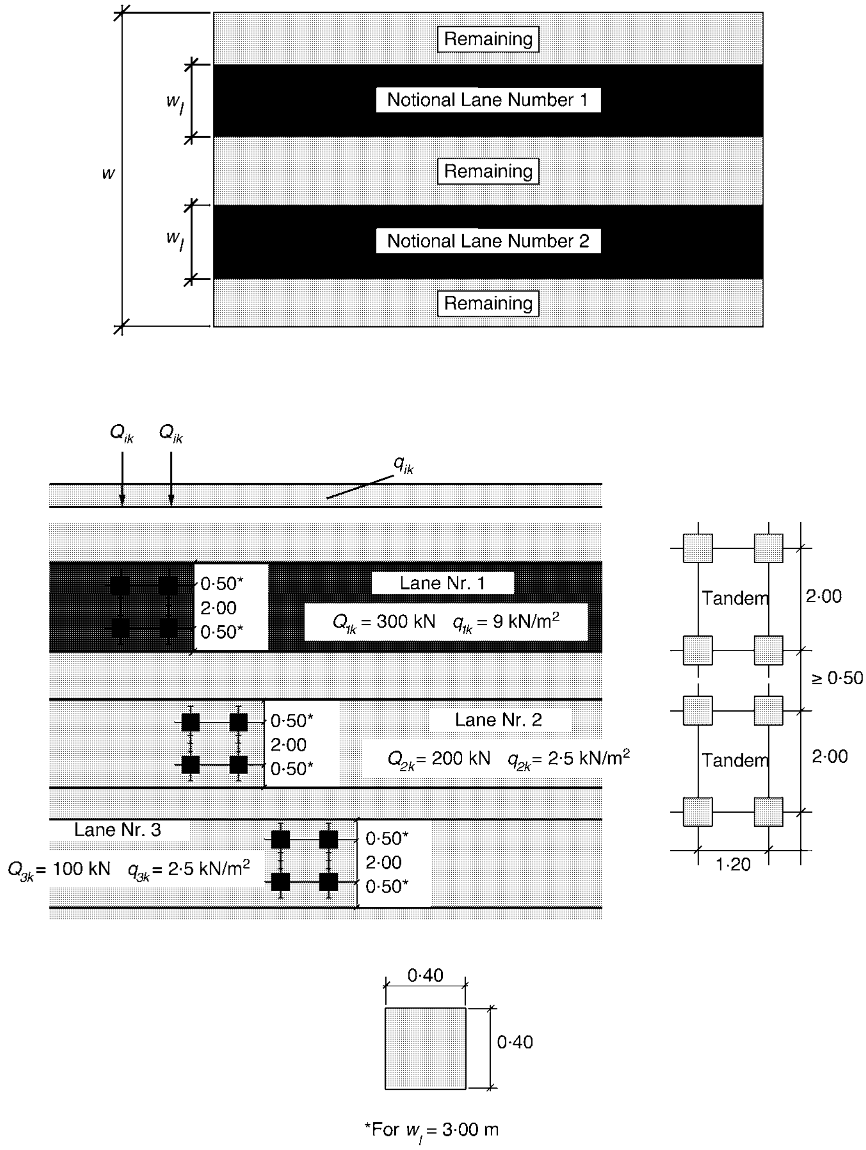


Fig. 8.5. Example of lane numbering in the most general case and load model 1

Table 8.6. Basic values

Location	Tandem system Axle loads Q_{ik}: kN	UDL system q_{ik} (or q_{rk}): kN/m^2
Lane number 1	300	9
Lane number 2	200	2·5
Lane number 3	100	2·5
Other lanes	0	2·5
Remaining area (q_{rk})	0	2·5

(*b*) for span lengths greater than 10 m, by replacing each tandem system in each lane by a one-axle concentrated load of weight equal to the total weight of the two axles. However, the relevant authorities may restrict the application of this simplification. The single axle weight is:

$600\alpha_{Q1}$ kN on lane number 1
$400\alpha_{Q2}$ kN on lane number 2
$200\alpha_{Q3}$ kN on lane number 3.

The values of the factors α_{Qi}, α_{qi} and α_{qr} (adjustment factors) may be different for different classes of route or of expected traffic. In the absence of specification, these factors are taken as equal to 1. In all classes, for bridges without road signs restricting vehicle weights

$\alpha_{Q1} \geqslant 0{\cdot}8$ and

for: $i \geqslant 2$, $\alpha_{qi} \geqslant 1$; this restriction is not applicable to α_{qr}. Note that α_{Qi}, α_{qi} and α_{qr} factors other than 1 should be used only if they are chosen or agreed by the relevant authority.

Single axle model (load model 2)

This model consists of a single axle load $\beta_Q Q_{ak}$ with Q_{ak} equal to 400 kN, dynamic amplification included, which should be applied at any location on the carriageway. However, when relevant, only one wheel of 200 β_Q (kN) may be considered. Unless otherwise specified, β_Q is equal to α_{Q1}.

Unless it is specified that the same contact surface as for load model 1 should be adopted, the contact surface of each wheel is a rectangle of sides 0·35 m and 0·60 m as shown in Fig. 8.6.

Set of models of special vehicles (load model 3)

When one or more of the standardised models of this set is required by the client to be taken into account, the load values and dimensions should be as described in annex A of the code concerned.

The characteristic loads associated with the special vehicles should be taken as nominal values and should be considered as associated solely with transient design situations.

Unless otherwise specified the following should be assumed.

(*a*) Each standardised model is applicable on one notional traffic lane (considered as lane number 1) for the models composed of 150 or 200 kN axles, or on two adjacent notional lanes (considered as lane

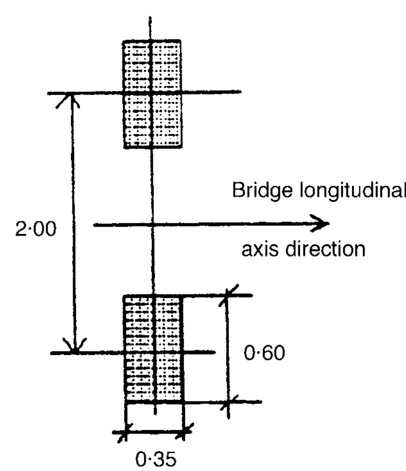


Fig. 8.6. Load model 2

numbers 1 and 2 — see Fig. 8.8) for models composed of heavier axles. The lanes are located as unfavourably as possible in the carriageway. For this case, the carriageway width may be defined as excluding hard shoulders, hard strips and marker strips.

(*b*) Special vehicles simulated by the models are assumed to move at low speed (not more than 5 km/h); only vertical loads without dynamic amplification have therefore to be considered.

(*c*) Each notional lane and the remaining area of the bridge deck are loaded by the main loading system. On the lane(s) occupied by the standardised vehicle, this system should not be applied at less than 25 m from the outer axles of the vehicle under consideration.

Crowd loading (load model 4)

Crowd loading, if relevant, is represented by a nominal load (which includes dynamic amplification). Unless otherwise specified, it should be applied on the relevant parts of the length and width of the road bridge deck, the central reservation being included where relevant. This loading system, intended for general verifications, is associated solely with a transient situation.

Dispersal of concentrated loads

The various concentrated loads to be considered for local verifications, associated with load models 1, 2 and 3, are assumed to be uniformly distributed across their whole contact area. The dispersal through the pavement and concrete slabs is taken at a spread-to-depth ratio of 1 horizontally to 1 vertically down to the level of the centroid of the structural flange below (see Figs 8.7 and 8.8).

8.1.3. Highway loads based on AASHTO

Standard truck and lane loads

The highway live loadings on the roadways of bridges or incidental structures shall consist of standard trucks or lane loads that are equivalent to truck trains. Two systems of loading are provided, the H loadings and the HS loadings — the HS loadings being heavier than the corresponding H loadings.

Each lane load shall consist of a uniform load per linear foot of traffic lane combined with a single concentrated load (or two concentrated loads in the case of continuous spans), so placed on the span as to produce maximum stress. The concentrated load and uniform load shall be considered as uniformly distributed over a 10 ft width on a line normal to the centre line of the lane.

For the computation of moments and shears, different loads shall be used as indicated in Fig. 8.9. The lighter concentrated loads shall be used when the

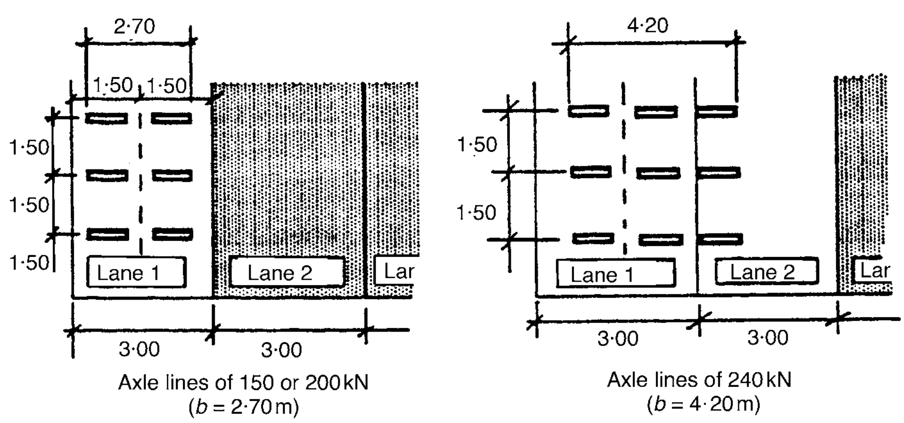


Fig. 8.7. Location of special vehicles

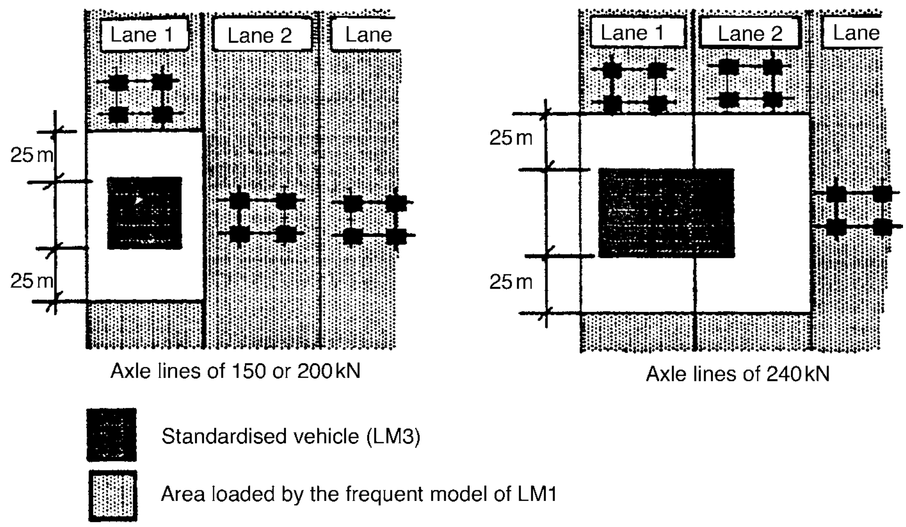


Fig. 8.8. Simultaneity of load models 1 and 3

stresses are primarily bending stresses, and the heavier concentrated loads shall be used when the stresses are primarily shearing stresses.

Classes of loading

There are four standard classes of highway loading: H 20, H 15, HS 20, and HS 15. Loading H 15 is 75% of loading H 20. Loading HS 15 is 75% of loading HS 20. If loadings other than those designated are desired, they shall be obtained by proportionately changing the weights shown for both the standard truck and the corresponding lane loads.

Designation of loadings

The policy of affixing the year to loadings to identify them was instituted with the publication of the 1944 Edition of the code in the following manner:

H 15 loading, 1944 Edition shall be designated	H 15-44
H 20 loading, 1944 Edition shall be designated	H 20-44
H 15-S 12 loading, 1944 Edition shall be designated	HS 15-44
H 20-S 16 loading, 1944 Edition shall be designated	HS 20-44

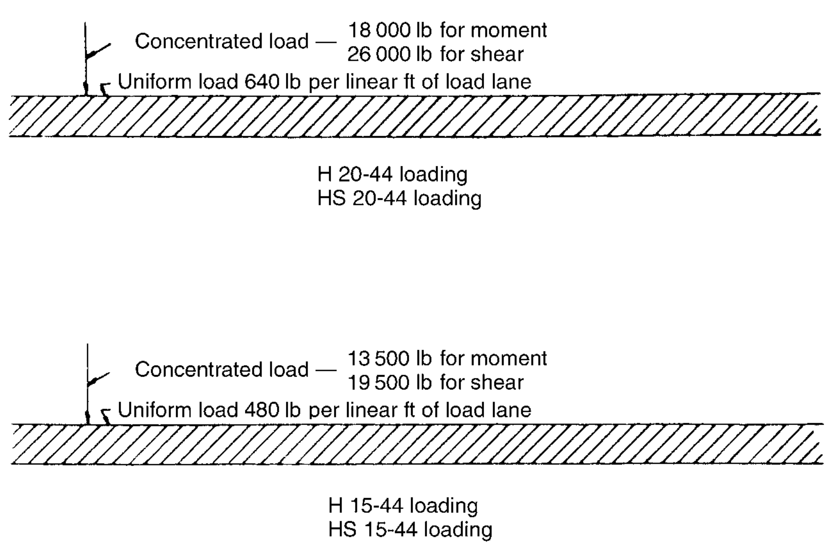


Fig. 8.9. Lane loading

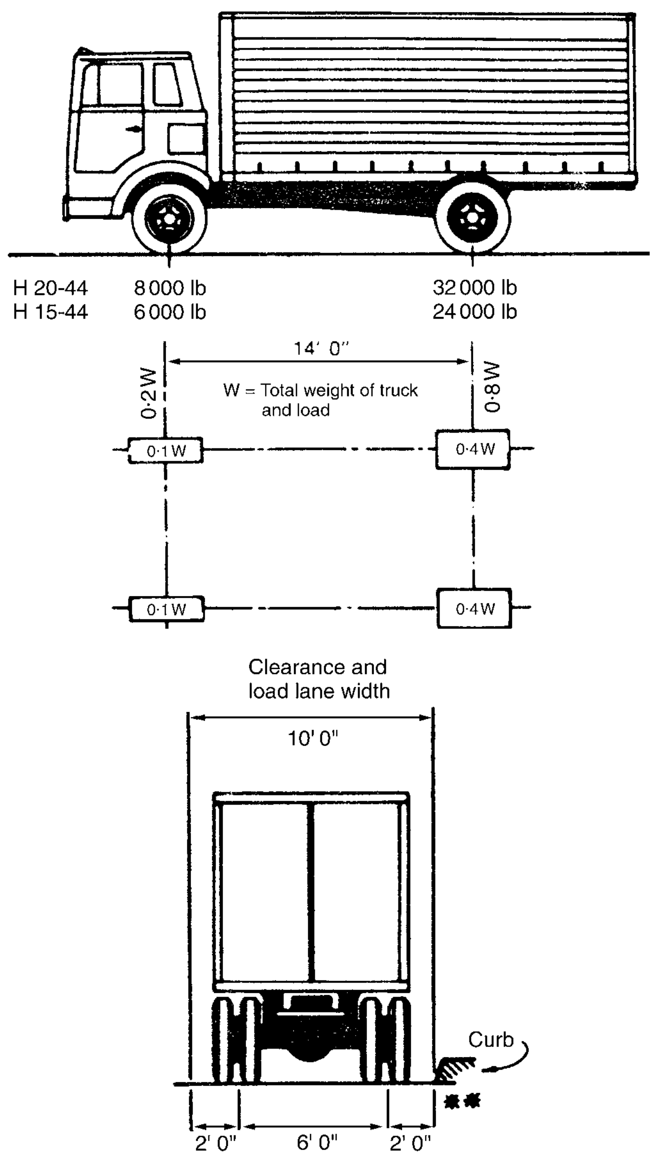
The affix shall remain unchanged until such time as the loading specification is revised. The same policy for identification shall be applied, for future reference, to loadings previously adopted by the American Association of State Highway and Transportation Officials.

Minimum loading

Bridges supporting Interstate highways or other highways which carry, or which may carry, heavy truck traffic, shall be designed for HS 20-44 loading or an alternate military loading of two axles four feet apart with each axle weighing 24 000 pounds, whichever produces the greatest stress.

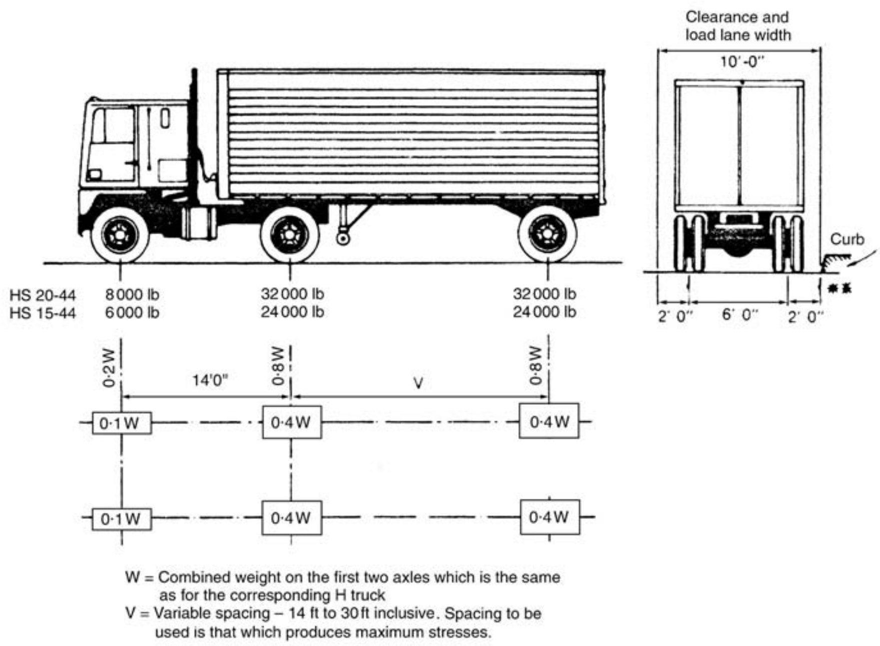
H loading

The H loadings consist of a two-axle truck or the corresponding lane loading as illustrated in Figs 8.9 and 8.10. The H loadings are designated H followed by a number indicating the gross weight in tons of the standard truck.



* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24 000 lb or two axle loads of 16 000 lb each spaced 4 ft apart may be used, whichever produces the greater stress, instead of the 32 000 lb axle shown.
** For slab design, the centre line of wheels shall be assumed to be 1 ft from face of curb.

Fig. 8.10. Standard H trucks



* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24 000 lb or two axle loads of 16 000 lb each spaced 4 ft apart may be used, whichever produces the greater stress, instead of the 32 000 lb axle shown.
** For slab design, the centre line of wheels shall be assumed to be 1 ft from face of curb.

Fig. 8.11. Vehicular loading — HS trucks

HS loading

The HS loadings consist of a tractor truck with semi-trailer or the corresponding lane load as illustrated in Figs 8.9 and 8.11. The HS loadings are designated by the letters HS followed by a number indicating the gross weight in tons of the tractor truck. The variable axle spacing has been introduced in order that the spacing of axles may approximate more closely the tractor trailers now is use. The variable spacing also provides a more satisfactory loading for continuous spans, in that heavy axle loads may be so placed on adjoining spans as to produce maximum negative moments.

Application of live load

In computing stresses, each 10 ft lane load or single standard truck shall be considered as a unit, and fractions of load lane widths or trucks shall not be used. The number and position of the lane load or truck loads shall be as specified above and, whether lane or truck loads, shall be such as to produce maximum stress, subject to the reduction specified below.

Reduction in load intensity

Where maximum stresses are produced in any member by loading a number of traffic lanes simultaneously, the following percentages of the live loads shall be used in view of the improbability of coincident maximum loading:

- one or two lanes 100%
- three lanes 90%
- four lanes or more 75%

The reduction in intensity of loads on transverse members such as floor beams shall be determined as in the case of main trusses or girders, using the number of traffic lanes across the width of roadway that must be loaded to produce maximum stresses in the floor beam.

Sidewalk, curb, and railing loading

Sidewalk floors, stringers, and their immediate supports shall be designed for a live load of 85 lb/ft^2 of sidewalk area. Girders, trusses, arches and other members shall be designed for the following sidewalk live loads:

- spans 0–25 ft in length 85 lb/ft^2
- spans 26–100 ft in length 60 lb/ft^2
- spans over 100 ft in length according to the formula

$$P = \left(30 + \frac{3000}{L}\right)\left(\frac{55 - W}{50}\right) \tag{8.4}$$

in which

P = live load per ft^2, max. 60 lb/ft^2
L = loaded length of sidewalk in ft
W = width of sidewalk in ft.

In calculating stresses in structures that support cantilevered sidewalks, the sidewalk shall be fully loaded on only one side of the structure if this condition produces maximum stress.

Bridges for pedestrian and/or bicycle traffic shall be designed for a live load of 85 PSF. Where bicycle or pedestrian bridges are expected to be used by maintenance vehicles, special design consideration should be allowed for these loads.

Curbs shall be designed to resist a lateral force of not less than 500 lb per linear ft of curb, applied at the top of the curb, or at an elevation 10 in. above the floor if the curb is higher than 10 in. Where sidewalk, curb, and traffic rail form an integral system, the traffic railing loading shall be applied and stresses in curbs computed accordingly.

Superstructure design

Group II and Group V loadings A wind load of the following intensity shall be applied horizontally at right angles to the longitudinal axis of the structure:

- for trusses and arches 75 lb/ft^2
- for girders and beams 50 lb/ft^2

The total force shall not be less than 300 lb per linear ft in the plane of the windward chord and 150 lb per linear ft in the plane of the leeward chord on truss spans, and not less than 300 lb per linear ft on girder spans.

Group III and Group VI loadings Group III and Group VI loadings shall comprise the loads used for Group II and Group V loadings reduced by 70% and a load of 100 lb per linear ft applied at right angles to the longitudinal axis of the structure and 6 ft above the deck as a wind load on a moving live load. When a reinforced concrete floor slab or a steel grid deck is keyed to or attached to its supporting members, it may be assumed that the deck resists, within its plane, the shear resulting from the wind load on the moving live load.

Combinations of loads

The following Group represents various combinations of loads and forces to which a structure may be subjected. Each component of the structure, or the foundation on which it rests, shall be proportioned to withstand safely all group combinations of these forces that are applicable to the particular site or type. Group loading combinations for service load design and load factor design are given by the following.

$$\text{Group (N)} = \gamma[\beta_D \cdot D + \beta_L(L + I) + \beta_C CF + \beta_E E + \beta_B B + \beta_S SF + \beta_W W + \beta_{WL} WL + \beta_L \cdot LF + \beta_R(R + S + T) + \beta_{EQ} EQ + \beta_{ICE} ICE]$$

where

N = group number
γ = load factor, see Table 8.7
β = coefficient, see Table 8.7
D = dead load
L = live load
I = live load impact
E = earth pressure
B = buoyancy
W = wind load on structure
WL = wind load on live load — 100 lb per linear ft
LF = longitudinal force from live load
CF = centrifugal force
R = rib shortening
S = shrinkage
T = temperature
EQ = earthquake
SF = stream flow pressure
ICE = ice pressure.

For service load design, the percentage of the basic unit stress for the various groups is given in Table 8.7. The loads and forces in each group shall be taken as appropriate. The maximum section required shall be used.

For load factor design, the gamma and beta factors given in Table 8.7 shall be used for designing structural members and foundations by the load factor concept.

A simpler, more tractable model has been developed. The objective of this model is to prescribe a set of loads such that the same extreme load effects of the model are approximately the same as the exclusion vehicles. This model consists of three distinctly different loads:

- design truck
- design tandem
- design lane.

As illustrated in Fig. 8.11, the design truck (the first of three separate live load configurations) is a model load that resembles the typical semi-trailer truck. The front axle is 35 kN, located 4300 mm before the drive axle which has a load of 145 kN. The rear trailer axle is also 145 kN and is positioned at a variable distance ranging between 4300 and 9000 mm. The variable range means that the spacing used should cause critical load effect. The long spacing typically only controls where the front and rear portions of the truck may be positioned in adjacent structurally continuous spans such as for continuous short-span bridges. The design truck is the same configuration that has been used by AASHTO (1996) Standard Specification since 1944 and is commonly referred to as HS 20. The H denotes highway, the S denotes semi-trailer, and

Table 8.7. Table of coefficients γ and β. From Standard Specification for Highway Bridges, Copyright 1996, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used by permission

Col. No.		1	2	3	3A	4	5	6	7	8	9	10	11	12	13	14	
			β FACTORS														
GROUP		γ	D	$(L+I)_n$	$(L+I)_P$	CF	E	B	SF	W	WL	LF	R+S+T	EQ	ICE	%	
SERVICE LOAD	I	1·0	1	1	0	1	β_E	1	1	0	0	0	0	0	0	100	
	1A	1·0	1	2	0	0	0	0	0	0	0	0	0	0	0	150	
	1B	1·0	1	0	1	1	β_E	1	1	0	0	0	0	0	0	**	
	II	1·0	1	0	0	0	1	1	1	1	0	0	0	0	0	125	
	III	1·0	1	1	0	1	β_E	1	1	0·3	1	1	0	0	0	125	
	IV	1·0	1	1	0	1	β_E	1	1	0	0	0	1	0	0	125	
	V	1·0	1	0	0	0	1	1	1	1	0	0	1	0	0	140	
	VI	1·0	1	1	0	1	β_E	1	1	0·3	1	1	1	0	0	140	
	VII	1·0	1	0	0	0	1	1	1	0	0	0	0	1	0	133	
	VIII	1·0	1	1	0	1	1	1	1	0	0	0	0	0	1	140	
	IX	1·0	1	0	0	0	1	1	1	1	0	0	0	0	1	150	
	X	1·0	1	1	0	0	β_E	0	0	0	0	0	0	0	0	100	Culvert
LOAD FACTOR DESIGN	I	1·3	β_D	1·67*	0	1·0	β_E	1	1	0	0	0	0	0	0	Not Applicable	
	IA	1·3	β_D	2·20	0	0	0	0	0	0	0	0	0	0	0		
	IB	1·3	β_D	0	1	1·0	β_E	1	1	0	0	0	0	0	0		
	II	1·3	β_D	0	0	0	β_E	1	1	1	0	0	0	0	0		
	III	1·3	β_D	1	0	1	β_E	1	1	0·3	1	1	0	0	0		
	IV	1·3	β_D	1	0	1	β_E	1	1	0	0	0	1	0	0		
	V	1·25	β_D	0	0	0	β_E	1	1	1	0	0	1	0	0		
	VI	1·25	β_D	1	0	1	β_E	1	1	0·3	1	1	1	0	0		
	VII	1·3	β_D	0	0	0	β_E	1	1	0	0	0	0	1	0		
	VIII	1·3	β_D	1	0	1	β_E	1	1	0	0	0	0	0	1		
	IX	1·20	β_D	0	0	0	β_E	1	1	1	0	0	0	0	1		
	X	1·30	1	1·67	0	0	β_E	0	0	0	0	0	0	0	0		Culvert

$(L+I)_n$—live load plus impact for AASHTO Highway H or HS loading.
$(L+I)_p$—live load plus impact consistent with the overload criteria of the operation agency.
* 1·25 may be used for design of outside roadway beam when combination of sidewalk live load as well as traffic live load plus impact governs the design, but the capacity of the section should not be less than required for highway traffic live load only using a beta factor of 1·67. 1·00 may be used for design of deck slab with combination of loads.

$$\text{** Percentage} = \frac{\text{maximum unit stress (operating rating)}}{\text{allowable basic unit stress}} \times 100$$

For service load design

% (Column 14) percentage of basic unit stress

No increase in allowable unit stresses shall be permitted for members or connections carrying wind loads only

$\beta_E = 1·00$ for vertical and lateral loads on all other structures.

For culvert loading specifications.

$\beta_E = 1·0$ and 0·5 for lateral loads on rigid frames (check both loadings to see which one governs).

For load factor design

$\beta_E = 1·3$ for lateral earth pressure for retaining walls and rigid frames excluding rigid culverts. For lateral at-rest earth pressures, $\beta_E = 1·15$
$\beta_E = 0·5$ for lateral earth pressure when checking positive moments in rigid frames.
$\beta_E = 1·0$ for vertical earth pressure
$\beta_D = 0·75$ when checking member for minimum axial load and maximum moment or maximum eccentricity
$\beta_D = 1·0$ when checking member for maximum axial load and minimum moment
(For Column Design)
$\beta_D = 1·0$ for flexural and tension members
$\beta_E = 1·0$ for rigid culverts
$\beta_E = 1·5$ for flexible culverts

For Group X loading (culverts) the β_E factor shall be applied to vertical and horizontal loads.

the 20 is the weight of the tractor in tons (U.S. customary units). The new vehicle combinations as described in AASHTO (1994) LRFD Bridge Specifications are designated as HL-93 for highway loading accepted in 1993 (see Fig. 8.12).

The second configuration is the design tandem which consists of two axles weighing 110 kN each spaced at 1200 mm, which is similar to the tandem axle used in previous AASHTO Standard Specifications except that the load is changed from 24 to 25 kips (110 kN).

The third load is the design lane load that consists of a uniformly distributed load of 9.3 N/mm and is assumed to occupy a region 3000 mm transversely. This load is the same as a uniform pressure of 64 lb/ft^2 (3·1 kPa) applied in a 10 ft (3000 mm) design lane. This load is similar to the lane load outlined in the AASHTO Standard Specifications for many years with the exception that the LRFD lane load does not require any concentrated loads.

The load effects of the design truck and the design tandem must each be *superimposed with* the load effects of the design lane load. This combination of lane and axle loads is a major deviation from the requirements of the earlier AASHTO Standard Specifications, where the loads were considered separately. It is important to understand that these loads are not designed to model any one vehicle or combination of vehicles, but rather the spectra of loads and their associated load effects.

8.2. Steel access bridge of trussed arch design (based on EC3 and ENV 1995)

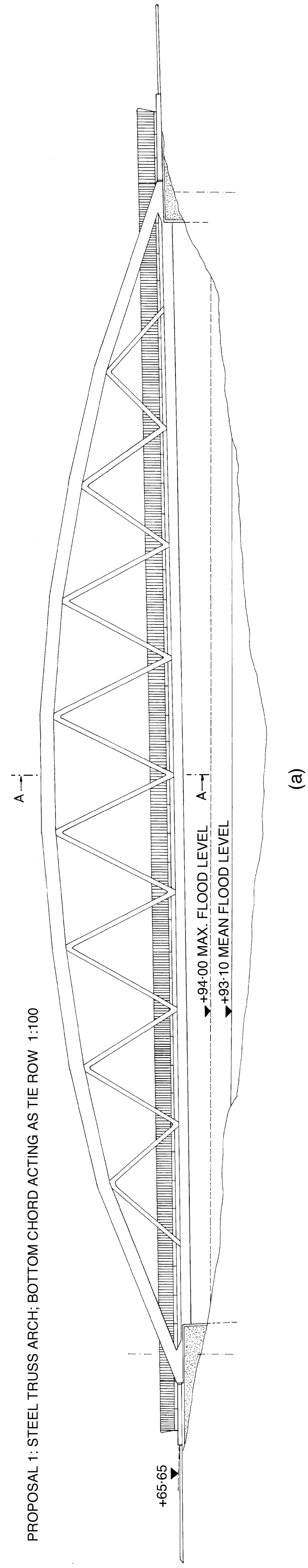


Fig. 8.13. Access bridge—a comparative study: (a) elevation (courtesy of Frank Hyder, Leipzig, Germany)

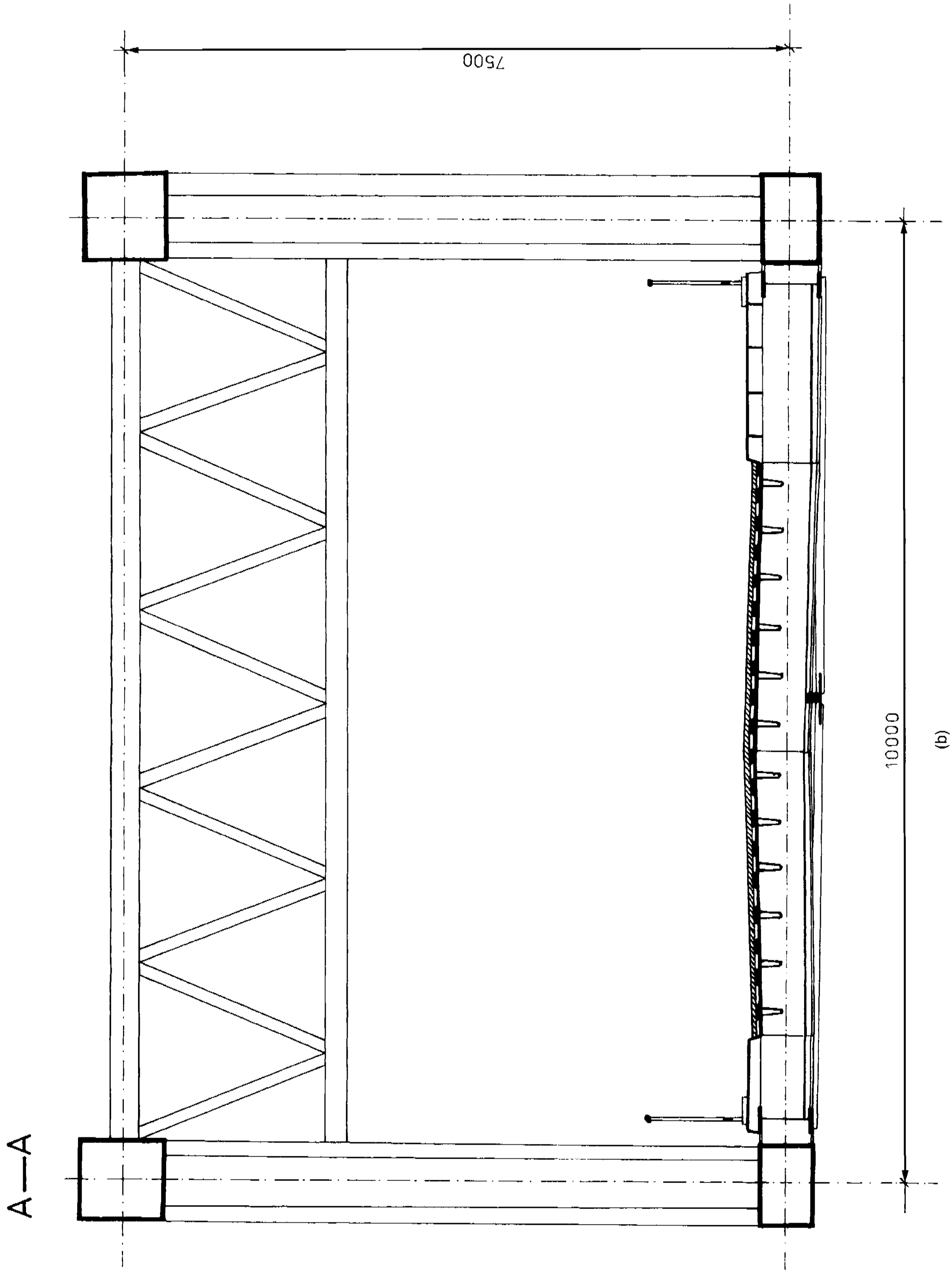


Fig. 8.13. Access bridge—a comparative study: (b) section (courtesy of Frank Hyder, Leipzig, Germany)

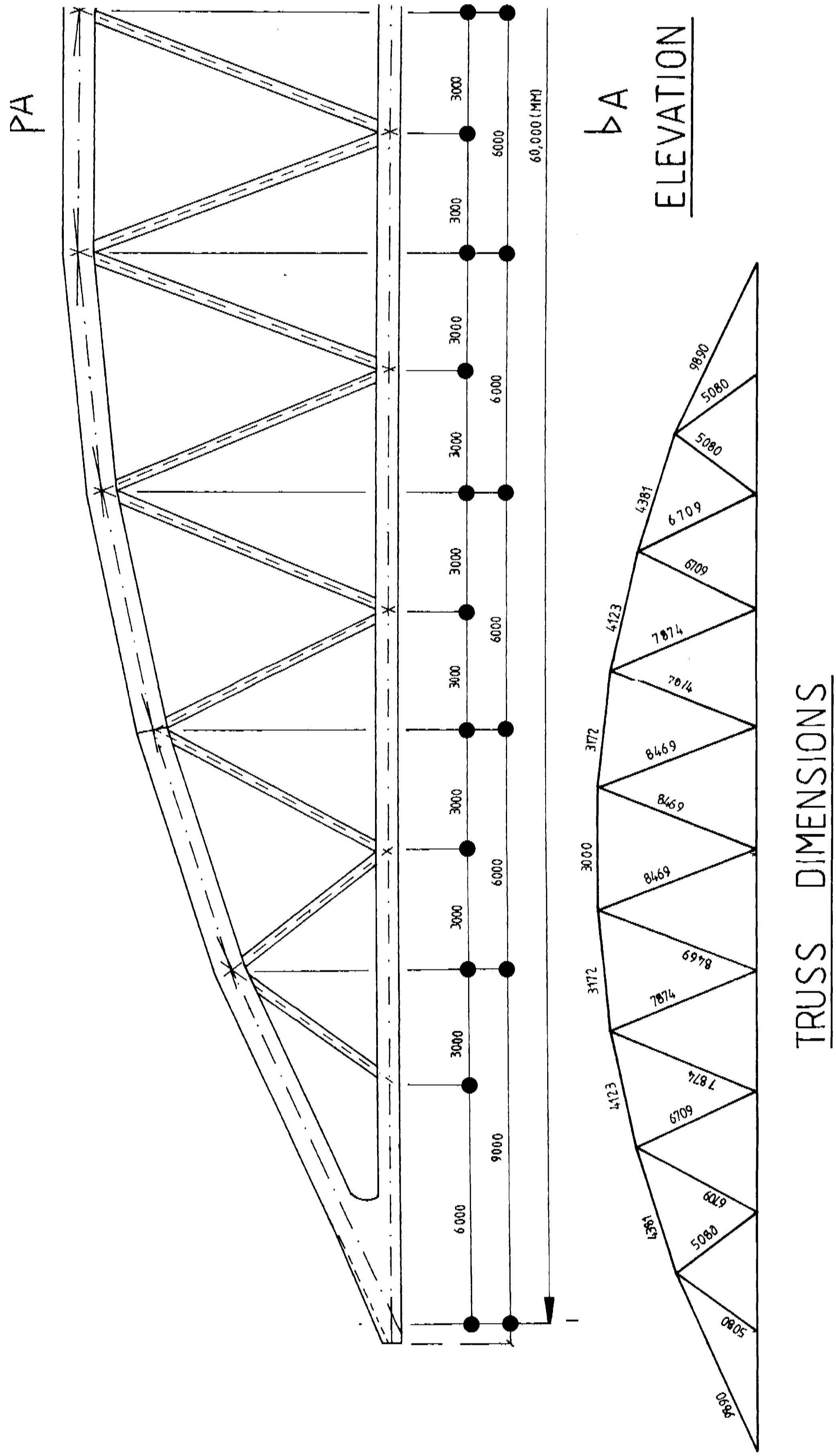
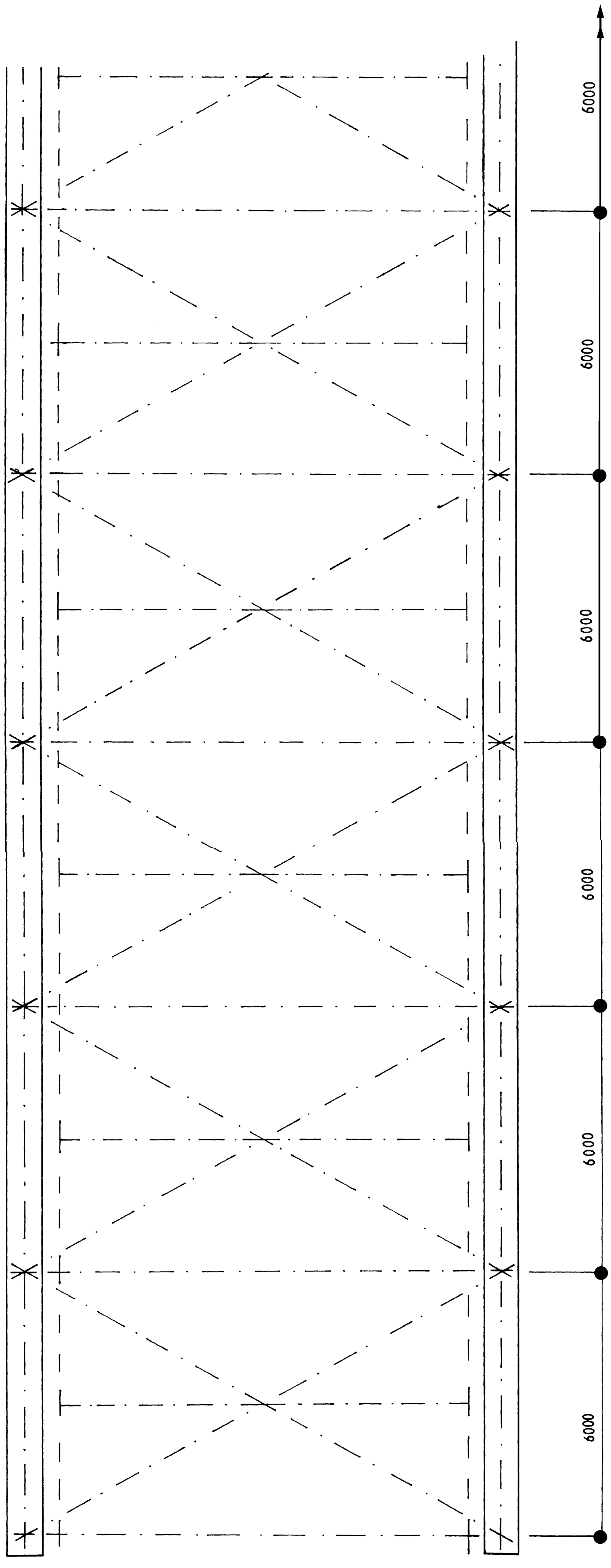


Fig. 8.14. Access bridge—(a) elevation (courtesy of Frank Hyder, Leipzig, Germany)



Bottom lateral bracing

Fig. 8.14. Access bridge—(b) plans showing bracings (courtesy of Frank Hyder, Leipzig, Germany)

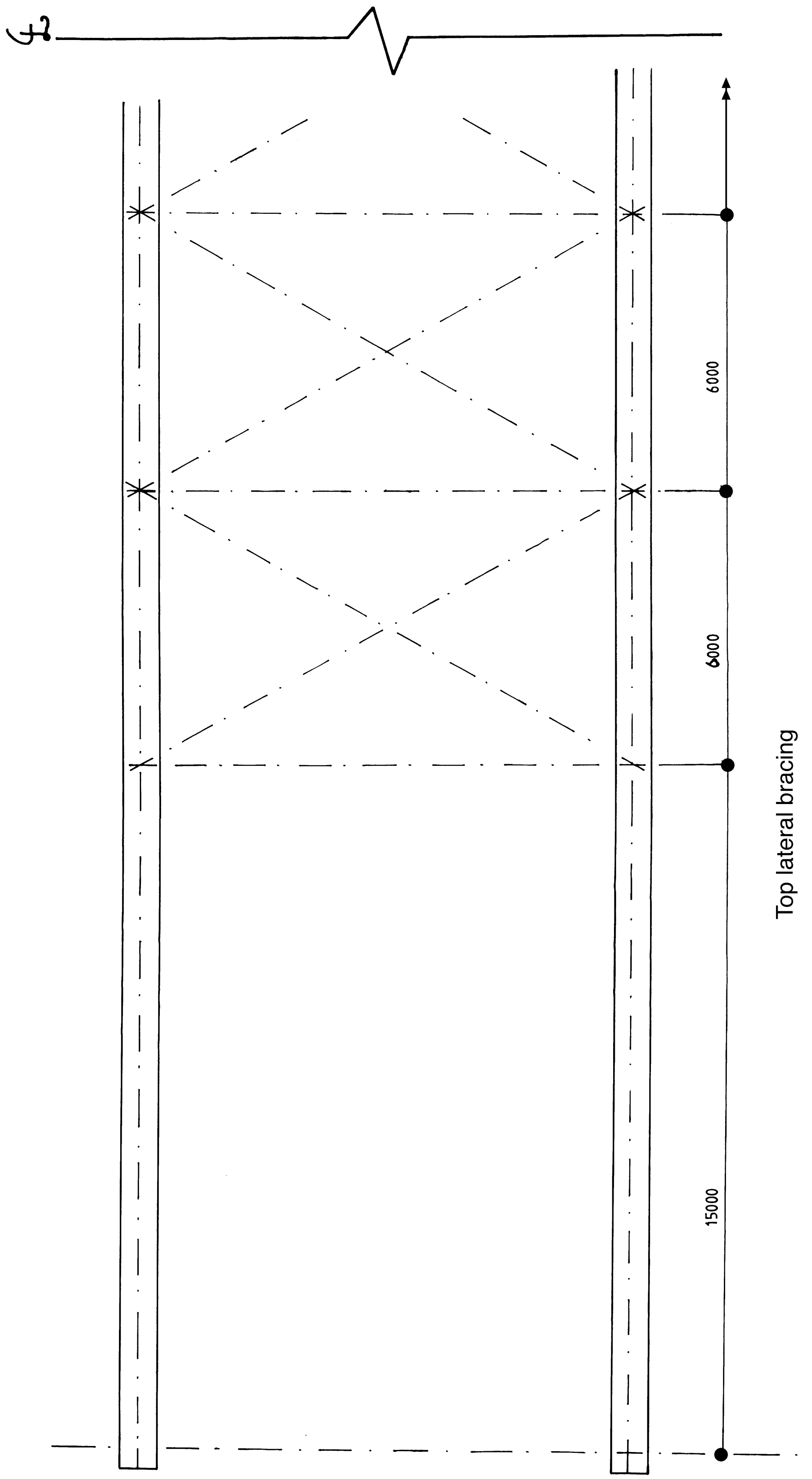


Fig. 8.14. Access bridge—(c) plans showing bracings (courtesy of Frank Hyder, Leipzig, Germany)

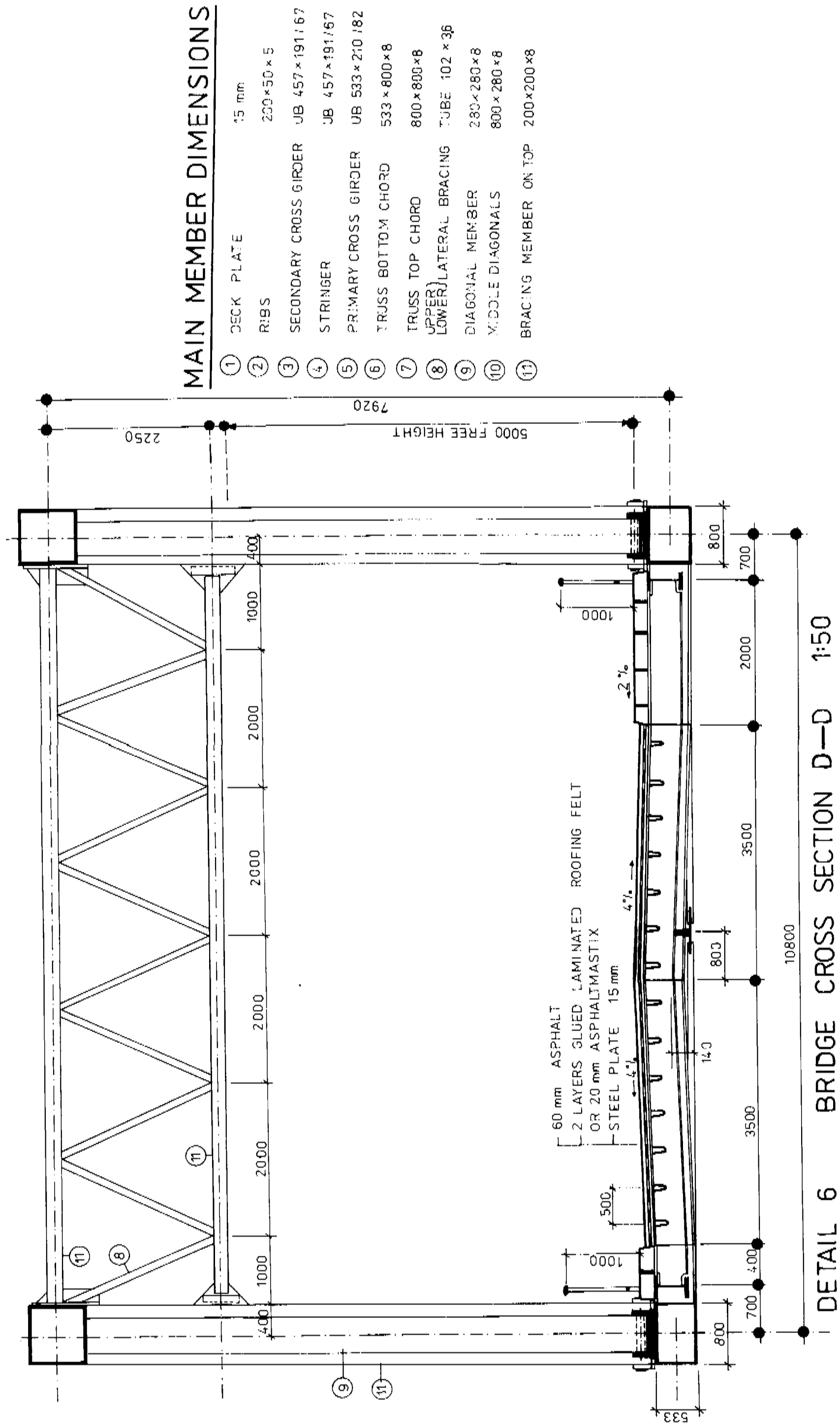
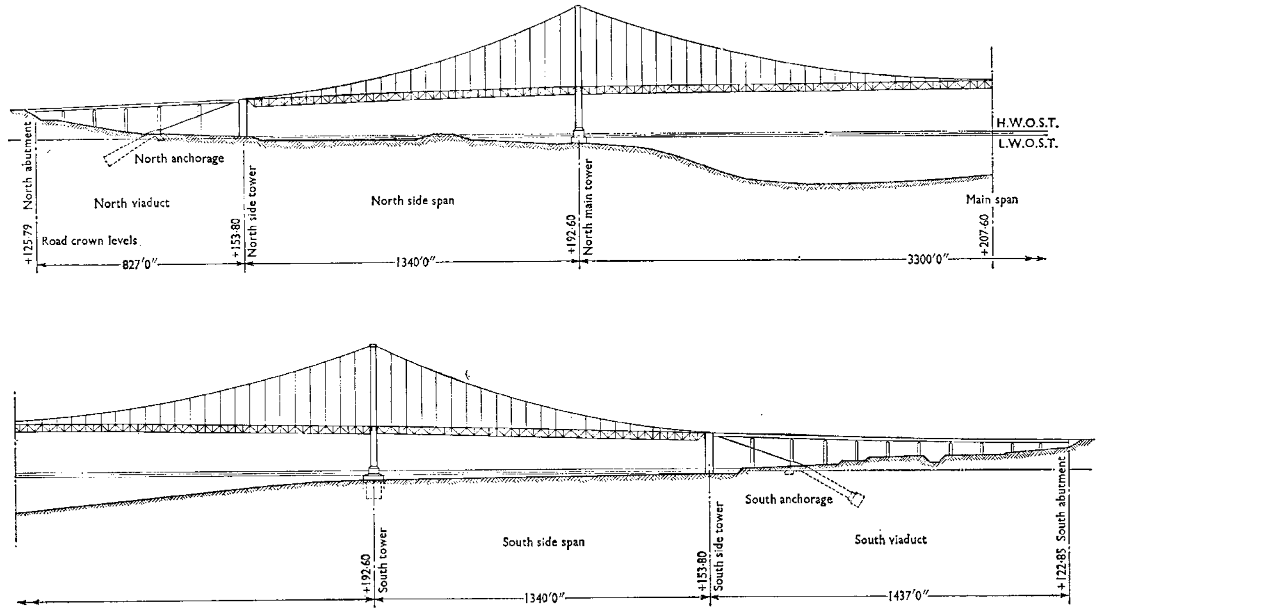
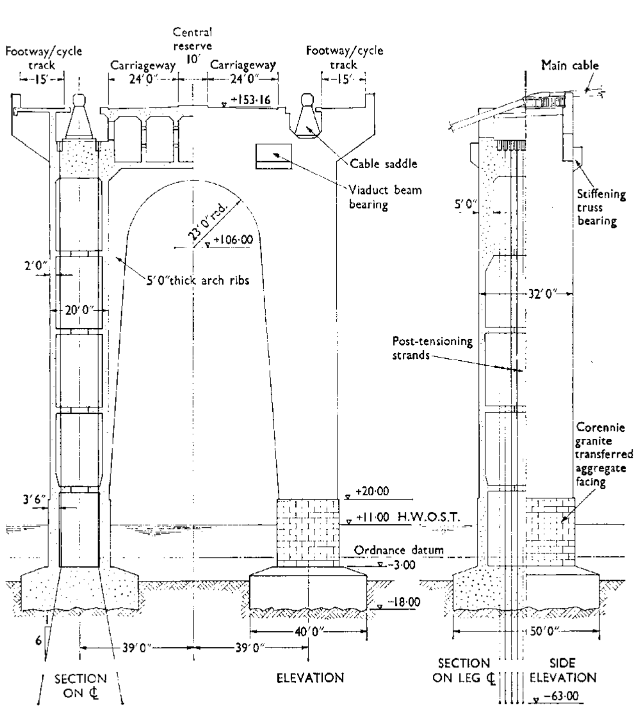
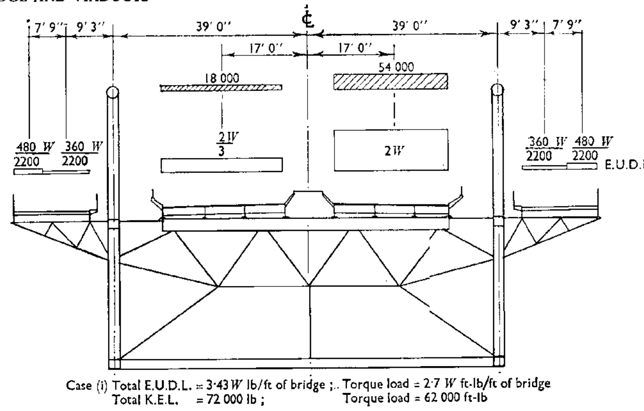


Fig. 8.15. Access bridge—cross-section and structural details (courtesy of Frank Hyder, Leipzig, Germany)

8.3. Structural details of a suspension bridge based on a British code



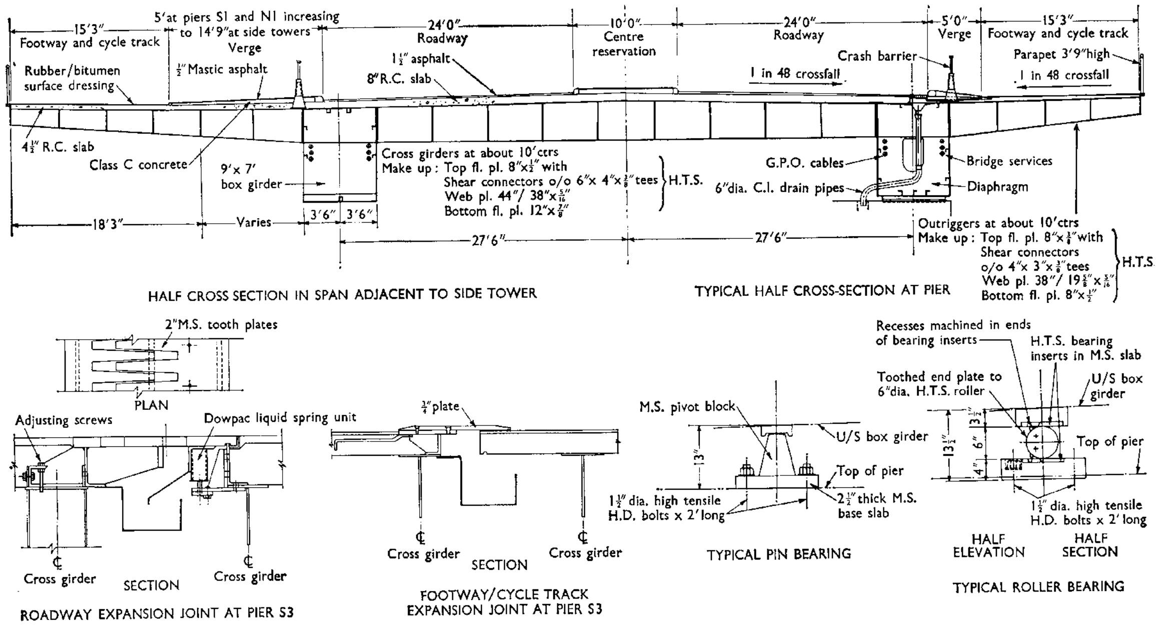




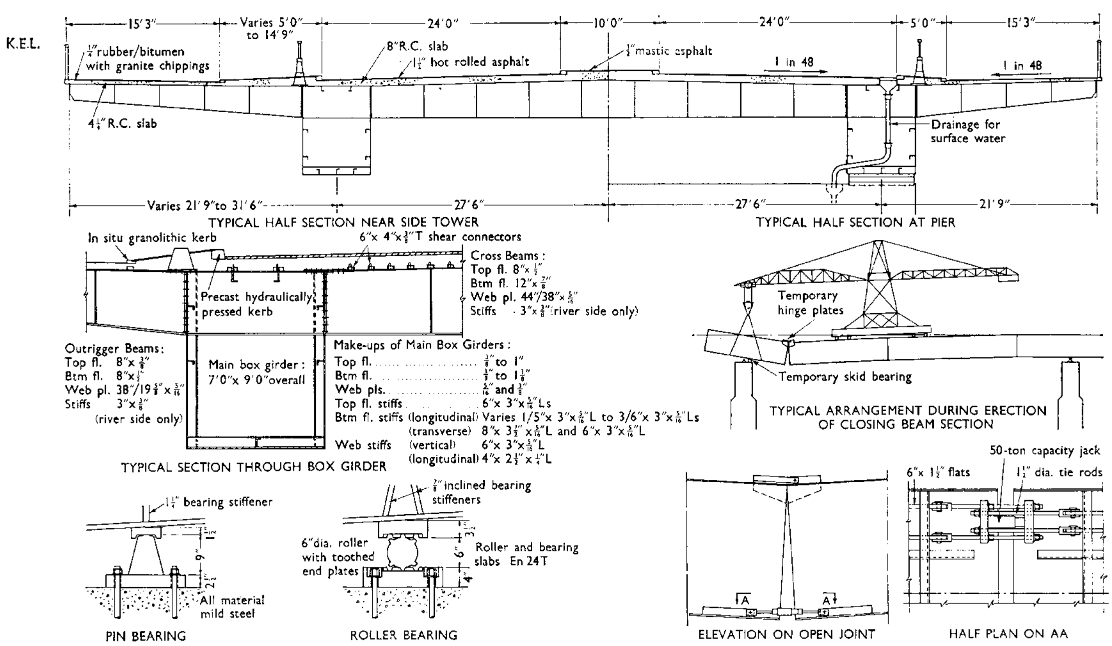
ORGANIZATIONS ASSOCIATED WITH THE PROJECT

Forth Road Bridge Joint Board
Scottish Development Department
Messrs Mott, Hay and Anderson
Messrs Freeman, Fox and Partners
Sir Giles Scott, Son and Partner
Farran Ltd., Edinburgh
John Howard & Co. Ltd.
A.C.D. Bridge Co.
A. M. Carmichael Ltd.
Messrs Reed & Mallik
Head Wrightson & Co. Ltd.
Whatlings Ltd.
The Limmer & Trinidad Lake Asphalt Co. Ltd.
Amalgamated Asphalte Companies Ltd.
Communication Systems Ltd.
Franco Traffic Signs Ltd.
Holland, Hannen & Cubitts Ltd.
Hugh C. Gibson's Heirs
John A. Roebling's Sons Corporation of America

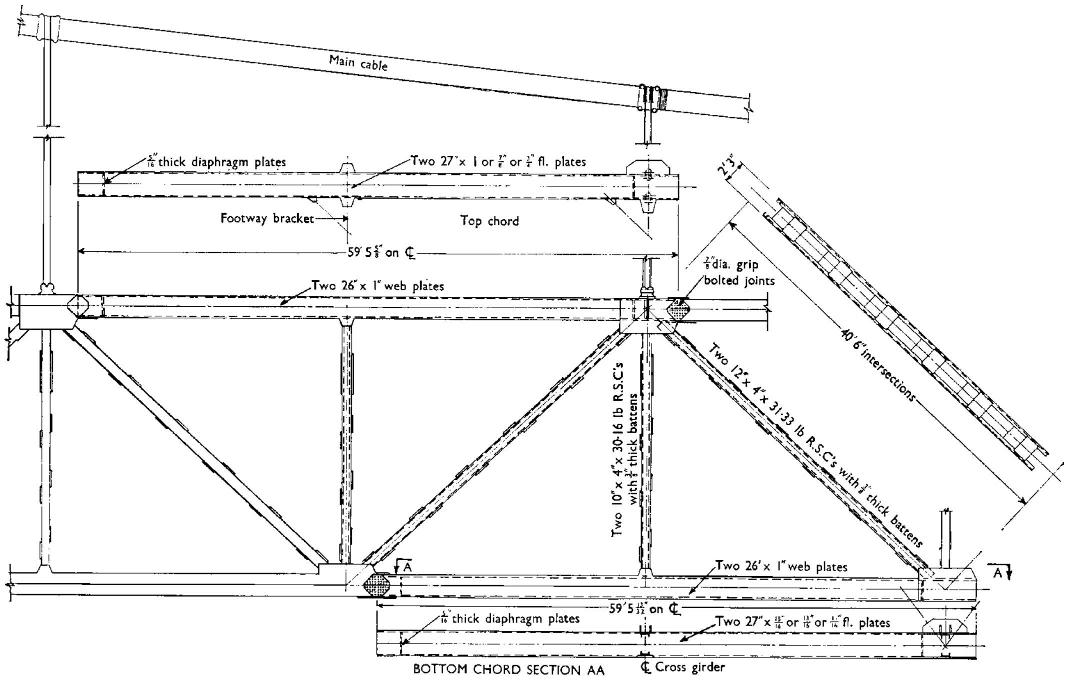
Fig. 8.16. Elevation of a suspension bridge and viaduct details



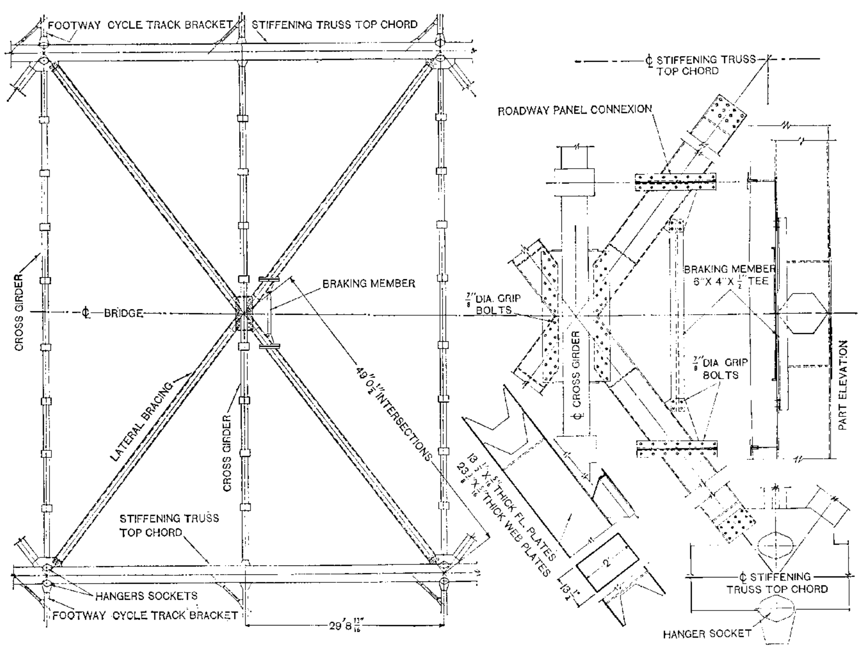
APPROACH VIADUCT DECK CROSS-SECTION AND DETAILS



VIADUCT STEELWORK DETAILS

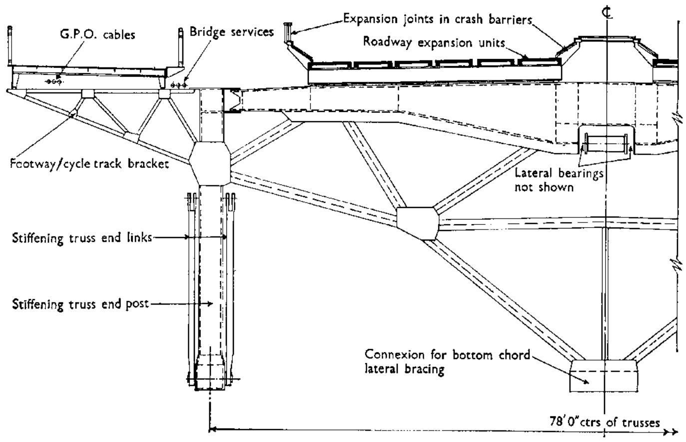


PART OUTSIDE ELEVATION OF STIFFENING TRUSS

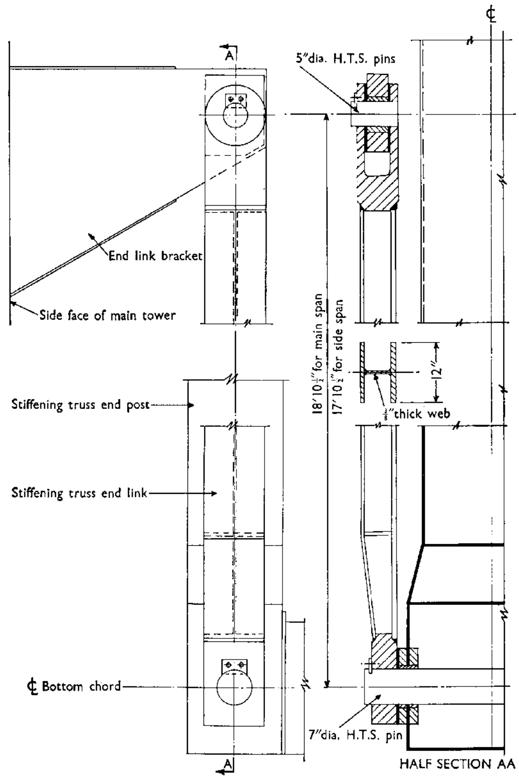


TOP CHORD LATERAL BRACING

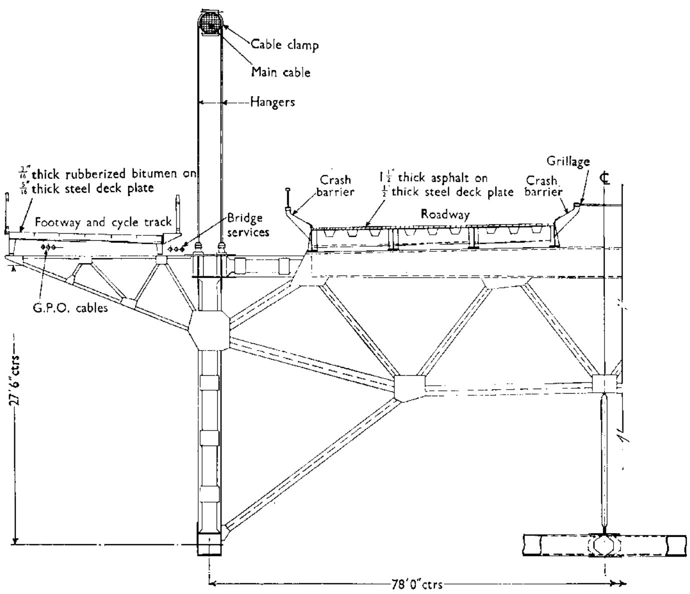
Fig. 8.17. Elevations, cross-section and structural details of trusses



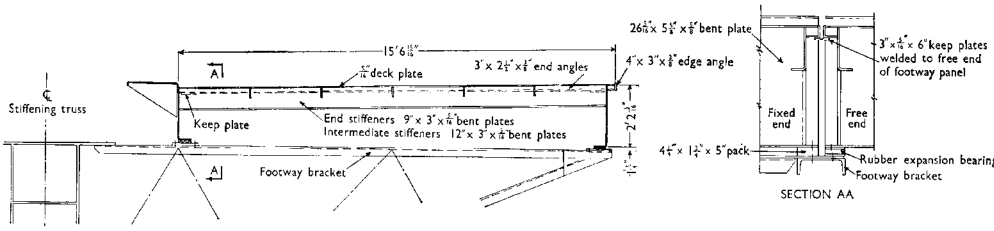
CROSS GIRDER OF MAIN SPAN AT MAIN TOWER



STIFFENING TRUSS END LINK



CROSS GIRDER OF MAIN SPAN



SECTION THROUGH FOOTWAY/CYCLE TRACK DECK PANEL

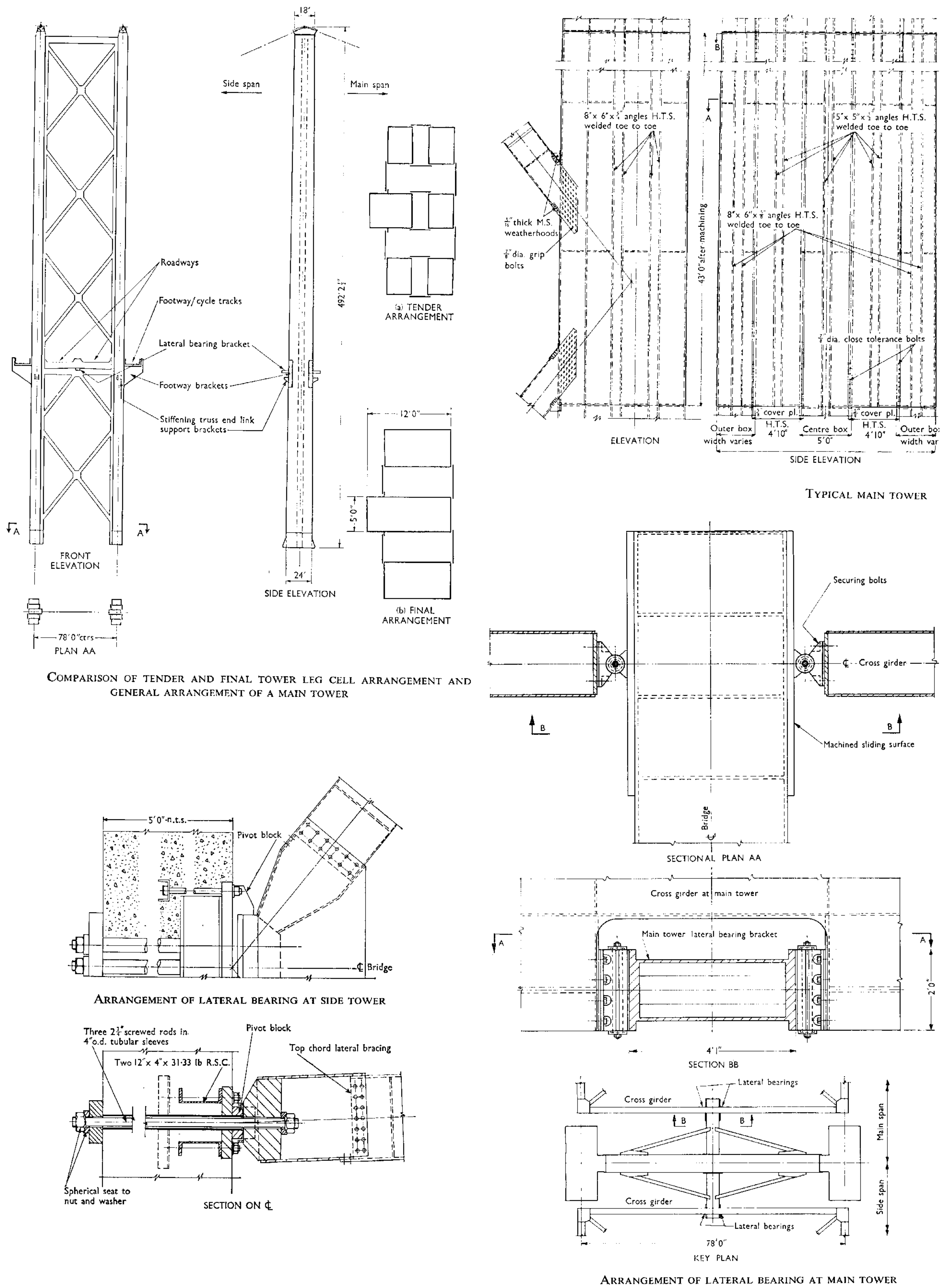
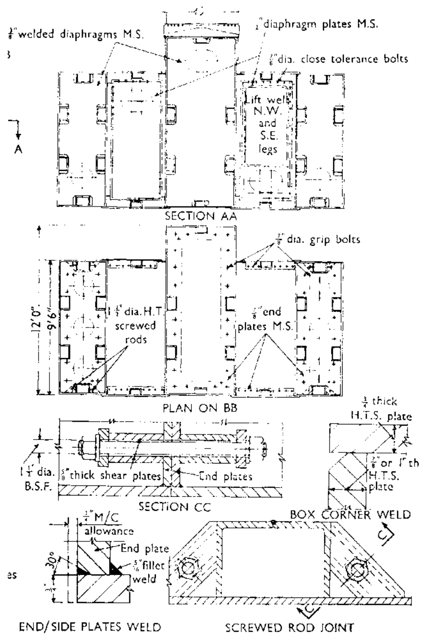
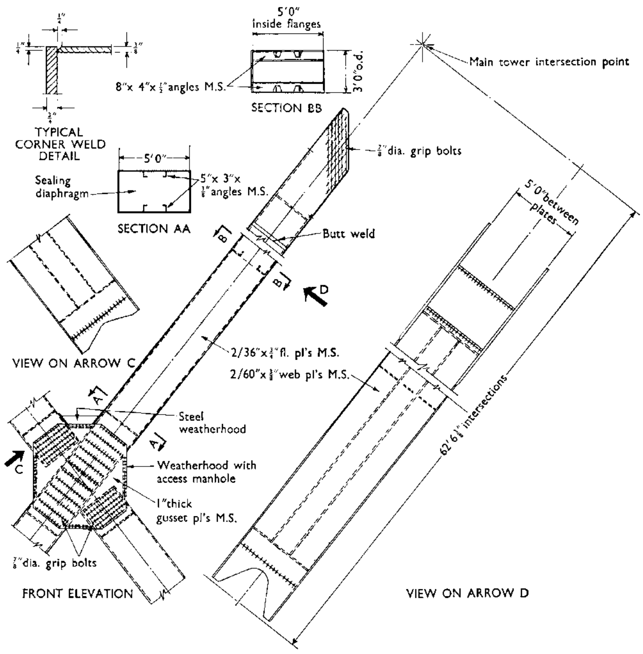


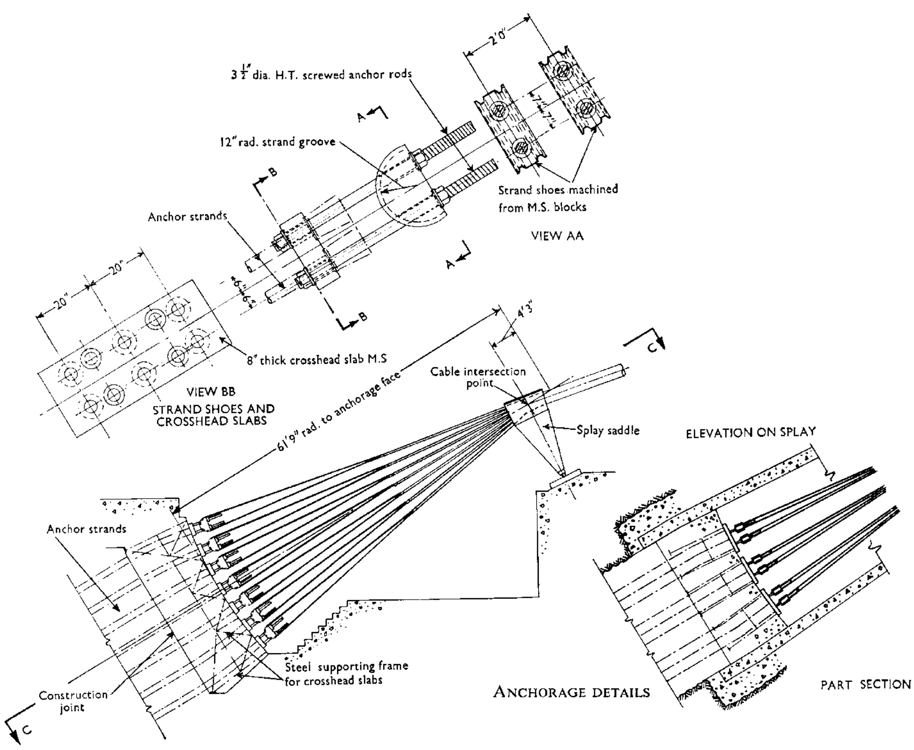
Fig. 8.18. Tower, anchorage and bearing details



LEG DETAILS



TYPICAL MAIN TOWER BRACING DETAILS



ANCHORAGE DETAILS

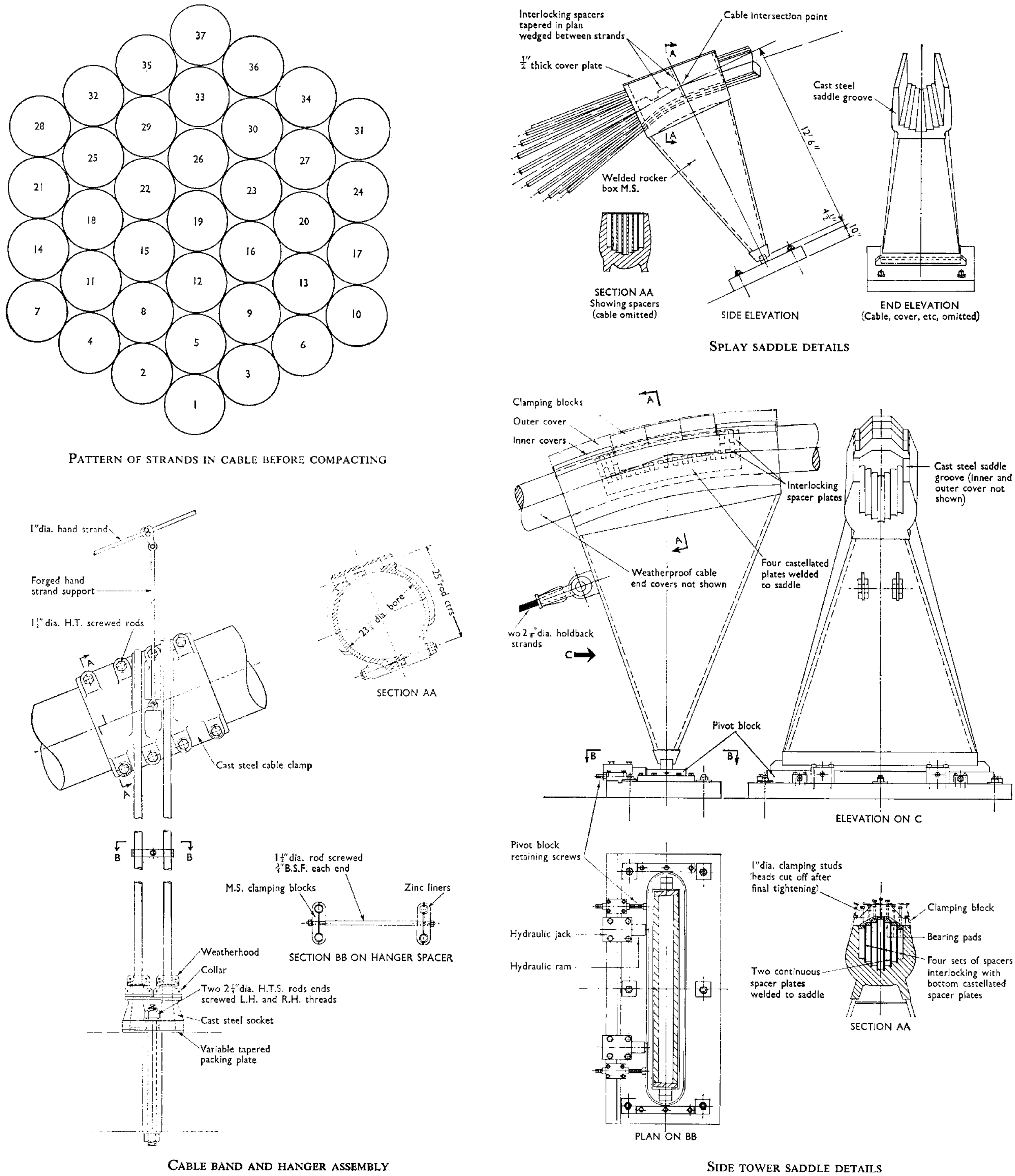
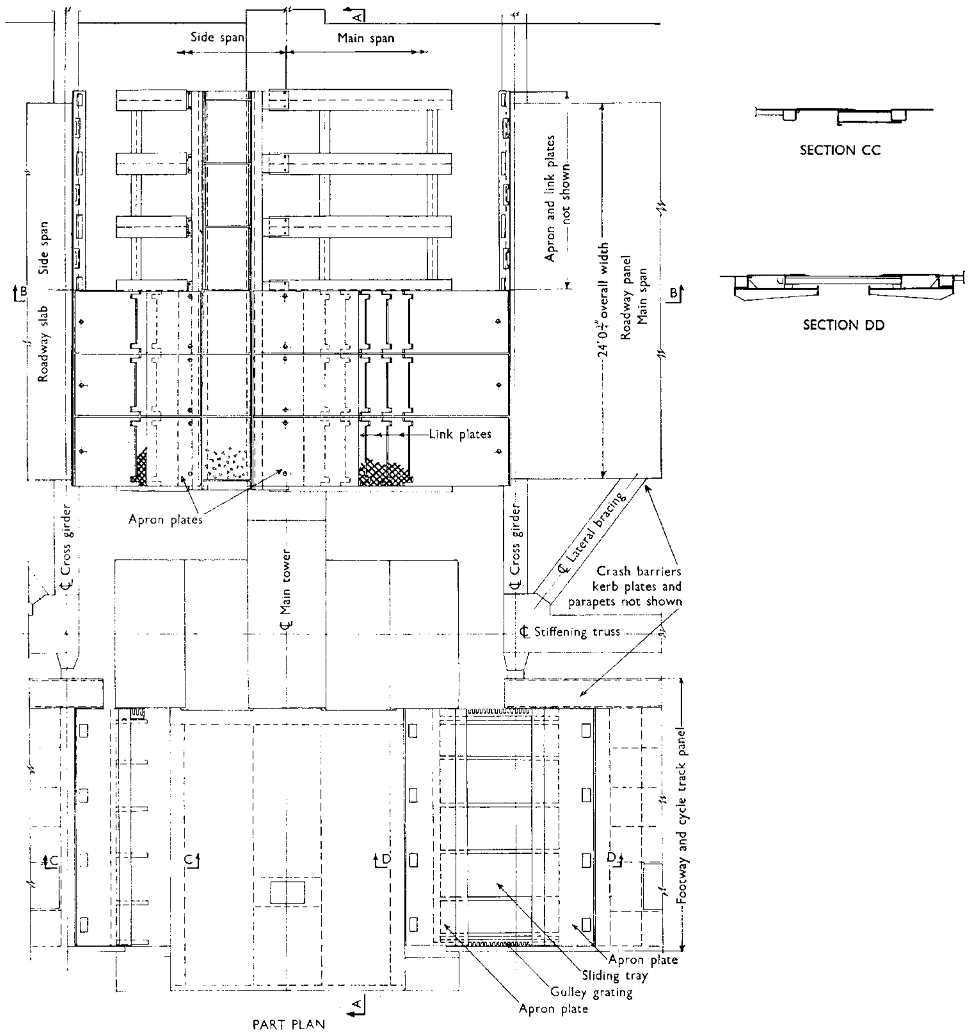
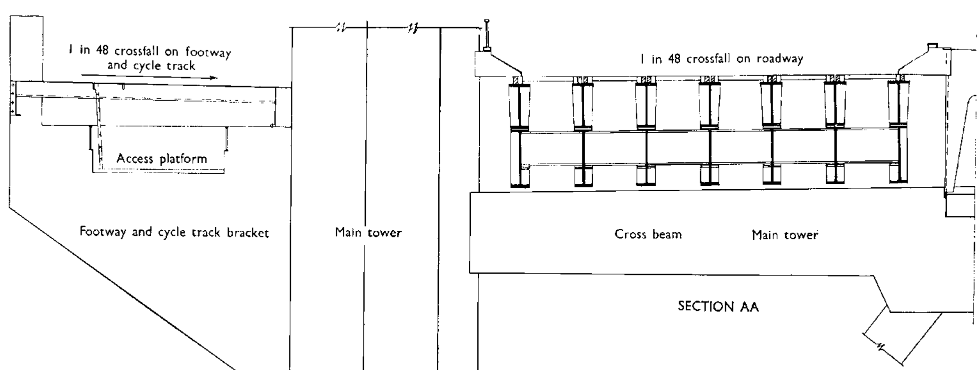
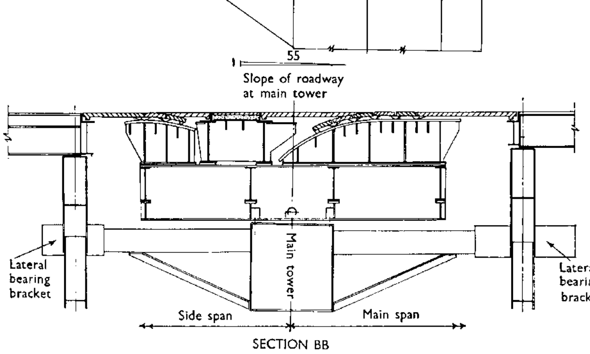


Fig. 8.19. Cable details and hanger assembly







EXPANSION JOINTS AT MAIN TOWERS

8.4. Cable-stayed bridge based on EC3 and ENV-1-1991

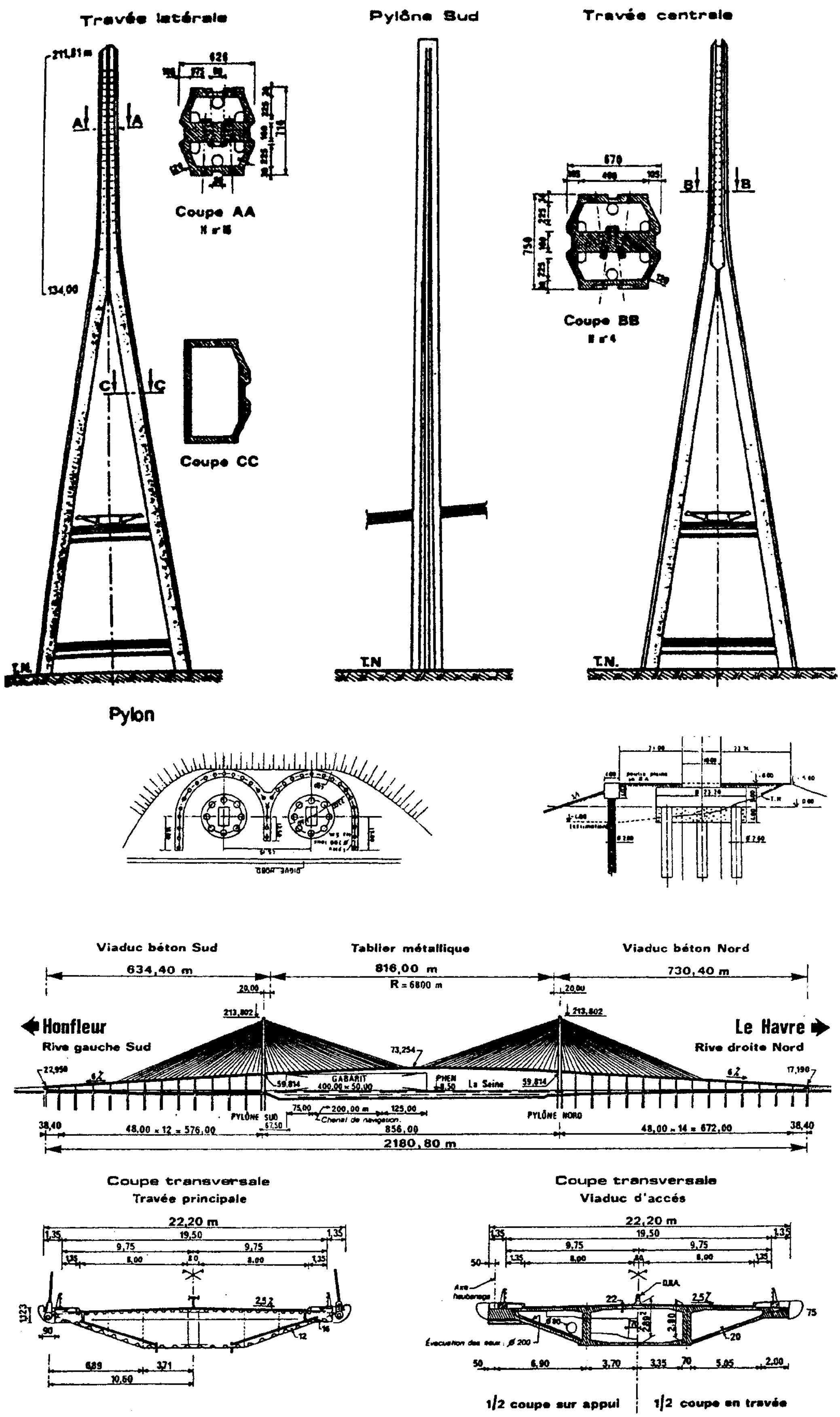


Fig. 8.20. Elevation, cross-section and pylon structural details

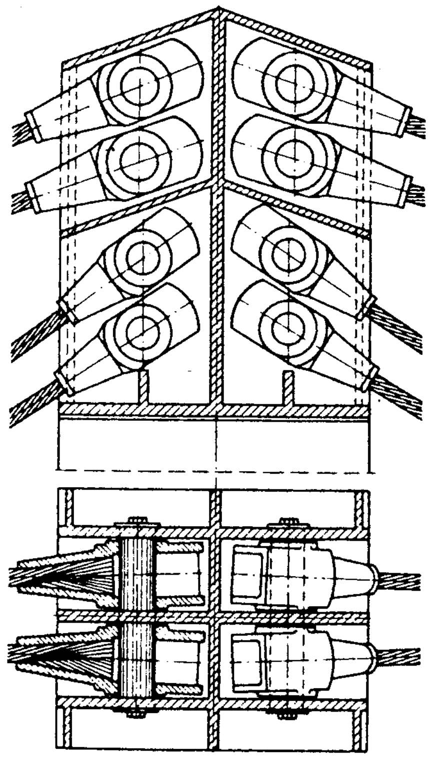


Fig. 8.21. Typical cable anchorages

8.5. Poole Harbour Crossing: a cable-stayed bridge

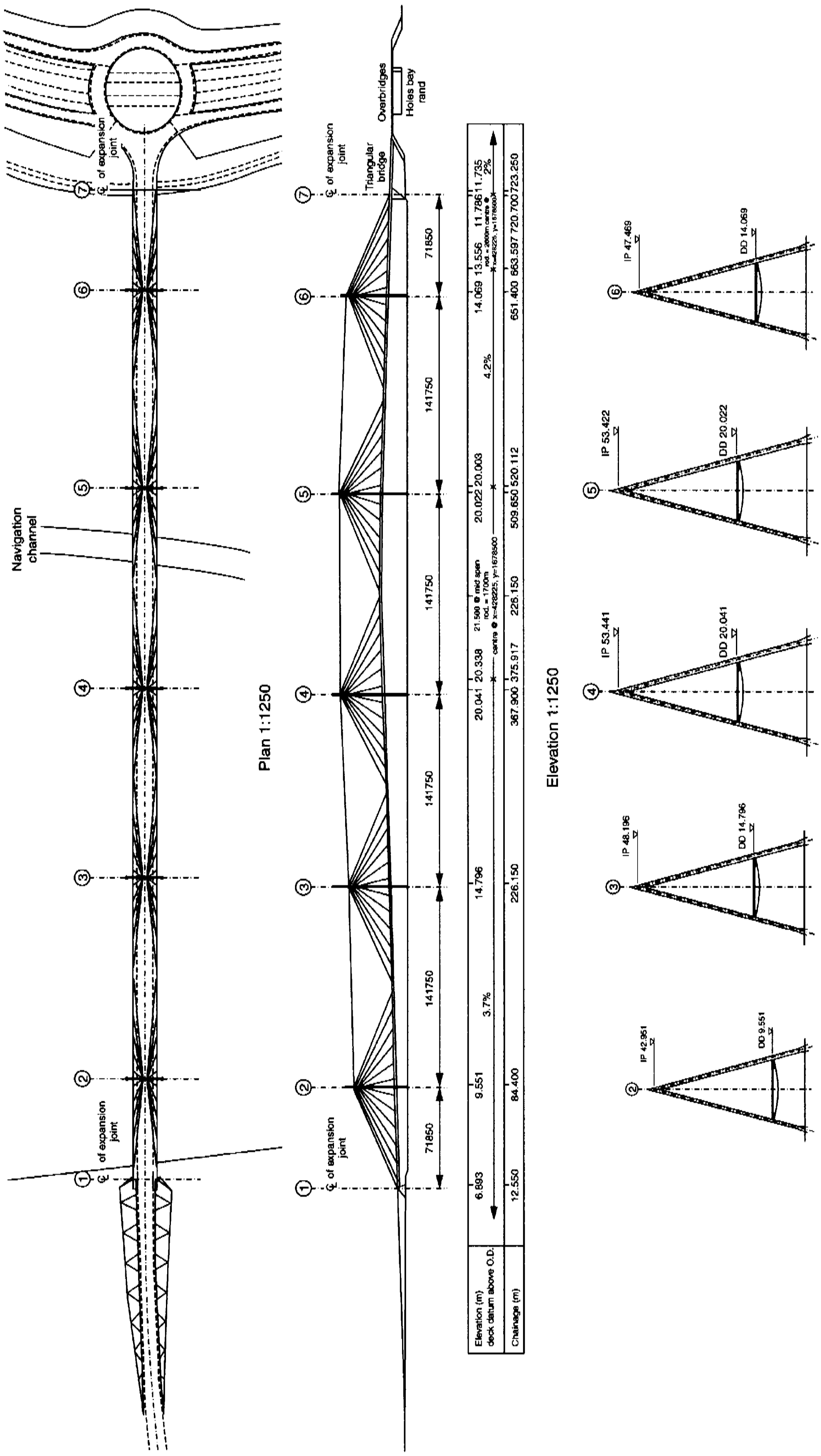


Fig. 8.22. Cable-stayed bridge, plan, elevation and pylons (with compliments of Flint & Neal, Consulting Engineers, London)

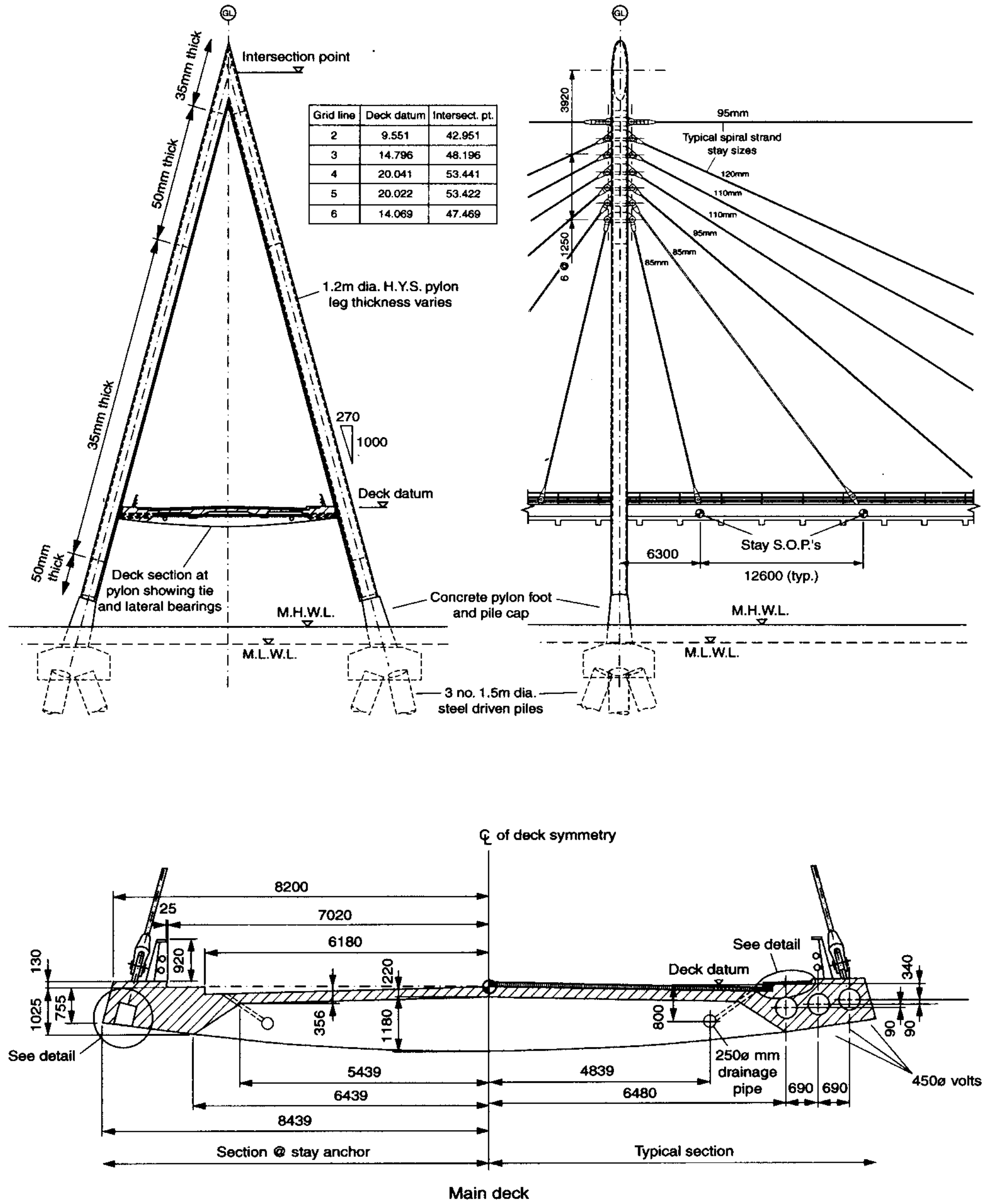


Fig. 8.22. Continued, pylons and bridge deck

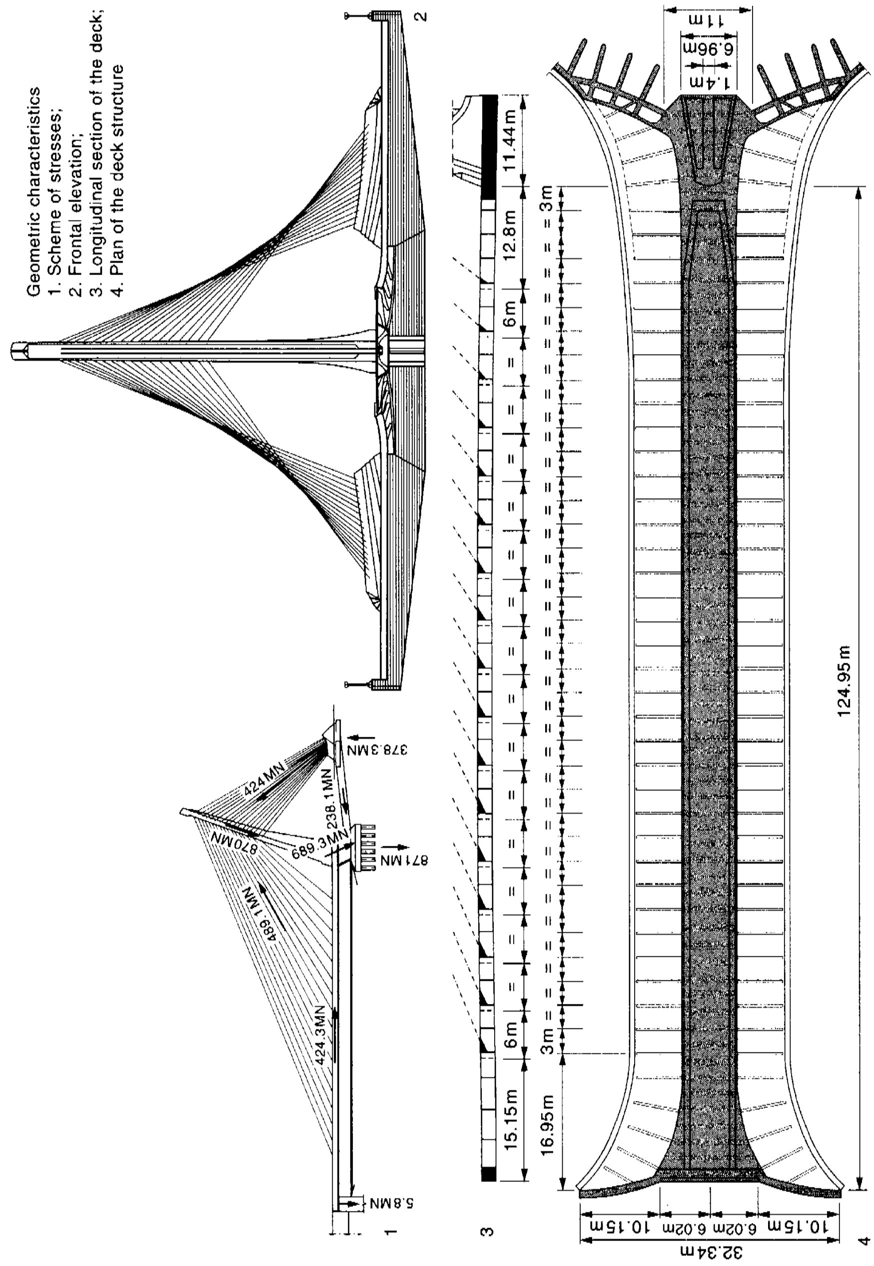


Fig. 8.22. Continued, geometric characteristics: sections, elevation and plan

8.6. Handrails, guard rails, bearings and expansion joints

Detail 12 Railing variants 1:20

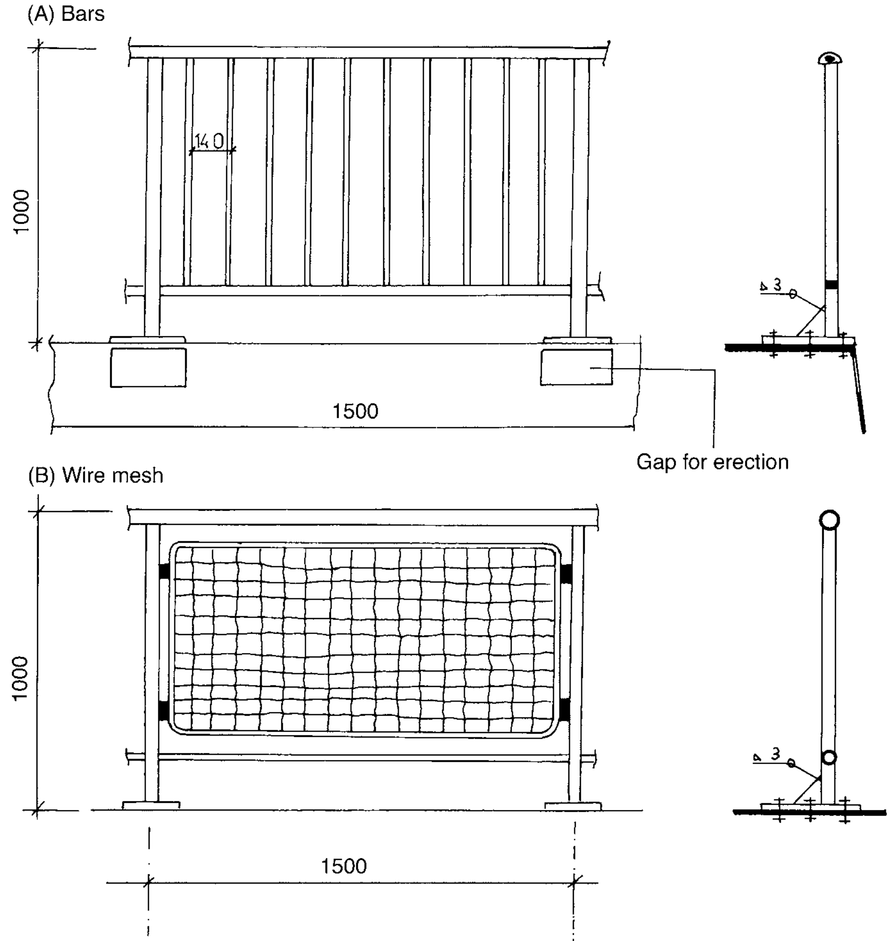
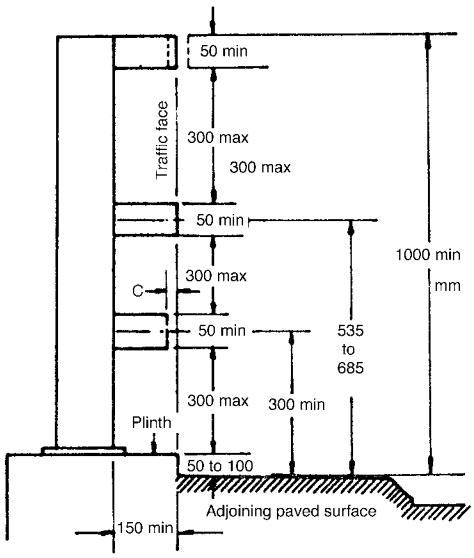
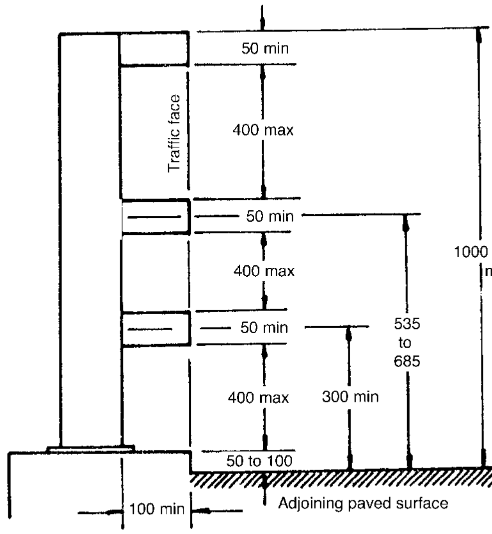


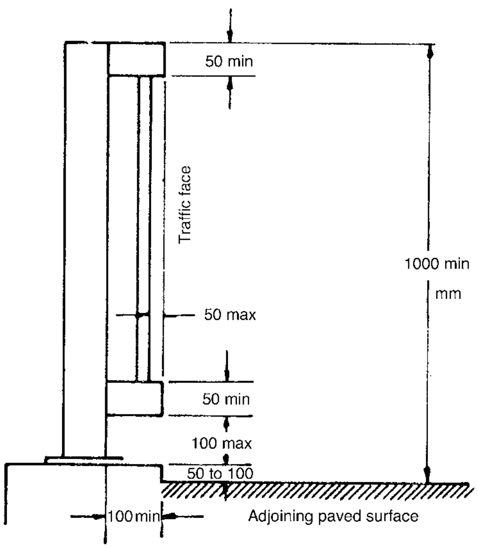
Fig. 8.23. Handrails and guard rails—structural detailing



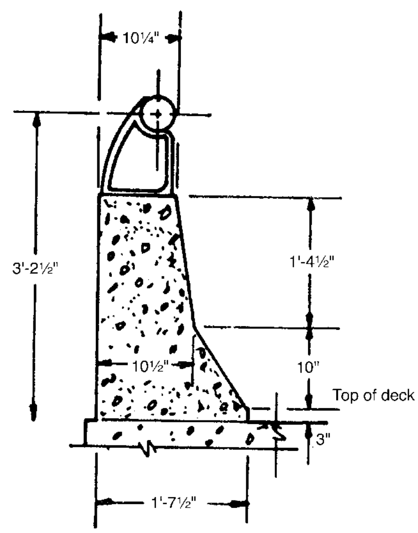
P1 'Vehicle-Parapet' with plinth less than 700 mm high for use on motorway under-bridges



P2 'Vehicle-Pedestrian Parapet' for use on all pupose road bridges. The design speed being stated

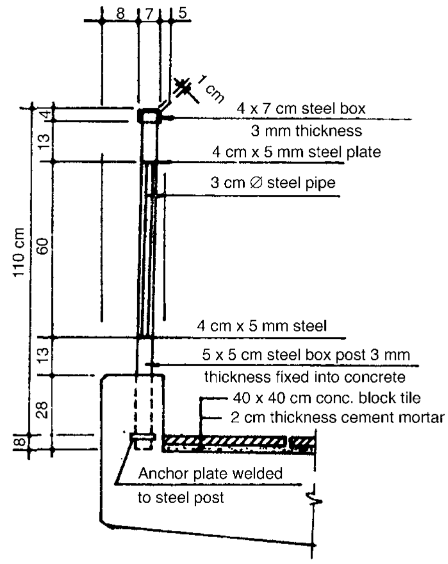


P2 'Vehicle-Pedestrian Parapet' for use in road bridges where speed is restricted to 48 km/hr

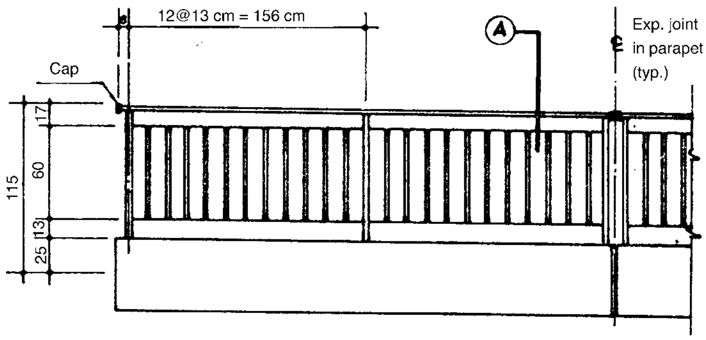


Vehicle-Parapet Kerb (reinforcement not shown) AASHTO/ACI

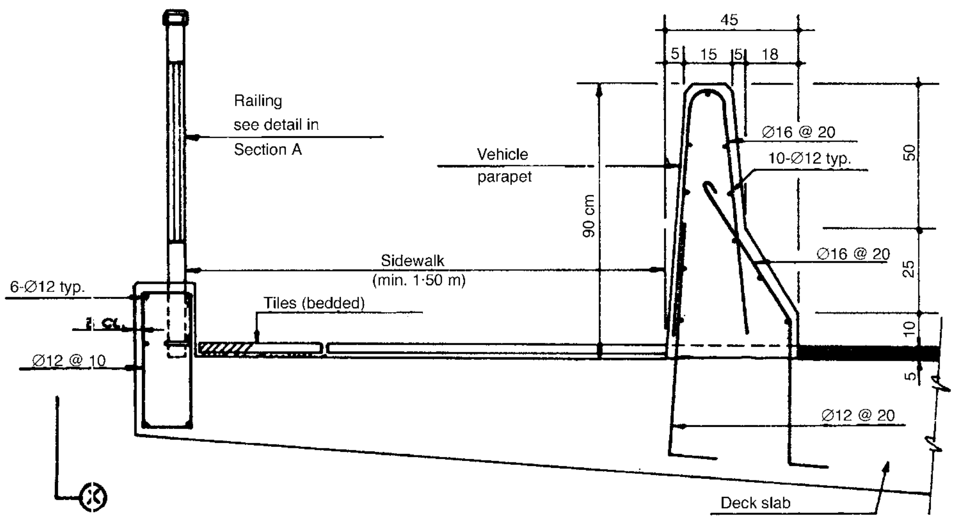
Fig. 8.24. Vehicle parapets and railings



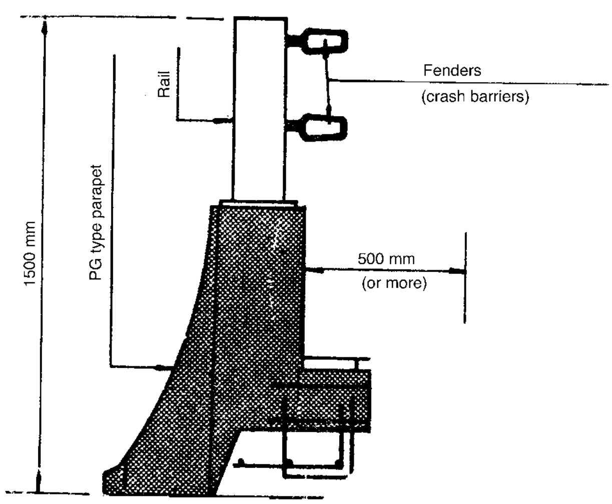
Section – A (Railing)



Elevation – X (Railing)



Vehicle-parapet and railing for bridge with side-walk (slab reinforcement not shown.)



8.7. Steel shoes or bearings and expansion joints for steel bridges

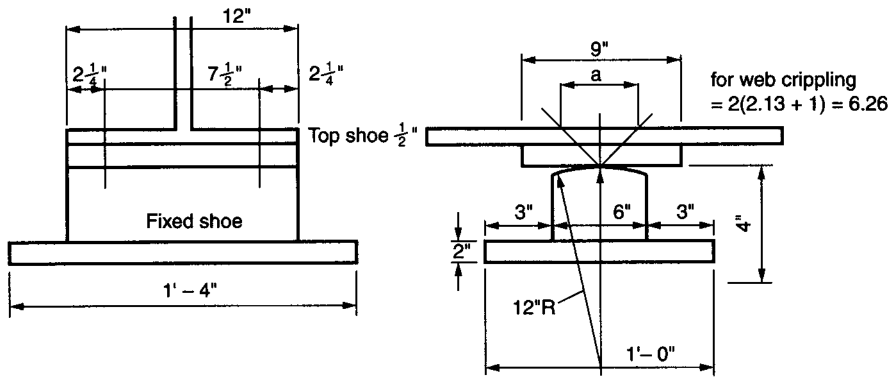


Fig. 8.25. Structural details and shoe (bearing) setting data

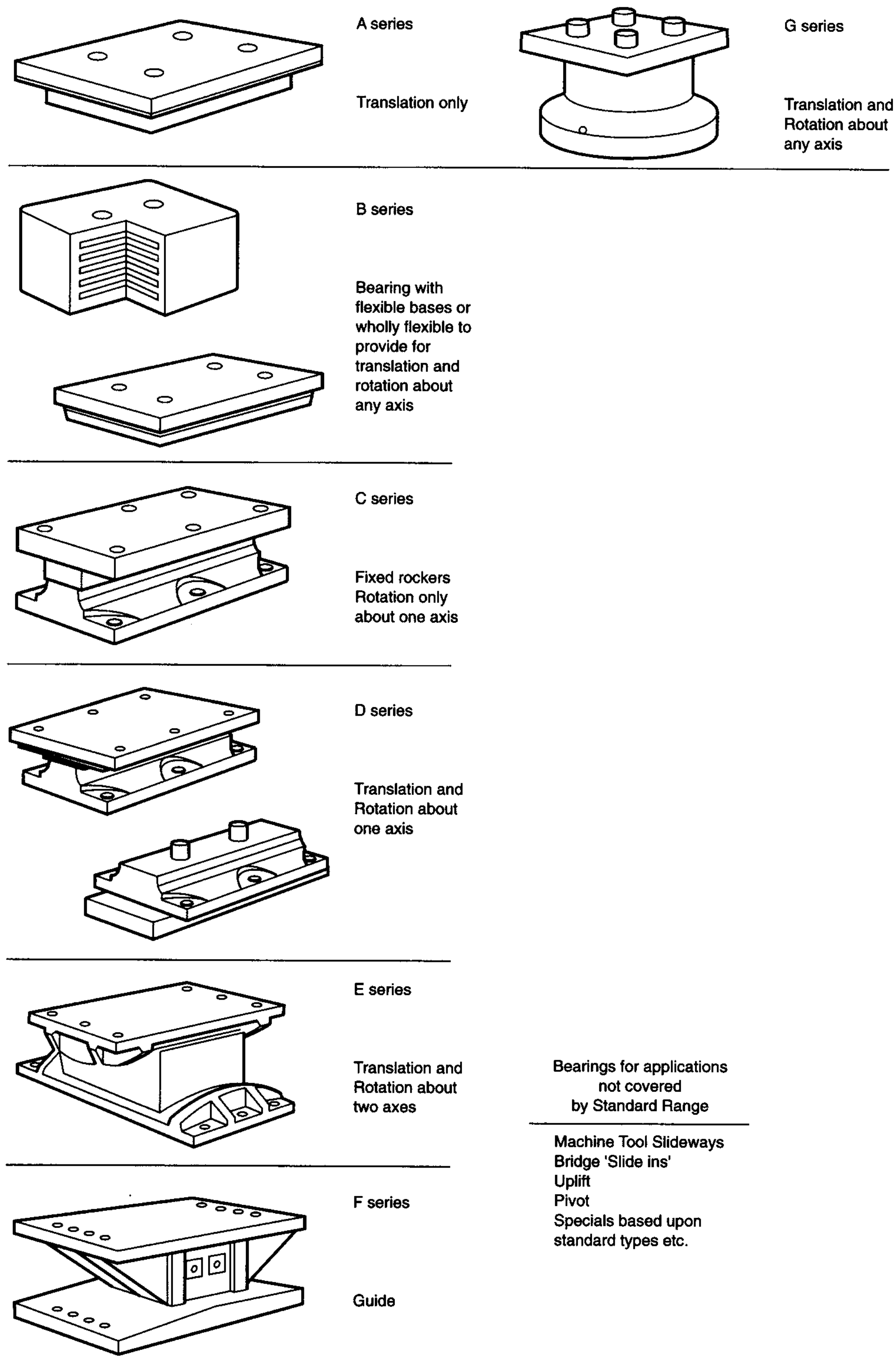


Fig. 8.26. Structural design of various types of bearings

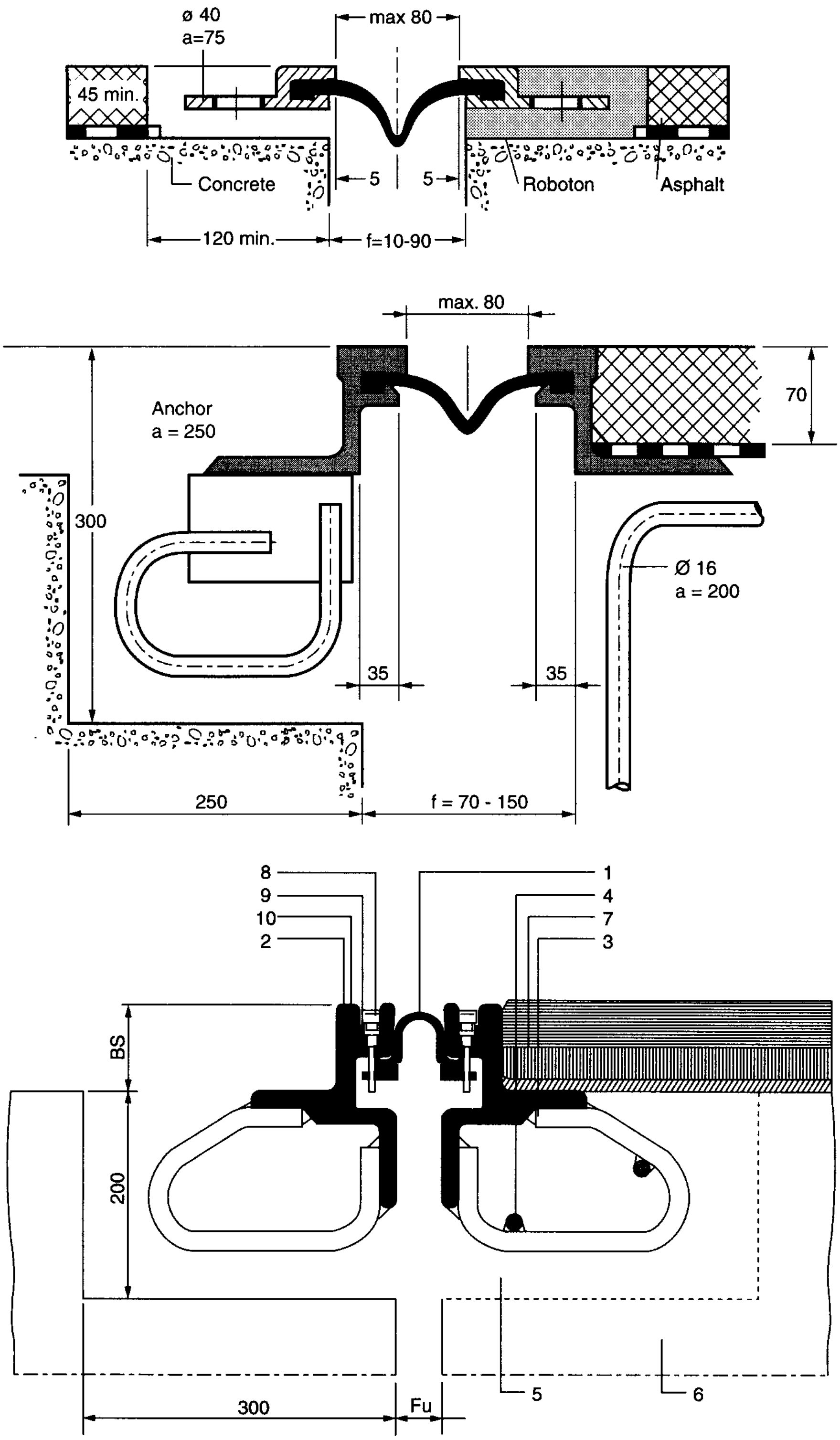


Fig. 8.27. Expansion joints

Appendix. Section properties

UNIVERSAL BEAMS
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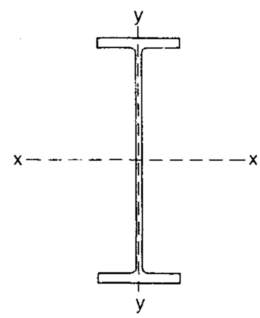

Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter *u*	Torsional Index *x*	Warping Constant *H*	Torsional Constant *J*	Area of Section	Mass per metre	Designation
Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y							
cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2	kg/m	
18·7	3·37	1571	153	1811	240	0·873	27·4	0·591	89·2	105	82·1	**457 x 152 x 82**
18·6	3·33	1414	136	1627	213	0·873	30·1	0·518	65·9	94·5	74·2	**457 x 152 x 74**
18·4	3·27	1263	119	1453	187	0·869	33·6	0·448	47·7	85·6	67·2	**457 x 152 x 67**
18·3	3·23	1122	104	1287	163	0·868	37·5	0·387	33·8	76·2	59·8	**457 x 152 x 60**
17·9	3·11	950	84·6	1096	133	0·859	43·9	0·311	21·4	66·6	52·3	**457 x 152 x 52**
17·0	4·04	1323	172	1501	267	0·882	27·6	0·608	62·8	94·5	74·2	**406 x 178 x 74**
16·9	3·99	1189	153	1346	237	0·880	30·5	0·533	46·1	85·5	67·1	**406 x 178 x 67**
16·8	3·97	1063	135	1199	209	0·880	33·8	0·466	33·3	76·5	60·1	**406 x 178 x 60**
16·5	3·85	930	115	1055	178	0·871	38·3	0·392	23·1	69·0	54·1	**406 x 178 x 54**
16·4	3·03	778	75·7	888	118	0·871	38·9	0·207	19·0	58·6	46·0	**406 x 140 x 46**
15·9	2·87	629	57·8	724	90·8	0·858	47·5	0·155	10·7	49·7	39·0	**406 x 140 x 39**
15·1	3·99	1071	157	1211	243	0·886	24·4	0·412	55·7	85·5	67·1	**356 x 171 x 67**
14·9	3·91	896	129	1010	199	0·882	28·8	0·330	33·4	72·6	57·0	**356 x 171 x 57**
14·8	3·86	796	113	896	174	0·881	32·1	0·286	23·8	64·9	51·0	**356 x 171 x 51**
14·5	3·76	687	94·8	775	147	0·874	36·8	0·237	15·8	57·3	45·0	**356 x 171 x 45**
14·3	2·68	576	56·8	659	89·1	0·871	35·2	0·105	15·1	49·8	39·1	**356 x 127 x 39**
14·0	2·58	473	44·7	543	70·3	0·863	42·2	0·0812	8·79	42·1	33·1	**356 x 127 x 33**
13·0	3·93	754	127	846	196	0·889	23·6	0·234	34·8	68·8	54·0	**305 x 165 x 54**
13·0	3·90	646	108	720	166	0·891	27·1	0·195	22·2	58·7	46·1	**305 x 165 x 46**
12·9	3·86	560	92·6	623	142	0·889	31·0	0·164	14·7	51·3	40·3	**305 x 165 x 40**
12·5	2·74	616	73·6	711	116	0·873	23·3	0·102	31·8	61·2	48·1	**305 x 127 x 48**
12·4	2·70	534	62·6	614	98·4	0·872	26·5	0·0846	21·1	53·4	41·9	**305 x 127 x 42**
12·3	2·67	471	54·5	539	85·4	0·872	29·7	0·0725	14·8	47·2	37·0	**305 x 127 x 37**
12·5	2·15	416	37·9	481	60·0	0·866	31·6	0·0442	12·2	41·8	32·8	**305 x 102 x 33**
12·2	2·08	348	30·5	403	48·5	0·859	37·4	0·0349	7·40	35·9	28·2	**305 x 102 x 28**
11·9	1·97	292	24·2	342	38·8	0·846	43·4	0·0273	4·77	31·6	24·8	**305 x 102 x 25**
10·9	3·52	504	92·0	566	141	0·891	21·2	0·103	23·9	54·8	43·0	**254 x 146 x 43**
10·8	3·48	433	78·0	483	119	0·890	24·3	0·0857	15·3	47·2	37·0	**254 x 146 x 37**
10·5	3·36	351	61·3	393	94·1	0·880	29·6	0·0660	8·55	39·7	31·1	**254 x 146 x 31**
10·5	2·22	308	34·9	353	54·8	0·874	27·5	0·0280	9·57	36·1	28·3	**254 x 102 x 28**
10·3	2·15	266	29·2	306	46·0	0·866	31·5	0·0230	6·42	32·0	25·2	**254 x 102 x 25**
10·1	2·06	224	23·5	259	37·3	0·856	36·4	0·0182	4·15	28·0	22·0	**254 x 102 x 22**
8·71	3·17	280	57·5	314	88·2	0·881	21·5	0·0374	10·3	38·2	30·0	**203 x 133 x 30**
8·56	3·10	230	46·2	258	70·9	0·877	25·6	0·0294	5·96	32·0	25·1	**203 x 133 x 25**
8·46	2·36	207	32·2	234	49·8	0·888	22·5	0·0154	7·02	29·4	23·1	**203 x 102 x 23**
7·48	2·37	153	27·0	171	41·6	0·888	22·6	0·00987	4·41	24·3	19·0	**178 x 102 x 19**
6·41	2·10	109	20·2	123	31·2	0·890	19·6	0·00470	3·56	20·3	16·0	**152 x 89 x 16**
5·35	1·84	74·6	14·7	84·2	22·6	0·895	16·3	0·00199	2·85	16·5	13·0	**127 x 76 x 13**

UNIVERSAL BEAMS
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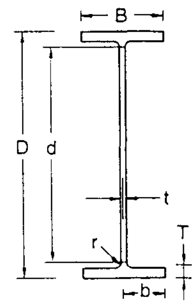
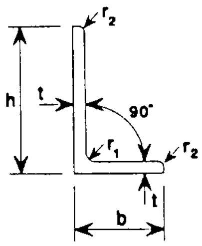
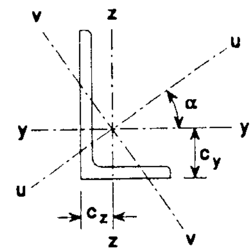


Designation	Mass per metre	Depth of Section D	Width of Section B	Thickness Web t	Thickness Flange T	Root Radius r	Depth between fillets d	Ratios for Local Buckling: Flange b/T	Ratios for Local Buckling: Web d/t	Second Moment of Area: Axis x-x	Second Moment of Area: Axis y-y
	kg/m	mm	mm	mm	mm	mm	mm			cm⁴	cm⁴
457 x 152 x 82	82·1	465·8	155·3	10·5	18·9	10·2	407·6	4·11	38·8	36590	1185
457 x 152 x 74	74·2	462·0	154·4	9·6	17·0	10·2	407·6	4·54	42·5	32670	1047
457 x 152 x 67	67·2	458·0	153·8	9·0	15·0	10·2	407·6	5·13	45·3	28930	913
457 x 152 x 60	59·8	454·6	152·9	8·1	13·3	10·2	407·6	5·75	50·3	25500	795
457 x 152 x 52	52·3	449·8	152·4	7·6	10·9	10·2	407·6	6·99	53·6	21370	645
406 x 178 x 74	74·2	412·8	179·5	9·5	16·0	10·2	360·4	5·61	37·9	27310	1545
406 x 178 x 67	67·1	409·4	178·8	8·8	14·3	10·2	360·4	6·25	41·0	24330	1365
406 x 178 x 60	60·1	406·4	177·9	7·9	12·8	10·2	360·4	6·95	45·6	21600	1203
406 x 178 x 54	54·1	402·6	177·7	7·7	10·9	10·2	360·4	8·15	46·8	18720	1021
406 x 140 x 46	46·0	403·2	142·2	6·8	11·2	10·2	360·4	6·35	53·0	15690	538
406 x 140 x 39	39·0	398·0	141·8	6·4	8·6	10·2	360·4	8·24	56·3	12510	410
356 x 171 x 67	67·1	363·4	173·2	9·1	15·7	10·2	311·6	5·52	34·2	19460	1362
356 x 171 x 57	57·0	358·0	172·2	8·1	13·0	10·2	311·6	6·62	38·5	16040	1108
356 x 171 x 51	51·0	355·0	171·5	7·4	11·5	10·2	311·6	7·46	42·1	14140	968
356 x 171 x 45	45·0	351·4	171·1	7·0	9·7	10·2	311·6	8·82	44·5	12070	811
356 x 127 x 39	39·1	353·4	126·0	6·6	10·7	10·2	311·6	5·89	47·2	10170	358
356 x 127 x 33	33·1	349·0	125·4	6·0	8·5	10·2	311·6	7·38	51·9	8249	280
305 x 165 x 54	54·0	310·4	166·9	7·9	13·7	8·9	265·2	6·09	33·6	11700	1063
305 x 165 x 46	46·1	306·6	165·7	6·7	11·8	8·9	265·2	7·02	39·6	9899	896
305 x 165 x 40	40·3	303·4	165·0	6·0	10·2	8·9	265·2	8·09	44·2	8503	764
305 x 127 x 48	48·1	311·0	125·3	9·0	14·0	8·9	265·2	4·47	29·5	9575	461
305 x 127 x 42	41·9	307·2	124·3	8·0	12·1	8·9	265·2	5·14	33·2	8196	389
305 x 127 x 37	37·0	304·4	123·3	7·1	10·7	8·9	265·2	5·77	37·4	7171	336
305 x 102 x 33	32·8	312·7	102·4	6·6	10·8	7·6	275·9	4·74	41·8	6501	194
305 x 102 x 28	28·2	308·7	101·8	6·0	8·8	7·6	275·9	5·78	46·0	5366	155
305 x 102 x 25	24·8	305·1	101·6	5·8	7·0	7·6	275·9	7·26	47·6	4455	123
254 x 146 x 43	43·0	259·6	147·3	7·2	12·7	7·6	219·0	5·80	30·4	6544	677
254 x 146 x 37	37·0	256·0	146·4	6·3	10·9	7·6	219·0	6·72	34·8	5537	571
254 x 146 x 31	31·1	251·4	146·1	6·0	8·6	7·6	219·0	8·49	36·5	4413	448
254 x 102 x 28	28·3	260·4	102·2	6·3	10·0	7·6	225·2	5·11	35·7	4005	179
254 x 102 x 25	25·2	257·2	101·9	6·0	8·4	7·6	225·2	6·07	37·5	3415	149
254 x 102 x 22	22·0	254·0	101·6	5·7	6·8	7·6	225·2	7·47	39·5	2841	119
203 x 133 x 30	30·0	206·8	133·9	6·4	9·6	7·6	172·4	6·97	26·9	2896	385
203 x 133 x 25	25·1	203·2	133·2	5·7	7·8	7·6	172·4	8·54	30·2	2340	308
203 x 102 x 23	23·1	203·2	101·8	5·4	9·3	7·6	169·4	5·47	31·4	2105	164
178 x 102 x 19	19·0	177·8	101·2	4·8	7·9	7·6	146·8	6·41	30·6	1356	137
152 x 89 x 16	16·0	152·4	88·7	4·5	7·7	7·6	121·8	5·76	27·1	834	89·8
127 x 76 x 13	13·0	127·0	76·0	4·0	7·6	7·6	96·6	5·00	24·1	473	55·7

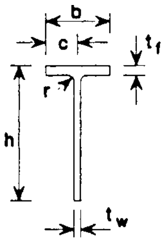


UNEQUAL ANGLES

EC3 CLASSIFICATION

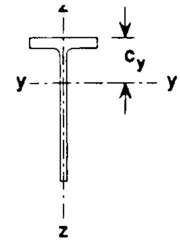


Designation		Fe 430 (S 275)					Fe 510 (S 355)				
Serial Size	Thick-ness	Axial Load only	Bending only				Axial Load only	Bending only			
			yy Toe in tens	yy Toe in comp	zz Toe in tens	zz Toe in comp		yy Toe in tens	yy Toe in comp	zz Toe in tens	zz Toe in comp
mm	mm										
40x25	4,0	2	1	1	2	1	3	1	1	3	1
60x30	5,0	3	1	1	3	1	3	1	2	3	1
	6,0	2	1	1	2	1	3	1	1	3	1
65x50	5,0	4	2	3	3	1	4	3	3	4	3
	6,0	3	1	1	3	1	4	2	3	3	1
	8,0	1	1	1	1	1	1	1	1	1	1
75x50	6,0	3	1	2	3	1	4	2	3	4	1
	8,0	2	1	1	2	1	3	1	1	3	1
80x60	6,0	4	2	3	3	1	4	3	3	4	3
	7,0	3	1	2	3	1	4	2	3	3	1
	8,0	2	1	1	2	1	3	1	2	3	1
100x65	7,0	4	2	3	4	1	4	3	3	4	2
	8,0	3	1	2	3	1	4	1	3	4	1
	10,0	2	1	1	2	1	3	1	1	3	1
100x75	8,0	4	2	3	3	1	4	3	3	4	2
	10,0	2	1	1	2	1	3	1	2	3	1
	12,0	1	1	1	1	1	2	1	1	2	1
125x75	6,5	4	3	4	4	3	4	3	4	4	3
	8,0	4	2	3	4	1	4	3	4	4	2
	10,0	3	1	2	3	1	4	1	3	4	1
	12,0	3	1	1	3	1	3	1	1	3	1
137x102	6,4	4	4	4	4	3	4	4	4	4	4
	7,9	4	3	3	4	3	4	4	4	4	3
	9,5	4	3	3	4	2	4	3	3	4	3
150x75	10,0	4	1	3	4	1	4	1	3	4	1
	12,0	3	1	1	3	1	4	1	3	4	1
	15,0	2	1	1	2	1	3	1	1	3	1
150x90	10,0	4	1	3	4	1	4	3	3	4	2
	12,0	3	1	2	3	1	4	1	3	4	1
	15,0	2	1	1	2	1	3	1	1	3	1
200x100	10,0	4	2	4	4	2	4	3	4	4	3
	12,0	4	1	3	4	1	4	2	4	4	1
	15,0	3	1	2	3	1	4	1	3	4	1
200x150	12,0	4	3	3	4	3	4	4	4	4	3
	15,0	4	2	3	3	1	4	3	3	4	3
	18,0	3	1	2	3	1	4	2	3	3	1

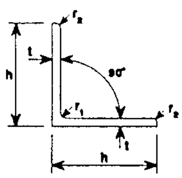


STRUCTURAL TEES
CUT FROM UNIVERSAL BEAMS

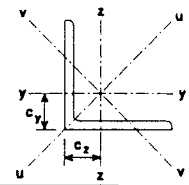
DIMENSIONS AND EC3 CLASSIFICATION



Designation		Width of Section	Depth of Section	Thickness		Root Radius	Centre of gravity	Shear Area	Ratios for Local Buckling		EC3 Classification							
											Fe 430 (S 275)				Fe 510 (S 355)			
Serial Size	Mass per Metre			Web	Flange				Flange	Web	Axial Load only	Bending only			Axial Load only	Bending only		
		b	h	t_w	t_f	r	C_y	A_v	c/t_f	h/t_w		yy Flange in comp	yy Flange in tens	zz		yy Flange in comp	yy Flange in tens	zz
mm	kg	mm	mm	mm	mm	mm	cm	cm^2										
76x64	7	76,2	63,5	4,2	7,6	7,6	1,3	3,33	5,01	15,1	4	1	3	1	4	1	4	1
89x76	8	88,9	76,2	4,6	7,7	7,6	1,6	4,16	5,77	16,6	4	1	3	1	4	1	4	1
102x89	10	101,6	88,9	4,7	7,9	7,6	1,8	4,84	6,43	18,9	4	1	4	1	4	1	4	1
102x102	12	101,6	101,6	5,2	9,3	7,6	2,2	6,00	5,46	19,5	4	1	4	1	4	1	4	1
133x102	13	133,4	101,6	5,8	7,8	7,6	2,1	6,51	8,55	17,5	4	1	4	1	4	2	4	2
	15	133,8	103,4	6,3	9,6	7,6	2,1	7,19	6,97	16,4	4	1	3	1	4	1	4	1
102x127	11	101,6	127,0	5,8	6,8	7,6	3,5	7,93	7,47	21,9	4	1	4	1	4	1	4	1
	13	101,9	128,5	6,1	8,4	7,6	3,3	8,47	6,07	21,1	4	1	4	1	4	1	4	1
	14	102,1	130,2	6,4	10,0	7,6	3,3	9,02	5,11	20,3	4	1	4	1	4	1	4	1
146x127	16	146,1	125,7	6,1	8,6	7,6	2,7	8,31	8,49	20,6	4	1	4	1	4	2	4	2
	19	146,4	128,0	6,4	10,9	7,6	2,6	8,92	6,72	20,0	4	1	4	1	4	1	4	1
	22	147,3	129,8	7,3	12,7	7,6	2,7	10,2	5,80	17,8	4	1	4	1	4	1	4	1
102x153	13	101,6	152,4	5,8	6,8	7,6	4,5	9,41	7,47	26,3	4	1	4	1	4	1	4	1
	14	101,9	154,4	6,1	8,9	7,6	4,2	10,1	5,72	25,3	4	1	4	1	4	1	4	1
	17	102,4	156,3	6,6	10,8	7,6	4,1	11,0	4,74	23,7	4	1	4	1	4	1	4	1
127x152	19	123,5	151,9	7,2	10,7	8,9	3,8	11,8	5,77	21,1	4	1	4	1	4	1	4	1
	21	124,3	153,3	8,0	12,1	8,9	3,9	13,2	5,14	19,2	4	1	4	1	4	1	4	1
	24	125,2	155,2	8,9	14,0	8,9	3,9	14,8	4,47	17,4	4	1	4	1	4	1	4	1
165x152	20	165,1	151,9	6,1	10,2	8,9	3,1	10,2	8,09	24,9	4	1	4	1	4	1	4	1
	23	165,7	153,5	6,7	11,8	8,9	3,1	11,3	7,02	22,9	4	1	4	1	4	1	4	1
	27	166,8	155,4	7,7	13,7	8,9	3,2	13,0	6,09	20,2	4	1	4	1	4	1	4	1
127x178	17	125,4	174,2	5,9	8,5	10,2	4,5	11,3	7,38	29,5	4	1	4	1	4	1	4	1
	20	126,0	176,4	6,5	10,7	10,2	4,4	12,7	5,89	27,1	4	1	4	1	4	1	4	1
171x178	23	171,0	176,0	6,9	9,7	10,2	4,0	13,2	8,81	25,5	4	1	4	1	4	2	4	2
	26	171,5	177,8	7,3	11,5	10,2	3,9	14,2	7,46	24,4	4	1	4	1	4	1	4	1
	29	172,1	179,3	8,0	13,0	10,2	4,0	15,6	6,62	22,4	4	1	4	1	4	1	4	1
	34	173,2	182,0	9,1	15,7	10,2	4,0	17,9	5,52	20,0	4	1	4	1	4	1	4	1
140x203	20	141,8	198,6	6,3	8,6	10,2	5,3	13,6	8,24	31,5	4	1	4	1	4	2	4	2
	23	142,4	201,2	6,9	11,2	10,2	5,0	15,1	6,36	29,2	4	1	4	1	4	1	4	1
178x203	27	177,6	201,3	7,6	10,9	10,2	4,8	16,4	8,15	26,5	4	1	4	1	4	2	4	2
	30	177,8	203,2	7,8	12,8	10,2	4,6	17,1	6,95	26,1	4	1	4	1	4	1	4	1
	34	178,8	204,7	8,8	14,3	10,2	4,7	19,3	6,25	23,3	4	1	4	1	4	1	4	1
	37	179,7	206,4	9,7	16,0	10,2	4,8	21,3	5,62	21,3	4	1	4	1	4	1	4	1



EQUAL ANGLES



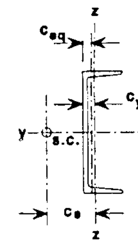
DIMENSIONS AND PROPERTIES

Designation: Size $h \times h$ mm	Designation: Thickness t mm	Mass per Metre kg	Radius: Root r_1 mm	Radius: Toe r_2 mm	Area of Section A cm^2	Distance of Centre of Gravity c_y and c_z cm	Second Moment of Area: Axis y-y, z-z I_y, I_z cm^4	Second Moment of Area: Axis u-u I_u cm^4	Second Moment of Area: Axis v-v I_v cm^4	Radius of Gyration: Axis y-y, z-z i_y, i_z cm	Radius of Gyration: Axis u-u i_u cm	Radius of Gyration: Axis v-v i_v cm	Elastic Modulus: Axis y-y, z-z W_{el} cm^3
25x25	3	1,11	3,5	2,4	1,41	0,718	0,784	1,24	0,325	0,745	0,939	0,480	0,440
	4	1,45	3,5	2,4	1,84	0,758	1,00	1,58	0,421	0,737	0,926	0,478	0,574
	5	1,77	3,5	2,4	2,25	0,796	1,19	1,87	0,515	0,728	0,912	0,478	0,701
30x30	3	1,36	5,0	2,4	1,74	0,836	1,41	2,23	0,588	0,900	1,13	0,581	0,652
	4	1,78	5,0	2,4	2,27	0,879	1,81	2,86	0,756	0,893	1,12	0,577	0,852
	5	2,18	5,0	2,4	2,78	0,919	2,17	3,42	0,919	0,883	1,11	0,575	1,04
40x40	3	1,84	6,0	2,4	2,36	1,08	3,51	5,55	1,47	1,22	1,53	0,788	1,20
	4	2,42	6,0	2,4	3,09	1,12	4,53	7,18	1,89	1,21	1,52	0,781	1,58
	5	2,97	6,0	2,4	3,80	1,17	5,48	8,68	2,29	1,20	1,51	0,776	1,93
	6	3,52	6,0	2,4	4,49	1,20	6,37	10,1	2,68	1,19	1,50	0,773	2,28
45x45	3	2,09	7,0	2,4	2,69	1,20	5,08	8,03	2,14	1,37	1,73	0,892	1,54
	4	2,74	7,0	2,4	3,52	1,24	6,58	10,4	2,75	1,37	1,72	0,883	2,02
	5	3,38	7,0	2,4	4,33	1,29	7,99	12,6	3,33	1,36	1,71	0,877	2,49
	6	4,00	7,0	2,4	5,12	1,33	9,30	14,7	3,90	1,35	1,69	0,872	2,93
50x50	3	2,33	7,0	2,4	2,99	1,32	7,06	11,1	2,97	1,54	1,93	0,996	1,92
	4	3,06	7,0	2,4	3,92	1,37	9,16	14,5	3,82	1,53	1,92	0,987	2,52
	5	3,77	7,0	2,4	4,83	1,41	11,1	17,7	4,63	1,52	1,91	0,979	3,11
	6	4,47	7,0	2,4	5,72	1,45	13,0	20,6	5,43	1,51	1,90	0,974	3,67
	8	5,82	7,0	2,4	7,44	1,53	16,5	25,9	6,96	1,49	1,87	0,968	4,74
60x60	5	4,57	8,0	2,4	5,86	1,65	19,8	31,4	8,23	1,84	2,31	1,18	4,56
	6	5,42	8,0	2,4	6,95	1,70	23,2	36,8	9,64	1,83	2,30	1,18	5,39
	8	7,09	8,0	2,4	9,07	1,78	29,6	46,7	12,4	1,80	2,27	1,17	7,00
	10	8,69	8,0	2,4	11,1	1,85	35,3	55,6	15,0	1,78	2,24	1,16	8,51
70x70	6	6,38	9,0	2,4	8,19	1,94	37,7	59,8	15,6	2,15	2,70	1,38	7,45
	8	8,36	9,0	2,4	10,7	2,02	48,3	76,5	20,1	2,12	2,67	1,37	9,70
	10	10,3	9,0	2,4	13,1	2,10	58,0	91,6	24,4	2,10	2,64	1,36	11,8
80x80	6	7,34	10,0	4,8	9,36	2,17	56,0	88,7	23,2	2,45	3,08	1,57	9,60
	8	9,63	10,0	4,8	12,3	2,26	72,4	115	29,9	2,43	3,06	1,56	12,6
	10	11,9	10,0	4,8	15,1	2,34	87,6	139	36,4	2,41	3,03	1,55	15,5

EC3 CLASSIFICATION

Designation: Serial Size mm	Designation: Thickness mm	Fe 430 (S 275): Axial Load only	Fe 430 (S 275): Bending only yy/zz Toe in tens	Fe 430 (S 275): Bending only yy/zz Toe in comp	Fe 510 (S 355): Axial Load only	Fe 510 (S 355): Bending only yy/zz Toe in tens	Fe 510 (S 355): Bending only yy/zz Toe in comp
25x25	3	1	1	1	2	2	1
	4	1	1	1	1	1	1
	5	1	1	1	1	1	1
30x30	3	2	2	1	4	3	3
	4	1	1	1	1	1	1
	5	1	1	1	1	1	1
40x40	3	4	3	3	4	4	3
	4	2	2	1	4	3	3
	5	1	1	1	1	1	1
	6	1	1	1	1	1	1
45x45	3	4	4	3	4	4	3
	4	4	3	3	4	3	3
	5	1	1	1	3	3	1
	6	1	1	1	1	1	1

Designation: Serial Size mm	Designation: Thickness mm	Fe 430 (S 275): Axial Load only	Fe 430 (S 275): Bending only yy/zz Toe in tens	Fe 430 (S 275): Bending only yy/zz Toe in comp	Fe 510 (S 355): Axial Load only	Fe 510 (S 355): Bending only yy/zz Toe in tens	Fe 510 (S 355): Bending only yy/zz Toe in comp
50x50	3	4	4	3	4	4	4
	4	4	3	3	4	4	3
	5	2	2	1	4	3	3
	6	1	1	1	2	2	1
	8	1	1	1	1	1	1
60x60	5	4	3	3	4	3	3
	6	2	2	1	4	3	3
	8	1	1	1	1	1	1
	10	1	1	1	1	1	1
70x70	6	4	3	3	4	3	3
	8	1	1	1	2	2	1
	10	1	1	1	1	1	1
80x80	6	4	3	3	4	4	3
	8	2	2	1	4	3	3
	10	1	1	1	1	1	1



CHANNELS

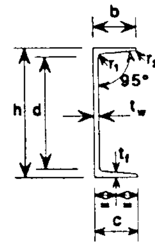
PROPERTIES

Designation		Second Moment of Area		Radius of Gyration		Lateral-torsional Buckling Constants [1]			Elastic Modulus		Plastic Modulus		Warping Constant	Torsion Constant	Area of Section
Serial Size	Mass per Metre	Axis y-y	Axis z-z	Axis y-y	Axis z-z				Axis y-y	Axis z-z	Axis y-y	Axis z-z			
		I_y	I_z	i_y	i_z	i_{LT}	a_{LT}	a_{LT}/i_{LT}	$W_{el.y}$	$W_{el.z}$	$W_{pl.y}$	$W_{pl.z}$	I_w	I_t	A
mm	kg	cm^4	cm^4	cm	cm	cm	cm		cm^3	cm^3	cm^3	cm^3	dm^6	cm^4	cm^2
76x38	6,70	74,3	10,7	2,95	1,12	1,18	8,95	7,6	19,5	4,09	23,5	7,78	0,000101	1,26	8,56
102x51	10,42	207	29,0	3,95	1,48	1,58	14,1	8,9	40,8	8,14	48,7	15,7	0,000512	2,58	13,3
127x64	14,90	482	67,2	5,04	1,88	1,99	19,4	9,7	76,0	15,2	89,4	29,3	0,00188	5,00	19,0
152x76	17,88	852	114	6,11	2,23	2,39	28,4	11,9	112	21,0	130	41,2	0,00486	6,05	22,8
152x89	23,84	1168	216	6,20	2,66	2,78	26,3	9,5	153	35,8	178	68,3	0,00882	12,7	30,4
178x76	20,84	1338	134	7,10	2,25	2,40	30,4	12,7	151	24,8	176	48,1	0,00765	8,26	26,6
178x89	26,81	1753	241	7,17	2,66	2,80	29,6	10,6	197	39,3	230	75,4	0,0134	15,3	34,1
203x76	23,82	1955	152	8,02	2,24	2,40	32,6	13,6	192	27,7	226	53,5	0,0112	10,6	30,4
203x89	29,78	2492	265	8,11	2,64	2,80	32,6	11,6	245	42,4	287	81,7	0,0192	18,1	37,9
229x76	26,06	2615	159	8,87	2,19	2,39	36,1	15,1	229	28,3	271	54,5	0,0151	11,6	33,2
229x89	32,76	3383	285	9,01	2,61	2,80	35,7	12,8	296	44,8	348	86,3	0,0263	20,6	41,6
254x76	28,29	3355	162	9,67	2,12	2,37	39,7	16,8	264	28,1	316	53,9	0,0194	12,3	35,9
254x89	35,74	4445	302	9,89	2,58	2,80	38,7	13,8	350	46,7	414	89,6	0,0347	23,2	45,4
305x89	41,69	7078	326	11,5	2,47	2,76	44,3	16,1	464	48,6	559	92,9	0,0552	28,1	53,3
305x102	46,18	8208	499	11,8	2,91	3,19	48,4	15,2	539	66,5	638	128	0,0842	35,9	58,9
381x102	55,10	14870	579	14,6	2,87	3,18	57,5	18,1	781	75,7	931	144	0,153	46,4	70,1
432x102	65,54	21370	627	16,0	2,74	3,11	59,3	19,1	990	79,9	1205	153	0,216	61,5	83,4

[1] The lateral-torsional buckling constants i_{LT} and a_{LT} are for use with Annex F of EC3:Part 1

SHEAR CENTRE, CENTROIDAL AND EQUAL AREA AXIS

Designation		Distances to back of channel		Distance from the Centroidal Axis to the Shear Centre	Designation		Distances to back of channel		Distance from the Centroidal Axis to the Shear Centre	Designation		Distances to back of channel		Distance from the Centroida Axis to the Shear Centre
Serial Size	Mass per Metre	From centre of gravity	From equal area axis		Serial Size	Mass per Metre	From centre of gravity	From equal area axis		Serial Size	Mass per Metre	From centre of gravity	From equal area axis	
mm	kg	cm	cm	cm	mm	kg	cm	cm	cm	mm	kg	cm	cm	cm
76x38	6,70	1,19	0,67	2,37	178x89	26,81	2,76	1,70	5,93	254x89	35,74	2,42	0,89	5,16
102x51	10,42	1,51	0,76	3,10	203x76	23,82	2,14	0,89	4,62	305x89	41,69	2,18	0,87	4,60
127x64	14,90	1,94	1,09	4,80	203x89	29,78	2,65	1,40	5,68	305x102	46,18	2,65	0,97	5,73
152x76	17,88	2,21	1,15	4,85	229x76	26,06	2,00	0,73	4,32	381x102	55,10	2,52	0,92	5,44
152x89	23,84	2,87	1,99	6,16	229x89	32,76	2,53	1,10	5,42	432x102	65,54	2,31	0,97	4,83
178x76	20,84	2,20	1,09	4,80	254x76	28,29	1,85	0,71	4,00					



CHANNELS

DIMENSIONS AND EC3 CLASSIFICATION

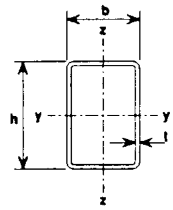
Designation		Depth of Section	Width of Section	Thickness		Root Radius	Toe Radius	Depth between Fillets	Shear Area	Ratios for Local Buckling		EC3 Classification					
												Fe 430 (S 275)			Fe 510 (S 355)		
Serial Size	Mass per Metre			Web	Flange					Flange	Web	Axial Load only	Bending only		Axial Load only	Bending only	
		h	b	t_w	t_f	r_1	r_2	d	A_v	c/t_f	d/t_w		yy	zz[1)]		yy	zz[1)]
mm	kg	mm	mm	mm	mm	mm	mm	mm	cm^2								
76x38	6,70*	76,2	38,1	5,1	7,0	7,6	2,4	45,8	3,86	5,44	8,98	1	1	1	1	1	1
102x51	10,42*	101,6	50,8	6,1	7,9	9,1	2,4	65,8	6,12	6,43	10,8	1	1	1	1	1	1
127x64	14,90	127,0	63,5	6,4	9,5	10,7	2,4	84,0	8,17	6,68	13,1	1	1	1	1	1	1
152x76	17,88	152,4	76,2	6,4	9,3	12,2	2,4	105,9	9,92	8,19	16,5	1	1	1	2	2	1
152x89	23,84	152,4	88,9	7,1	11,9	13,7	3,2	96,9	11,1	7,47	13,6	1	1	1	1	1	1
178x76	20,84	177,8	76,2	6,6	10,6	12,2	3,2	128,8	11,9	7,19	19,5	1	1	1	1	1	1
178x89	26,81	177,8	88,9	7,6	12,6	13,7	3,2	121,0	13,7	7,06	15,9	1	1	1	1	1	1
203x76	23,82	203,2	76,2	7,1	11,5	12,2	3,2	152,4	14,5	6,63	21,5	1	1	1	1	1	1
203x89	29,78	203,2	88,9	8,1	13,3	13,7	3,2	145,2	16,6	6,68	17,9	1	1	1	1	1	1
229x76	26,06	228,6	76,2	7,6	11,5	12,2	3,2	177,8	17,4	6,63	23,4	1	1	1	1	1	1
229x89	32,76	228,6	88,9	8,6	13,7	13,7	3,2	169,9	19,6	6,49	19,8	1	1	1	1	1	1
254x76	28,29	254,0	76,2	8,1	11,3	12,2	3,2	203,9	20,4	6,74	25,2	1	1	1	1	1	1
254x89	35,74	254,0	88,9	9,1	14,0	13,7	3,2	194,7	23,0	6,35	21,4	1	1	1	1	1	1
305x89	41,69	304,8	88,9	10,2	14,1	13,7	3,2	245,4	30,6	6,30	24,1	1	1	1	1	1	1
305x102	46,18	304,8	101,6	10,2	15,2	15,2	4,8	239,3	30,8	6,68	23,5	1	1	1	1	1	1
381x102	55,10	381,0	101,6	10,4	16,8	15,2	4,8	312,6	39,4	6,05	30,1	1	1	1	2	1	1
432x102	65,54	431,8	101,6	12,2	17,3	15,2	4,8	362,5	51,8	5,87	29,7	1	1	1	2	1	1

* Check availability of section

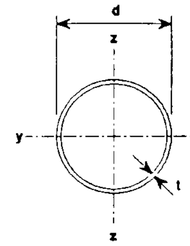
1) EC3 classification for minor axis (z-z) bending of a channel generally depends on whether the toe of the flange is in tension or compression However for all the sections tabulated the classification is 1 in both cases.

RECTANGULAR HOLLOW SECTIONS

DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION



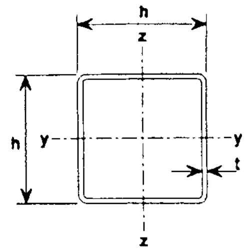
Designation		Mass per Metre	Area of Section	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Torsional Constants		EC3 Classification					
Size	Thick-ness			Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z			Fe 430 (S 275)			Fe 510 (S 355)		
														Axial Load only	Bending only		Axial Load only	Bending only	
h x b	t		A	I_y	I_z	i_y	i_z	$W_{el.y}$	$W_{el.z}$	$W_{pl.y}$	$W_{pl.z}$	I_t	C_t		yy	zz		yy	zz
mm	mm	kg	cm²	cm⁴	cm⁴	cm	cm	cm³	cm³	cm³	cm³	cm⁴	cm³						
150x100	5,0	18,7	23,9	747	396	5,59	4,07	99,5	79,1	121	90,8	806	127	1	1	1	2	1	2
	6,3	23,3	29,7	910	479	5,53	4,02	121	95,9	148	111	985	153	1	1	1	1	1	1
	8,0	29,1	37,1	1106	577	5,46	3,94	147	115	183	137	1202	184	1	1	1	1	1	1
	10,0	35,7	45,5	1312	678	5,37	3,86	175	136	220	164	1431	215	1	1	1	1	1	1
	12,5	43,6	55,5	1532	781	5,25	3,75	204	156	263	194	1680	246	1	1	1	1	1	1
160x80	5,0	18,0	22,9	753	251	5,74	3,31	94,1	62,8	117	71,7	599	106	1	1	1	2	1	2
	6,3	22,3	28,5	917	302	5,68	3,26	115	75,6	144	87,7	729	127	1	1	1	1	1	1
	8,0	27,9	35,5	1113	361	5,60	3,19	139	90,2	177	107	882	151	1	1	1	1	1	1
	10,0	34,2	43,5	1318	419	5,50	3,10	165	105	213	127	1041	175	1	1	1	1	1	1
	12,5	41,6	53,0	1536	476	5,38	3,00	192	119	254	150	1206	199	1	1	1	1	1	1
200x100	5,0	22,7	28,9	1509	509	7,23	4,20	151	102	186	115	1202	172	3	1	3	4	1	4
	6,3	28,3	36,0	1851	618	7,17	4,14	185	124	231	141	1473	208	1	1	1	2	1	2
	8,0	35,4	45,1	2269	747	7,09	4,07	227	149	286	174	1802	251	1	1	1	1	1	1
	10,0	43,6	55,5	2718	881	7,00	3,98	272	176	346	209	2154	296	1	1	1	1	1	1
	12,5	53,4	68,0	3218	1022	6,88	3,88	322	204	417	249	2541	342	1	1	1	1	1	1
	16,0	66,4	84,5	3808	1175	6,71	3,73	381	235	505	297	2988	393	1	1	1	1	1	1
200x120	5,0	24,2	30,9	1699	767	7,42	4,98	170	128	206	144	1646	210	3	1	3	4	1	4
	6,0	28,9	36,8	2000	899	7,37	4,94	200	150	244	171	1940	245	1	1	1	2	1	2
	6,3	30,3	38,5	2087	937	7,36	4,93	209	156	255	178	2025	256	1	1	1	2	1	2
	8,0	37,9	48,3	2564	1140	7,28	4,86	256	190	316	220	2491	310	1	1	1	1	1	1
	10,0	46,7	59,5	3079	1356	7,19	4,77	308	226	384	266	2997	367	1	1	1	1	1	1
	12,5	57,3	73,0	3658	1589	7,08	4,67	366	265	464	319	3567	429	1	1	1	1	1	1
250x150	5,0	30,5	38,9	3382	1535	9,33	6,28	271	205	326	229	3275	337	4	1	4	4	2	4
	6,3	38,2	48,6	4178	1886	9,27	6,23	334	252	405	284	4049	413	3	1	3	4	1	4
	8,0	48,0	61,1	5167	2317	9,19	6,16	413	309	505	353	5014	506	1	1	1	2	1	2
	10,0	59,3	75,5	6259	2784	9,10	6,07	501	371	618	430	6082	606	1	1	1	1	1	1
	12,5	73,0	93,0	7518	3310	8,99	5,97	601	441	751	520	7317	717	1	1	1	1	1	1
	16,0	91,5	117	9089	3943	8,83	5,82	727	526	924	635	8863	851	1	1	1	1	1	1
300x200	6,3	48,1	61,2	7880	4216	11,3	8,30	525	422	627	475	8468	681	4	1	4	4	2	4
	8,0	60,5	77,1	9798	5219	11,3	8,23	653	522	785	593	10550	840	2	1	2	4	1	4
	10,0	75,0	95,5	11940	6331	11,2	8,14	796	633	964	726	12890	1016	1	1	1	2	1	2
	12,5	92,6	118	14460	7619	11,1	8,04	964	762	1179	886	15650	1217	1	1	1	1	1	1
	16,0	117	149	17700	9239	10,9	7,89	1180	924	1462	1094	19230	1469	1	1	1	1	1	1
400x200	8,0	73,1	93,1	19710	6695	14,5	8,48	985	669	1210	746	15720	1135	4	1	4	4	1	4
	10,0	90,7	116	24140	8138	14,5	8,39	1207	814	1492	916	19240	1377	3	1	3	4	1	4
	12,5	112	143	29410	9820	14,3	8,29	1471	982	1831	1120	23410	1657	1	1	1	2	1	2
	16,0	142	181	36300	11950	14,2	8,14	1815	1195	2285	1388	28840	2011	1	1	1	1	1	1
450x250	8,0	85,7	109	30270	12200	16,7	10,6	1345	976	1630	1086	27060	1629	4	1	4	4	2	4
	10,0	106	136	37180	14900	16,6	10,5	1653	1192	2013	1338	33250	1986	4	1	4	4	1	4
	12,5	132	168	45470	18100	16,5	10,4	2021	1448	2478	1642	40670	2407	2	1	2	3	1	3
	16,0	167	213	56420	22250	16,3	10,2	2508	1780	3103	2047	50480	2948	1	1	1	1	1	1
500x200	8,0	85,7	109	34270	8170	17,7	8,65	1371	817	1716	900	21100	1430	4	1	4	4	2	4
	10,0	106	136	42110	9945	17,6	8,57	1684	994	2119	1106	25840	1738	4	1	4	4	1	4
	12,5	132	168	51510	12020	17,5	8,46	2060	1202	2609	1354	31480	2097	3	1	3	4	1	4
	16,0	167	213	63930	14670	17,3	8,31	2557	1467	3267	1683	38830	2554	1	1	1	2	1	2
500x300	10,0	122	156	54120	24560	18,7	12,6	2165	1638	2609	1834	52400	2696	4	1	4	4	2	4
	12,5	152	193	66360	29970	18,5	12,5	2655	1998	3218	2257	64310	3282	3	1	3	4	1	4
	16,0	192	245	82670	37080	18,4	12,3	3307	2472	4042	2825	80220	4046	1	1	1	2	1	2
	20,0	237	302	100100	44550	18,2	12,1	4006	2970	4942	3442	97310	4845	1	1	1	1	1	1



CIRCULAR HOLLOW SECTIONS

DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION

Designation: Outside Diameter d (mm)	Designation: Thickness t (mm)	Mass per Metre (kg)	Area of Section A (cm²)	Second Moment of Area I (cm⁴)	Radius of Gyration i (cm)	Elastic Modulus W_{el} (cm³)	Plastic Modulus W_{pl} (cm³)	Torsional Constants I_t (cm⁴)	Torsional Constants C_t (cm³)	Ratio for Local Buckling d/t	EC3 Classification, Section under axial load and/or bending: Fe 430 (S 275)	EC3 Classification, Section under axial load and/or bending: Fe 510 (S 355)
244,5	6,3	37,0	47,1	3346	8,42	274	358	6692	548	38,8	1	2
	8,0	46,7	59,4	4160	8,37	340	448	8320	680	30,6	1	1
	10,0	57,8	73,7	5073	8,30	415	550	10150	830	24,5	1	1
	12,5	71,5	91,1	6147	8,21	503	673	12290	1006	19,6	1	1
	16,0	90,2	115	7533	8,10	616	837	15070	1232	15,3	1	1
	20,0	111	141	8957	7,97	733	1011	17910	1466	12,2	1	1
	25,0	135	172	10520	7,81	860	1210	21040	1720	9,78	1	1
273,0	6,3	41,4	52,8	4696	9,43	344	448	9392	688	43,3	2	2
	8,0	52,3	66,6	5852	9,37	429	562	11700	858	34,1	1	2
	10,0	64,9	82,6	7154	9,31	524	692	14310	1048	27,3	1	1
	12,5	80,3	102	8697	9,22	637	849	17390	1274	21,8	1	1
	16,0	101	129	10710	9,10	784	1058	21420	1568	17,1	1	1
	20,0	125	159	12800	8,97	938	1283	25600	1876	13,6	1	1
	25,0	153	195	15130	8,81	1108	1543	30260	2216	10,9	1	1
323,9	6,3	49,3	62,9	7929	11,2	490	636	15860	980	51,4	2	3
	8,0	62,3	79,4	9910	11,2	612	799	19820	1224	40,5	1	2
	10,0	77,4	98,6	12160	11,1	751	986	24320	1502	32,4	1	1
	12,5	96,0	122	14850	11,0	917	1213	29700	1834	25,9	1	1
	16,0	121	155	18390	10,9	1136	1518	36780	2272	20,2	1	1
	20,0	150	191	22140	10,8	1367	1850	44280	2734	16,2	1	1
	25,0	184	235	26400	10,6	1630	2239	52800	3260	13,0	1	1
355,6	8,0	68,6	87,4	13200	12,3	742	967	26400	1484	44,5	2	2
	10,0	85,2	109	16220	12,2	912	1195	32440	1824	35,6	1	2
	12,5	106	135	19850	12,1	1117	1472	39700	2234	28,4	1	1
	16,0	134	171	24660	12,0	1387	1847	49320	2774	22,2	1	1
	20,0	166	211	29790	11,9	1676	2255	59580	3352	17,8	1	1
	25,0	204	260	35680	11,7	2007	2738	71360	4014	14,2	1	1
406,4	10,0	97,8	125	24480	14,0	1205	1572	48960	2410	40,6	1	2
	12,5	121	155	30030	13,9	1478	1940	60060	2956	32,5	1	1
	16,0	154	196	37450	13,8	1843	2440	74900	3686	25,4	1	1
	20,0	191	243	45430	13,7	2236	2989	90860	4472	20,3	1	1
	25,0	235	300	54700	13,5	2692	3642	109400	5384	16,3	1	1
	32,0	295	376	66430	13,3	3269	4497	132900	6538	12,7	1	1
457,0	10,0	110	140	35090	15,8	1536	1998	70180	3072	45,7	2	2
	12,5	137	175	43140	15,7	1888	2470	86280	3776	36,6	1	2
	16,0	174	222	53960	15,6	2361	3113	107900	4722	28,6	1	1
	20,0	216	275	65680	15,5	2874	3822	131400	5748	22,9	1	1
	25,0	266	339	79420	15,3	3475	4671	158800	6950	18,3	1	1
	32,0	335	427	97010	15,1	4246	5791	194000	8492	14,3	1	1
	40,0	411	524	114900	14,8	5031	6977	229800	10060	11,4	1	1
508,0	10,0	123	156	48520	17,6	1910	2480	97040	3820	50,8	2	3
	12,5	153	195	59760	17,5	2353	3070	119500	4706	40,6	1	2
	16,0	194	247	74910	17,4	2949	3874	149800	5898	31,7	1	1
	20,0	241	307	91430	17,3	3600	4766	182900	7200	25,4	1	1
	25,0	298	379	110900	17,1	4367	5837	221800	8734	20,3	1	1
	32,0	376	479	136100	16,9	5360	7261	272200	10720	15,9	1	1
	40,0	462	588	162200	16,6	6385	8782	324400	12770	12,7	1	1
	50,0	565	719	190900	16,3	7515	10530	381800	15030	10,2	1	1



SQUARE HOLLOW SECTIONS

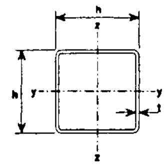
DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION

Designation: Size	Designation: Thickness	Mass per Metre	Area of Section	Second Moment of Area	Radius of Gyration	Elastic Modulus	Plastic Modulus	Torsional Constants		Ratio for Local Buckling	EC3 Classification: Fe 430 (S 275)		EC3 Classification: Fe 510 (S 355)	
											Axial Load only	Bending only	Axial Load only	Bending only
h x h	t		A	I	i	W_{el}	W_{pl}	I_t	C_t	d/t [1]		yy or zz		yy or zz
mm	mm	kg	cm^2	cm^4	cm	cm^3	cm^3	cm^4	cm^3					
20x20	2,0	1,12	1,42	0,759	0,731	0,759	0,951	1,22	1,07	7,00	1	1	1	1
	2,5	1,35	1,72	0,865	0,709	0,865	1,12	1,41	1,21	5,00	1	1	1	1
25x25	2,0	1,43	1,82	1,59	0,935	1,27	1,56	2,52	1,81	9,50	1	1	1	1
	2,5	1,74	2,22	1,85	0,914	1,48	1,86	2,97	2,09	7,00	1	1	1	1
	3,0	2,04	2,60	2,06	0,892	1,65	2,12	3,36	2,31	5,33	1	1	1	1
	3,2	2,15	2,74	2,14	0,883	1,71	2,21	3,49	2,38	4,81	1	1	1	1
30x30	2,5	2,14	2,72	3,40	1,12	2,27	2,79	5,40	3,22	9,00	1	1	1	1
	3,0	2,51	3,20	3,84	1,10	2,56	3,21	6,17	3,61	7,00	1	1	1	1
	3,2	2,65	3,38	4,00	1,09	2,67	3,37	6,45	3,75	6,38	1	1	1	1
40x40	2,5	2,92	3,72	8,67	1,53	4,33	5,21	13,6	6,23	13,0	1	1	1	1
	3,0	3,45	4,40	9,96	1,51	4,98	6,07	15,7	7,11	10,3	1	1	1	1
	3,2	3,66	4,66	10,4	1,50	5,22	6,40	16,5	7,43	9,50	1	1	1	1
	4,0	4,46	5,68	12,1	1,46	6,07	7,61	19,5	8,56	7,00	1	1	1	1
	5,0	5,40	6,88	13,8	1,42	6,92	8,92	22,6	9,65	5,00	1	1	1	1
50x50	2,5	3,71	4,72	17,7	1,94	7,07	8,38	27,4	10,2	17,0	1	1	1	1
	3,0	4,39	5,60	20,5	1,91	8,20	9,83	32,0	11,8	13,7	1	1	1	1
	3,2	4,66	5,94	21,6	1,91	8,62	10,4	33,8	12,4	12,6	1	1	1	1
	4,0	5,72	7,28	25,5	1,87	10,2	12,5	40,4	14,5	9,50	1	1	1	1
	5,0	6,97	8,88	29,6	1,83	11,9	14,9	47,6	16,7	7,00	1	1	1	1
	6,3	8,49	10,8	33,9	1,77	13,6	17,5	55,3	18,9	4,94	1	1	1	1
60x60	3,0	5,34	6,80	36,6	2,32	12,2	14,5	56,9	17,7	17,0	1	1	1	1
	3,2	5,67	7,22	38,7	2,31	12,9	15,3	60,1	18,6	15,7	1	1	1	1
	4,0	6,97	8,88	46,1	2,28	15,4	18,6	72,4	22,1	12,0	1	1	1	1
	5,0	8,54	10,9	54,4	2,24	18,1	22,3	86,3	25,8	9,00	1	1	1	1
	6,3	10,5	13,3	63,4	2,18	21,1	26,6	102	29,7	6,52	1	1	1	1
	8,0	12,8	16,3	72,4	2,11	24,1	31,4	119	33,5	4,50	1	1	1	1
70x70	3,0	6,28	8,00	59,6	2,73	17,0	20,0	92,1	24,8	20,3	1	1	1	1
	3,6	7,46	9,50	69,5	2,70	19,9	23,6	108	28,7	16,4	1	1	1	1
	5,0	10,1	12,9	90,1	2,64	25,7	31,2	142	36,8	11,0	1	1	1	1
	6,3	12,5	15,9	106	2,59	30,4	37,6	169	43,0	8,11	1	1	1	1
	8,0	15,3	19,5	123	2,51	35,3	45,0	200	49,4	5,75	1	1	1	1
80x80	3,0	7,22	9,20	90,6	3,14	22,7	26,5	139	33,1	23,7	1	1	1	1
	3,6	8,59	10,9	106	3,11	26,5	31,3	164	38,5	19,2	1	1	1	1
	5,0	11,7	14,9	139	3,05	34,7	41,7	217	49,8	13,0	1	1	1	1
	6,3	14,4	18,4	165	3,00	41,3	50,5	261	58,8	9,70	1	1	1	1
	8,0	17,8	22,7	194	2,92	48,6	60,9	312	68,5	7,00	1	1	1	1
90x90	3,6	9,27	12,4	154	3,52	34,1	40,0	237	49,7	22,0	1	1	1	1
	5,0	13,3	16,9	202	3,46	45,0	53,6	315	64,9	15,0	1	1	1	1
	6,3	16,4	20,9	242	3,41	53,9	65,3	381	77,1	11,3	1	1	1	1
	8,0	20,4	25,9	288	3,33	64,0	79,2	459	90,7	8,25	1	1	1	1
100x100	4,0	12,0	15,3	234	3,91	46,8	54,9	361	68,2	22,0	1	1	1	1
	5,0	14,8	18,9	283	3,87	56,6	67,1	439	81,9	17,0	1	1	1	1
	6,3	18,4	23,4	341	3,81	68,2	82,0	533	97,9	12,9	1	1	1	1
	8,0	22,9	29,1	408	3,74	81,5	99,9	646	116	9,50	1	1	1	1
	10,0	27,9	35,5	474	3,65	94,9	119	761	134	7,00	1	1	1	1

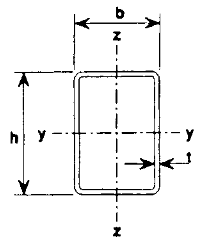
[1] d = h-3t

SQUARE HOLLOW SECTIONS

DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION



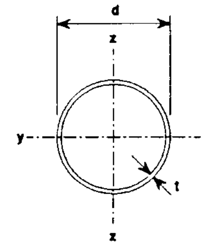
Designation: Size h x h mm	Designation: Thickness t mm	Mass per Metre kg	Area of Section A cm²	Second Moment of Area I cm⁴	Radius of Gyration i cm	Elastic Modulus W_{el} cm³	Plastic Modulus W_{pl} cm³	Torsional Constants I_t cm⁴	Torsional Constants C_t cm³	Ratio for Local Buckling d/t [1]	EC3 Classification Fe 430 (S 275) Axial Load only	Fe 430 (S 275) Bending only yy or zz	Fe 510 (S 355 Axial Load only	Fe 510 (S 355 Bending only yy or zz
120x120	5,0	18,0	22,9	503	4,69	83,8	98,4	775	122	21,0	1	1	1	1
	6,3	22,3	28,5	610	4,63	102	121	949	147	16,0	1	1	1	1
	8,0	27,9	35,5	738	4,56	123	149	1159	176	12,0	1	1	1	1
	10,0	34,2	43,5	870	4,47	145	178	1381	206	9,00	1	1	1	1
	12,5	41,6	53,0	1009	4,36	168	212	1624	237	6,60	1	1	1	1
140x140	5,0	21,1	26,9	814	5,50	116	136	1251	170	25,0	1	1	1	1
	6,3	26,3	33,5	994	5,45	142	168	1538	206	19,2	1	1	1	1
	8,0	32,9	41,9	1212	5,38	173	207	1889	249	14,5	1	1	1	1
	10,0	40,4	51,5	1441	5,29	206	250	2269	294	11,0	1	1	1	1
	12,5	49,5	63,0	1691	5,18	242	299	2695	342	8,20	1	1	1	1
150x150	5,0	22,7	28,9	1009	5,91	135	157	1548	197	27,0	1	1	2	2
	6,3	28,3	36,0	1236	5,86	165	194	1907	240	20,8	1	1	1	1
	8,0	35,4	45,1	1510	5,78	201	240	2348	291	15,7	1	1	1	1
	10,0	43,6	55,5	1803	5,70	240	290	2829	345	12,0	1	1	1	1
	12,5	53,4	68,0	2125	5,59	283	348	3372	403	9,00	1	1	1	1
	16,0	66,4	84,5	2500	5,44	333	421	4029	468	6,38	1	1	1	1
160x160	5,0	24,2	30,9	1234	6,32	154	179	1890	226	29,0	1	1	2	2
	6,0	28,9	36,8	1450	6,28	181	212	2230	264	23,7	1	1	1	1
	6,3	30,3	38,5	1513	6,27	189	222	2330	276	22,4	1	1	1	1
	8,0	37,9	48,3	1853	6,19	232	275	2875	335	17,0	1	1	1	1
	10,0	46,7	59,5	2219	6,11	277	333	3473	399	13,0	1	1	1	1
	12,5	57,3	73,0	2627	6,00	328	402	4154	468	9,80	1	1	1	1
180x180	5,0	27,4	34,9	1777	7,14	197	229	2715	290	33,0	2	2	3	3
	6,3	34,2	43,6	2186	7,08	243	283	3357	355	25,6	1	1	1	1
	8,0	43,0	54,7	2689	7,01	299	352	4156	434	19,5	1	1	1	1
	10,0	53,0	67,5	3237	6,92	360	429	5041	519	15,0	1	1	1	1
	12,5	65,2	83,0	3856	6,82	428	519	6062	613	11,4	1	1	1	1
	16,0	81,4	104	4607	6,66	512	634	7339	725	8,25	1	1	1	1
200x200	5,0	30,5	38,9	2460	7,95	246	284	3752	362	37,0	3	3	4	4
	6,3	38,2	48,6	3033	7,90	303	353	4647	444	28,7	1	1	2	2
	8,0	48,0	61,1	3744	7,83	374	439	5770	545	22,0	1	1	1	1
	10,0	59,3	75,5	4525	7,74	452	536	7020	655	17,0	1	1	1	1
	12,5	73,0	93,0	5419	7,63	542	651	8479	779	13,0	1	1	1	1
	16,0	91,5	117	6524	7,48	652	799	10330	929	9,50	1	1	1	1
250x250	6,3	48,1	61,2	6049	9,94	484	559	9228	712	36,7	3	3	4	4
	8,0	60,5	77,1	7510	9,87	601	699	11510	880	28,2	1	1	2	2
	10,0	75,0	95,5	9141	9,78	731	858	14090	1065	22,0	1	1	1	1
	12,5	92,6	118	11050	9,68	884	1048	17140	1279	17,0	1	1	1	1
	16,0	117	149	13480	9,53	1078	1298	21110	1548	12,6	1	1	1	1
300x300	6,3	57,9	73,8	10600	12,0	706	812	16120	1043	44,6	4	4	4	4
	8,0	73,1	93,1	13210	11,9	881	1018	20170	1294	34,5	2	2	4	4
	10,0	90,7	116	16150	11,8	1077	1254	24780	1575	27,0	1	1	2	2
	12,5	112	143	19630	11,7	1309	1538	30290	1905	21,0	1	1	1	1
	16,0	142	181	24160	11,6	1610	1916	37570	2327	15,7	1	1	1	1
350x350	8,0	85,7	109	21240	14,0	1214	1398	32350	1789	40,7	4	4	4	4
	10,0	106	136	26050	13,9	1489	1725	39840	2186	32,0	2	2	3	3
	12,5	132	168	31810	13,8	1817	2122	48870	2655	25,0	1	1	1	1
	16,0	167	213	39370	13,6	2250	2655	60900	3265	18,9	1	1	1	1
400x400	10,0	122	156	39350	15,9	1968	2272	60030	2896	37,0	3	3	4	4
	12,5	152	193	48190	15,8	2409	2800	73820	3530	29,0	1	1	2	2
	16,0	192	245	59910	15,7	2995	3514	92310	4363	22,0	1	1	1	1
	20,0	237	302	72390	15,5	3620	4292	112300	5240	17,0	1	1	1	1



RECTANGULAR HOLLOW SECTIONS

DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION

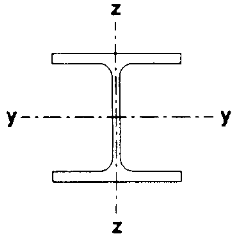
Designation		Mass per Metre	Area of Section	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Torsional Constants		EC3 Classification					
Size	Thick-ness													Fe 430 (S 275)			Fe 510 (S 355)		
				Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z			Axial Load only	Bending only		Axial Load only	Bending only	
h × b	t		A	I_y	I_z	i_y	i_z	$W_{el.y}$	$W_{el.z}$	$W_{pl.y}$	$W_{pl.z}$	I_t	C_t		yy	zz		yy	zz
mm	mm	kg	cm^2	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3	cm^4	cm^3						
50x25	2,5	2,72	3,47	10,6	3,44	1,75	0,996	4,25	2,75	5,41	3,26	8,41	4,62	1	1	1	1	1	1
	3,0	3,22	4,10	12,2	3,89	1,73	0,975	4,88	3,11	6,30	3,77	9,64	5,21	1	1	1	1	1	1
	3,2	3,41	4,34	12,8	4,05	1,72	0,966	5,11	3,24	6,64	3,96	10,1	5,42	1	1	1	1	1	1
50x30	2,5	2,92	3,72	12,0	5,30	1,80	1,19	4,81	3,53	6,01	4,16	11,7	5,74	1	1	1	1	1	1
	3,0	3,45	4,40	13,9	6,04	1,78	1,17	5,54	4,03	7,01	4,83	13,5	6,52	1	1	1	1	1	1
	3,2	3,66	4,66	14,5	6,31	1,77	1,16	5,82	4,21	7,39	5,08	14,2	6,81	1	1	1	1	1	1
	4,0	4,46	5,68	17,0	7,25	1,73	1,13	6,80	4,83	8,81	6,01	16,6	7,79	1	1	1	1	1	1
	5,0	5,40	6,88	19,5	8,13	1,68	1,09	7,79	5,42	10,4	6,98	19,0	8,71	1	1	1	1	1	1
60x40	2,5	3,71	4,72	23,1	12,2	2,21	1,61	7,71	6,10	9,43	7,09	25,0	9,74	1	1	1	1	1	1
	3,0	4,39	5,60	26,9	14,1	2,19	1,59	8,96	7,04	11,1	8,29	29,2	11,2	1	1	1	1	1	1
	3,2	4,66	5,94	28,3	14,8	2,18	1,58	9,44	7,39	11,7	8,75	30,8	11,8	1	1	1	1	1	1
	4,0	5,72	7,28	33,6	17,3	2,15	1,54	11,2	8,67	14,1	10,5	36,6	13,7	1	1	1	1	1	1
	5,0	6,97	8,88	39,2	20,0	2,10	1,50	13,1	10,0	16,8	12,4	43,0	15,8	1	1	1	1	1	1
	6,3	8,49	10,8	45,1	22,6	2,04	1,45	15,0	11,3	19,9	14,6	49,7	17,7	1	1	1	1	1	1
80x40	3,0	5,34	6,80	55,0	18,2	2,85	1,64	13,8	9,10	17,3	10,5	43,7	15,3	1	1	1	1	1	1
	3,2	5,67	7,22	58,1	19,1	2,84	1,63	14,5	9,56	18,3	11,1	46,1	16,1	1	1	1	1	1	1
	4,0	6,97	8,88	69,6	22,6	2,80	1,59	17,4	11,3	22,2	13,4	55,1	18,9	1	1	1	1	1	1
	5,0	8,54	10,9	82,4	26,2	2,75	1,55	20,6	13,1	26,7	15,9	65,0	21,9	1	1	1	1	1	1
	6,3	10,5	13,3	96,5	29,8	2,69	1,50	24,1	14,9	31,9	18,8	75,8	24,9	1	1	1	1	1	1
	8,0	12,8	16,3	111	33,1	2,61	1,42	27,7	16,6	37,8	21,8	86,3	27,6	1	1	1	1	1	1
90x50	3,0	6,28	8,00	85,4	33,8	3,27	2,05	19,0	13,5	23,4	15,5	76,4	22,4	1	1	1	2	1	2
	3,6	7,46	9,50	99,8	39,1	3,24	2,03	22,2	15,6	27,6	18,1	89,3	25,9	1	1	1	1	1	1
	5,0	10,1	12,9	130	50,0	3,18	1,97	28,9	20,0	36,6	23,9	116	32,9	1	1	1	1	1	1
	6,3	12,5	15,9	154	58,1	3,12	1,91	34,2	23,3	44,2	28,5	138	38,2	1	1	1	1	1	1
	8,0	15,3	19,5	180	66,3	3,04	1,84	40,0	26,5	53,0	33,7	161	43,4	1	1	1	1	1	1
100x50	3,0	6,75	8,60	111	37,1	3,59	2,08	22,2	14,8	27,6	16,9	88,3	25,0	1	1	1	2	1	2
	3,2	7,18	9,14	117	39,1	3,58	2,07	23,5	15,6	29,2	17,9	93,3	26,4	1	1	1	2	1	2
	4,0	8,86	11,3	142	46,7	3,55	2,03	28,4	18,7	35,7	21,7	113	31,4	1	1	1	1	1	1
	5,0	10,9	13,9	170	55,1	3,50	1,99	34,0	22,0	43,3	26,1	135	37,0	1	1	1	1	1	1
	6,3	13,4	17,1	202	64,2	3,44	1,94	40,5	25,7	52,5	31,3	160	43,0	1	1	1	1	1	1
	8,0	16,6	21,1	238	73,5	3,36	1,86	47,6	29,4	63,1	37,1	187	49,1	1	1	1	1	1	1
100x60	3,0	7,22	9,20	125	56,2	3,69	2,47	25,0	18,7	30,5	21,3	121	30,7	1	1	1	2	1	2
	3,6	8,59	10,9	147	65,4	3,66	2,45	29,3	21,8	36,0	25,1	142	35,6	1	1	1	1	1	1
	5,0	11,7	14,9	192	84,7	3,60	2,39	38,5	28,2	48,1	33,3	187	45,9	1	1	1	1	1	1
	6,3	14,4	18,4	230	99,9	3,54	2,33	46,0	33,3	58,4	40,2	224	53,9	1	1	1	1	1	1
	8,0	17,8	22,7	272	116	3,46	2,26	54,4	38,7	70,5	48,1	266	62,4	1	1	1	1	1	1
120x60	3,6	9,72	12,4	230	76,9	4,31	2,49	38,3	25,6	47,6	29,2	183	43,3	1	1	1	2	1	2
	5,0	13,3	16,9	304	99,9	4,24	2,43	50,7	33,3	63,9	38,8	242	56,0	1	1	1	1	1	1
	6,3	16,4	20,9	366	118	4,18	2,38	61,0	39,4	78,0	46,9	290	66,0	1	1	1	1	1	1
	8,0	20,4	25,9	437	138	4,10	2,31	72,8	45,9	94,8	56,4	344	76,8	1	1	1	1	1	1
120x80	5,0	14,8	18,9	370	195	4,43	3,21	61,7	48,8	75,4	56,7	401	77,9	1	1	1	1	1	1
	6,3	18,4	23,4	447	234	4,37	3,16	74,6	58,4	92,3	69,1	486	93,0	1	1	1	1	1	1
	8,0	22,9	29,1	537	278	4,29	3,09	89,5	69,4	113	83,9	586	110	1	1	1	1	1	1
	10,0	27,9	35,5	628	320	4,20	3,00	105	80,0	134	99,4	688	126	1	1	1	1	1	1



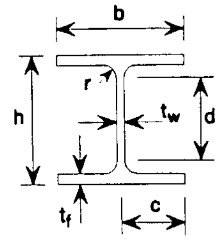
CIRCULAR HOLLOW SECTIONS

DIMENSIONS, PROPERTIES AND EC3 CLASSIFICATION

Designation		Mass per Metre	Area of Section	Second Moment of Area	Radius of Gyration	Elastic Modulus	Plastic Modulus	Torsional Constants		Ratio for Local Buckling	EC3 Classification Section under axial load and/or bending	
Outside Diameter	Thickness											
d	t		A	I	i	W_{el}	W_{pl}	I_t	C_t	d/t	Fe 430	Fe 510
mm	mm	kg	cm^2	cm^4	cm	cm^3	cm^3	cm^4	cm^3		(S 275)	(S 355)
21,3	3,2	1,43	1,82	0,768	0,650	0,722	1,06	1,54	1,44	6,66	1	1
26,9	3,2	1,87	2,38	1,70	0,846	1,27	1,81	3,40	2,54	8,41	1	1
33,7	2,6	1,99	2,54	3,09	1,10	1,84	2,52	6,18	3,68	13,0	1	1
	3,2	2,41	3,07	3,60	1,08	2,14	2,99	7,20	4,28	10,5	1	1
	4,0	2,93	3,73	4,19	1,06	2,49	3,55	8,38	4,98	8,43	1	1
42,4	2,6	2,55	3,25	6,46	1,41	3,05	4,12	12,9	6,10	16,3	1	1
	3,2	3,09	3,94	7,62	1,39	3,59	4,93	15,2	7,18	13,2	1	1
	4,0	3,79	4,83	8,99	1,36	4,24	5,92	18,0	8,48	10,6	1	1
48,3	3,2	3,56	4,53	11,6	1,60	4,80	6,52	23,2	9,60	15,1	1	1
	4,0	4,37	5,57	13,8	1,57	5,70	7,87	27,6	11,4	12,1	1	1
	5,0	5,34	6,80	16,2	1,54	6,69	9,42	32,4	13,4	9,66	1	1
60,3	3,2	4,51	5,74	23,5	2,02	7,78	10,4	47,0	15,6	18,8	1	1
	4,0	5,55	7,07	28,2	2,00	9,34	12,7	56,4	18,7	15,1	1	1
	5,0	6,82	8,69	33,5	1,96	11,1	15,3	67,0	22,2	12,1	1	1
76,1	3,2	5,75	7,33	48,8	2,58	12,8	17,0	97,6	25,6	23,8	1	1
	4,0	7,11	9,06	59,1	2,55	15,5	20,8	118	31,0	19,0	1	1
	5,0	8,77	11,2	70,9	2,52	18,6	25,3	142	37,2	15,2	1	1
88,9	3,2	6,76	8,62	79,2	3,03	17,8	23,5	158	35,6	27,8	1	1
	4,0	8,38	10,7	96,3	3,00	21,7	28,9	193	43,4	22,2	1	1
	5,0	10,3	13,2	116	2,97	26,2	35,2	232	52,4	17,8	1	1
114,3	3,6	9,83	12,5	192	3,92	33,6	44,1	384	67,2	31,8	1	1
	5,0	13,5	17,2	257	3,87	45,0	59,8	514	90,0	22,9	1	1
	6,3	16,8	21,4	313	3,82	54,7	73,6	626	109	18,1	1	1
139,7	5,0	16,6	21,2	481	4,77	68,8	90,8	962	138	27,9	1	1
	6,3	20,7	26,4	589	4,72	84,3	112	1178	169	22,2	1	1
	8,0	26,0	33,1	720	4,66	103	139	1440	206	17,5	1	1
	10,0	32,0	40,7	862	4,60	123	169	1724	246	14,0	1	1
168,3	5,0	20,1	25,7	856	5,78	102	133	1712	204	33,7	1	2
	6,3	25,2	32,1	1053	5,73	125	165	2106	250	26,7	1	1
	8,0	31,6	40,3	1297	5,67	154	206	2594	308	21,0	1	1
	10,0	39,0	49,7	1564	5,61	186	251	3128	372	16,8	1	1
193,7	5,0	23,3	29,6	1320	6,67	136	178	2640	272	38,7	1	2
	6,3	29,1	37,1	1630	6,63	168	221	3260	336	30,7	1	1
	8,0	36,6	46,7	2016	6,57	208	276	4032	416	24,2	1	1
	10,0	45,3	57,7	2442	6,50	252	338	4884	504	19,4	1	1
	12,5	55,9	71,2	2934	6,42	303	411	5868	606	15,5	1	1
	16,0	70,1	89,3	3554	6,31	367	507	7108	734	12,1	1	1
219,1	5,0	26,4	33,6	1928	7,57	176	229	3856	352	43,8	2	2
	6,3	33,1	42,1	2386	7,53	218	285	4772	436	34,8	1	2
	8,0	41,6	53,1	2960	7,47	270	357	5920	540	27,4	1	1
	10,0	51,6	65,7	3598	7,40	328	438	7196	656	21,9	1	1
	12,5	63,7	81,1	4345	7,32	397	534	8690	794	17,5	1	1
	16,0	80,1	102	5297	7,20	483	661	10590	966	13,7	1	1
	20,0	98,2	125	6261	7,07	572	795	12520	1144	11,0	1	1



UNIVERSAL BEARING PILES



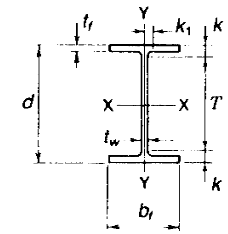
DIMENSIONS AND EC3 CLASSIFICATION

Designation		Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Shear Area	Ratios for Local Buckling		EC3 Classifcation					
Serial Size	Mass per Metre			Web	Flange				Flange	Web	Fe 430 (S 275)			Fe 510 (S 355)		
											Axial Load only	Bending only		Axial Load only	Bending only	
		h	b	t_w	t_f	r	d	A_v	c/t_f	d/t_w		yy	zz		yy	zz
mm	kg	mm	mm	mm	mm	mm	mm	cm^2								
203 × 203	45	200,2	205,4	9,5	9,5	10,2	160,8	20,9	10,8	16,9	3	3	3	3	3	3
	54	203,9	207,2	11,3	11,3	10,2	160,9	25,0	9,2	14,2	1	1	1	3	3	3
254 × 254	63	246,9	256,0	10,6	10,6	12,7	200,3	29,1	12,1	18,9	3	3	3	3	3	3
	71	249,9	257,5	12,1	12,1	12,7	200,3	33,2	10,6	16,6	3	3	3	3	3	3
	85	254,3	259,7	14,3	14,3	12,7	200,3	39,4	9,1	14,0	1	1	1	3	3	3
305 × 305	79	299,2	306,0	11,1	11,1	15,2	246,6	37,7	13,8	22,2	3	3	3	4	4	4
	88	301,7	307,2	12,3	12,3	15,2	246,7	41,7	12,5	20,1	3	3	3	4	4	4
	95	303,8	308,3	13,4	13,4	15,2	246,6	45,2	11,5	18,4	3	3	3	3	3	3
	110	307,9	310,3	15,4	15,4	15,2	246,7	51,5	10,1	16,0	2	2	2	3	3	3
	126	312,4	312,5	17,7	17,7	15,2	246,6	59,9	8,8	13,9	1	1	1	2	2	2
	149	318,5	315,6	20,7	20,7	15,2	246,7	69,9	7,6	11,9	1	1	1	1	1	1
	186	328,3	320,5	25,6	25,6	15,2	246,7	87,2	6,3	9,6	1	1	1	1	1	1
	223	338,0	325,4	30,5	30,5	15,2	246,6	105,1	5,3	8,1	1	1	1	1	1	1
356 × 368	109	346,4	370,5	12,9	12,9	15,2	290,2	49,0	14,4	22,5	4	4	4	4	4	4
	133	351,9	373,3	15,6	15,6	15,2	290,3	58,7	12,0	18,6	3	3	3	3	3	3
	152	356,4	375,5	17,9	17,9	15,2	290,2	68,2	10,5	16,2	3	3	3	3	3	3
	174	361,5	378,1	20,4	20,4	15,2	290,3	78,1	9,3	14,2	2	2	2	3	3	3

PROPERTIES

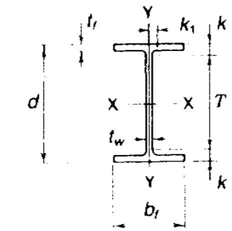
Designation		Second Moment of Area		Radius of Gyration		Lateral-torsional Buckling Constants [1]			Elastic Modulus		Plastic Modulus		Warping Constant	Torsion Constant	Area of Section
Serial Size	Mass per Metre	Axis y-y	Axis z-z	Axis y-y	Axis z-z				Axis y-y	Axis z-z	Axis y-y	Axis z-z			
		I_y	I_z	i_y	i_z	i_{LT}	a_{LT}	a_{LT}/i_{LT}	$W_{el.y}$	$W_{el.z}$	$W_{pl.y}$	$W_{pl.z}$	I_w	I_t	A
mm	kg	cm^4	cm^4	cm	cm	cm	cm		cm^3	cm^3	cm^3	cm^3	dm^6	cm^4	cm^2
203 × 203	45	4092	1374	8,46	4,90	5,35	80,7	15,1	409	134	458	205	0,125	19,2	57,1
	54	4979	1678	8,54	4,96	5,41	69,7	12,9	488	162	552	249	0,156	32,1	68,2
254 × 254	63	8764	2967	10,5	6,11	6,66	111	16,7	710	232	791	355	0,414	33,6	79,6
	71	10140	3448	10,6	6,15	6,71	99,2	14,8	812	268	910	411	0,487	49,5	91,0
	85	12250	4181	10,7	6,22	6,79	86,1	12,7	963	322	1089	495	0,602	81,2	108
305 × 305	79	16430	5306	12,8	7,26	7,92	152,7	19,3	1098	347	1218	530	1,10	47,2	101
	88	18380	5949	12,8	7,30	7,97	140,2	17,6	1218	387	1356	593	1,25	63,6	112
	95	20170	6552	12,9	7,34	8,00	130,0	16,2	1328	425	1484	651	1,38	81,7	122
	110	23550	7680	13,0	7,40	8,08	115,5	14,3	1530	495	1720	760	1,64	123	140
	126	27540	9019	13,1	7,47	8,16	102,7	12,6	1763	577	1996	888	1,96	186	162
	149	33050	10870	13,2	7,56	8,26	90,2	10,9	2075	689	2370	1063	2,41	296	190
	186	42580	14090	13,4	7,71	8,43	75,8	9,0	2594	879	3002	1363	3,23	562	237
	223	52840	17590	13,6	7,86	8,59	66,0	7,7	3127	1081	3664	1683	4,16	955	285
356 × 368	109	30620	10940	14,8	8,87	9,65	188,9	19,6	1768	591	1957	901	3,04	85,2	139
	133	37730	13540	15,0	8,96	9,76	160,3	16,4	2144	725	2391	1109	3,83	149	168
	152	43950	15810	15,1	9,03	9,84	142,2	14,5	2466	842	2766	1290	4,53	224	194
	174	51020	18400	15,2	9,11	9,92	126,9	12,8	2823	974	3187	1494	5,35	332	222

W SHAPES
Properties



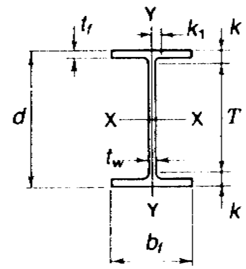
Nominal Wt. per Ft	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria F_y'	Compact Section Criteria $\frac{d}{t_w}$	Compact Section Criteria F_y'''	r_T	$\frac{d}{A_f}$	Elastic Properties Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Plastic Modulus Z_x	Plastic Modulus Z_y
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{3}	In.^{3}
619	2.4	—	19.5	—	4.51	0.64	41800	2170	15.2	2870	340	3.98	2560	537
567	2.6	—	20.9	—	4.46	0.69	37700	1990	15.1	2580	308	3.94	2330	485
515	2.8	—	22.6	—	4.42	0.75	33700	1810	14.9	2290	276	3.89	2110	433
468	3.0	—	24.2	—	4.37	0.82	30100	1630	14.8	2030	247	3.85	1890	387
424	3.3	—	26.3	—	4.33	0.90	26900	1480	14.7	1800	221	3.81	1700	345
387	3.6	—	28.5	—	4.30	0.97	24300	1350	14.7	1620	200	3.79	1550	312
354	3.8	—	30.6	—	4.27	1.06	21900	1230	14.5	1460	181	3.74	1420	282
318	4.2	—	33.8	57.8	4.24	1.16	19500	1110	14.4	1290	161	3.71	1270	250
291	4.6	—	36.3	50.1	4.21	1.27	17700	1010	14.4	1160	146	3.69	1150	226
263	5.0	—	39.7	41.9	4.18	1.39	15800	917	14.3	1030	131	3.66	1040	202
241	5.7	—	41.2	38.9	4.17	1.54	14200	829	14.1	932	118	3.63	939	182
221	6.2	—	43.8	34.5	4.15	1.68	12800	757	14.1	840	106	3.59	855	164
201	6.8	—	47.1	29.8	4.12	1.86	11500	684	14.0	749	95.2	3.56	772	147
169	4.7	—	50.5	25.9	2.95	2.41	9290	549	13.7	310	53.9	2.50	629	84.4
152	5.5	—	52.7	23.7	2.94	2.74	8160	487	13.5	273	47.2	2.47	559	73.9
141	6.0	—	55.0	21.8	2.92	3.01	7450	448	13.4	246	42.7	2.43	514	66.9
130	6.7	—	57.1	20.3	2.88	3.36	6710	406	13.2	218	37.9	2.39	467	59.5
118	7.8	—	59.7	18.5	2.84	3.87	5900	359	13.0	187	32.6	2.32	415	51.3
581	2.3	—	18.0	—	4.34	0.62	33000	1870	13.9	2530	312	3.86	2210	492
526	2.5	—	19.4	—	4.29	0.67	29300	1680	13.8	2230	278	3.80	1990	438
477	2.7	—	21.0	—	4.24	0.73	26100	1530	13.7	1970	249	3.75	1790	390
433	2.9	—	22.4	—	4.20	0.80	23200	1380	13.5	1750	222	3.71	1610	348
391	3.2	—	24.4	—	4.16	0.87	20700	1250	13.5	1550	198	3.68	1430	310
357	3.5	—	26.5	—	4.12	0.95	18600	1140	13.4	1390	179	3.65	1300	279
326	3.7	—	28.4	—	4.09	1.03	16800	1030	13.2	1240	162	3.61	1190	252
292	4.1	—	31.4	—	4.06	1.13	14900	928	13.2	1100	144	3.58	1060	223
261	4.6	—	34.0	57.2	4.02	1.26	13100	827	13.1	959	127	3.54	941	196
235	5.0	—	37.7	46.4	4.00	1.39	11700	746	13.0	855	114	3.52	845	175
211	5.7	—	39.9	41.4	3.99	1.56	10300	663	12.9	757	100	3.49	749	154
191	6.3	—	43.2	35.4	3.97	1.72	9170	598	12.8	673	89.5	3.46	673	138
173	7.0	—	46.5	30.6	3.94	1.91	8200	539	12.7	598	79.8	3.43	605	123

W SHAPES
Dimensions



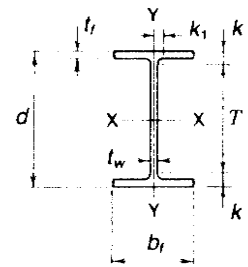
Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.
W 33×619[a]	181.0	38.47	38 1/2	1.970	2	1	16.910	16 7/8	3.540	3 9/16	29 3/4	4 3/8	1 3/4
×567[a]	166.0	37.91	37 7/8	1.810	1 13/16	1	16.750	16 3/4	3.270	3 1/4	29 3/4	4 1/16	1 11/16
×515[a]	151.0	37.36	37 3/8	1.650	1 5/8	13/16	16.590	16 5/8	2.990	3	29 3/4	3 13/16	1 5/8
×468[a]	137.0	36.81	36 3/4	1.520	1 1/2	3/4	16.455	16 1/2	2.720	2 3/4	29 3/4	3 1/2	1 9/16
×424[a]	124.0	36.34	36 3/8	1.380	1 3/8	11/16	16.315	16 3/8	2.480	2 1/2	29 3/4	3 5/16	1 7/16
×387[a]	113.0	35.95	36	1.260	1 1/4	5/8	16.200	16 1/4	2.280	2 1/4	29 3/4	3 1/8	1 3/8
×354[a]	104.0	35.55	35 1/2	1.160	1 3/16	5/8	16.100	16 1/8	2.090	2 1/16	29 3/4	2 7/8	1 3/8
×318[a]	93.5	35.16	35 1/8	1.040	1 1/16	9/16	15.985	16	1.890	1 7/8	29 3/4	2 11/16	1 5/16
×291	85.6	34.84	34 7/8	0.960	1	1/2	15.905	15 7/8	1.730	1 3/4	29 3/4	2 9/16	1 1/4
×263	77.4	34.53	34 1/2	0.870	7/8	7/16	15.805	15 3/4	1.570	1 9/16	29 3/4	2 3/8	1 3/16
×241	70.9	34.18	34 1/8	0.830	13/16	7/16	15.860	15 7/8	1.400	1 3/8	29 3/4	2 3/16	1 3/16
×221	65.0	33.93	33 7/8	0.775	3/4	3/8	15.805	15 3/4	1.275	1 1/4	29 3/4	2 1/16	1 3/16
×201	59.1	33.68	33 5/8	0.715	11/16	3/8	15.745	15 3/4	1.150	1 1/8	29 3/4	1 15/16	1 1/8
W 33×169[b]	49.5	33.82	33 7/8	0.670	11/16	3/8	11.500	11 1/2	1.220	1 1/4	29 3/4	2 1/16	1 1/8
×152	44.7	33.49	33 1/2	0.635	5/8	5/16	11.565	11 5/8	1.055	1 1/16	29 3/4	1 7/8	1 1/8
×141	41.6	33.30	33 1/4	0.605	5/8	5/16	11.535	11 1/2	0.960	15/16	29 3/4	1 3/4	1 1/16
×130	38.3	33.09	33 1/8	0.580	9/16	5/16	11.510	11 1/2	0.855	7/8	29 3/4	1 11/16	1 1/16
×118	34.7	32.86	32 7/8	0.550	9/16	5/16	11.480	11 1/2	0.740	3/4	29 3/4	1 9/16	1 1/16
W 30×581[a]	170.0	35.39	35 3/8	1.970	2	1	16.200	16 1/4	3.540	3 9/16	26 3/4	4 5/16	1 11/16
×526[a]	154.0	34.76	34 3/4	1.790	1 13/16	1	16.020	16	3.230	3 1/4	26 3/4	4	1 5/8
×477[a]	140.0	34.21	34 1/4	1.630	1 5/8	13/16	15.865	15 7/8	2.950	3	26 3/4	3 3/4	1 9/16
×433[a]	127.0	33.66	33 5/8	1.500	1 1/2	3/4	15.725	15 3/4	2.680	2 11/16	26 3/4	3 7/16	1 1/2
×391[a]	114.0	33.19	33 1/4	1.360	1 3/8	11/16	15.590	15 5/8	2.440	2 7/16	26 3/4	3 1/4	1 7/16
×357[a]	104.0	32.80	32 3/4	1.240	1 1/4	5/8	15.470	15 1/2	2.240	2 1/4	26 3/4	3	1 3/8
×326[a]	95.7	32.40	32 3/8	1.140	1 1/8	9/16	15.370	15 3/8	2.050	2 1/16	26 3/4	2 13/16	1 5/16
×292[a]	85.7	32.01	32	1.020	1	1/2	15.255	15 1/4	1.850	1 7/8	26 3/4	2 5/8	1 1/4
×261	76.7	31.61	31 5/8	0.930	15/16	1/2	15.155	15 1/8	1.650	1 5/8	26 3/4	2 7/16	1 3/16
×235	69.0	31.30	31 1/4	0.830	13/16	7/16	15.055	15	1.500	1 1/2	26 3/4	2 1/4	1 1/8
×211	62.0	30.94	31	0.775	3/4	3/8	15.105	15 1/8	1.315	1 5/16	26 3/4	2 1/8	1 1/8
×191	56.1	30.68	30 5/8	0.710	11/16	3/8	15.040	15	1.185	1 3/16	26 3/4	1 15/16	1 1/16
×173	50.8	30.44	30 1/2	0.655	5/8	5/16	14.985	15	1.065	1 1/16	26 3/4	1 7/8	1 1/16

W SHAPES
Properties

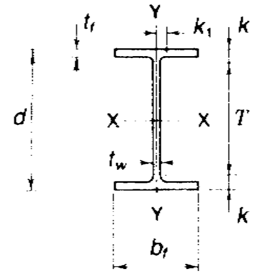


Nominal Wt. per Ft	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria F_y'	Compact Section Criteria $\frac{d}{t_w}$	Compact Section Criteria F_y'''	r_T	$\frac{d}{A_f}$	Elastic Properties Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Plastic Modulus Z_x	Plastic Modulus Z_y
Lb.		Ksi		Ksi	In.		$In.^4$	$In.^3$	In.	$In.^4$	$In.^3$	In.	$In.^3$	$In.^3$
285	3.3	—	43.0	35.7	2.95	2.10	24600	1120	17.1	490	83.0	2.42	1310	135
248	3.7	—	50.4	26.0	2.96	2.34	21400	983	17.2	435	74.0	2.44	1150	118
224	4.2	—	55.0	21.8	2.96	2.59	19200	889	17.1	391	66.0	2.44	1030	105
198	4.8	—	60.5	18.0	2.94	2.98	16700	776	16.9	336	57.0	2.41	902	90.0
328	5.2	—	44.0	34.2	4.73	1.29	26800	1340	16.7	1680	185	4.15	1510	286
298	5.7	—	47.8	28.9	4.70	1.41	24200	1220	16.6	1490	167	4.12	1370	257
268	6.3	—	52.5	24.0	4.67	1.57	21500	1090	16.5	1320	149	4.09	1220	229
244	7.0	—	55.0	21.8	4.63	1.75	19200	983	16.4	1170	132	4.04	1100	203
221	8.3	61.1	54.5	22.3	4.56	2.05	16600	858	16.0	988	112	3.90	967	172
192	10.7	37.1	53.8	22.8	4.43	2.60	13500	708	15.5	770	87.0	3.69	807	135
655	2.4	—	22.1	—	4.43	0.73	56500	2590	17.2	2860	339	3.86	3060	541
593	2.6	—	24.0	—	4.38	0.80	50400	2340	17.0	2520	302	3.81	2750	481
531	2.8	—	26.3	—	4.33	0.88	44300	2090	16.9	2200	266	3.75	2450	422
480	3.1	—	28.6	—	4.28	0.97	39500	1890	16.8	1940	237	3.72	2180	374
436	3.4	—	30.9	—	4.24	1.06	35400	1710	16.6	1720	212	3.67	1980	334
397	3.7	—	33.6	58.6	4.21	1.15	32000	1560	16.6	1540	191	3.65	1790	300
362	4.0	—	36.2	50.4	4.17	1.26	28900	1420	16.5	1380	173	3.61	1630	270
324	4.4	—	40.2	41.0	4.14	1.40	25600	1280	16.4	1220	153	3.57	1460	239
297	4.8	—	42.8	36.0	4.11	1.53	23200	1170	16.3	1090	138	3.54	1330	215
277	5.0	—	47.8	28.9	4.13	1.59	21900	1100	16.4	1040	132	3.58	1250	204
249	5.5	—	52.5	24.0	4.10	1.76	19500	992	16.3	926	118	3.56	1120	182
215	6.5	—	60.0	18.4	4.09	2.03	16700	858	16.2	796	101	3.54	963	156
199	7.4	—	59.5	18.7	4.04	2.31	14900	769	16.0	695	88.2	3.45	868	137
183	4.8	—	60.0	18.4	2.98	2.71	13300	682	15.7	336	56.9	2.50	781	89.6
167	5.8	—	59.4	18.7	2.91	3.19	11600	599	15.3	283	47.9	2.40	692	76.0
149	7.1	—	60.6	18.0	2.84	3.90	9780	512	14.9	229	38.8	2.29	597	62.2

W SHAPES
Dimensions



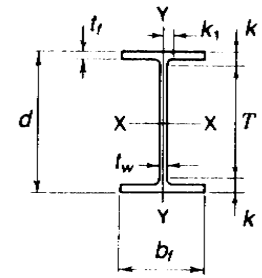
Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	$In.^2$	In.		In.		In.	In.		In.		In.	In.	In.
W 44×285	83.8	44.02	44	1.024	1	1/2	11.811	11 3/4	1.772	1 3/4	38 5/8	2 11/16	1 3/8
×248	72.8	43.62	43 5/8	0.865	7/8	7/16	11.811	11 3/4	1.575	1 9/16	38 5/8	2 1/2	1 5/16
×224	65.8	43.31	43 1/4	0.787	13/16	7/16	11.811	11 3/4	1.416	1 7/16	38 5/8	2 5/16	1 5/16
×198	58.0	42.91	42 7/8	0.709	11/16	3/8	11.811	11 3/4	1.220	1 1/4	38 5/8	2 1/8	1 1/4
W 40×328	96.4	40.00	40	0.910	15/16	1/2	17.910	17 7/8	1.730	1 3/4	33 3/4	3 1/8	1 11/16
×298	87.6	39.69	39 3/4	0.830	13/16	7/16	17.830	17 7/8	1.575	1 9/16	33 3/4	3	1 5/8
×268	78.8	39.37	39 3/8	0.750	3/4	3/8	17.750	17 3/4	1.415	1 7/16	33 3/4	2 13/16	1 9/16
×244	71.7	39.06	39	0.710	11/16	3/8	17.710	17 3/4	1.260	1 1/4	33 3/4	2 5/8	1 9/16
×221	64.8	38.67	38 5/8	0.710	11/16	3/8	17.710	17 3/4	1.065	1 1/16	33 3/4	2 7/16	1 9/16
×192	56.5	38.20	38 1/4	0.710	11/16	3/8	17.710	17 3/4	0.830	13/16	33 3/4	2 1/4	1 9/16
W 40×655[a]	192.0	43.62	43 5/8	1.970	2	1	16.870	16 7/8	3.540	3 9/16	33 3/4	4 15/16	2 1/4
×593[a]	174.0	42.99	43	1.790	1 13/16	1	16.690	16 3/4	3.230	3 1/4	33 3/4	4 5/8	2 1/8
×531[a]	156.0	42.34	42 3/8	1.610	1 5/8	13/16	16.510	16 1/2	2.910	2 15/16	33 3/4	4 5/16	2
×480[a]	140.0	41.81	41 3/4	1.460	1 7/16	3/4	16.360	16 3/8	2.640	2 5/8	33 3/4	4	2
×436[a]	128.0	41.34	41 3/8	1.340	1 5/16	11/16	16.240	16 1/4	2.400	2 3/8	33 3/4	3 13/16	1 15/16
×397[a]	116.0	40.95	41	1.220	1 1/4	5/8	16.120	16 1/8	2.200	2 3/16	33 3/4	3 5/8	1 7/8
×362[a]	106.0	40.55	40 1/2	1.120	1 1/8	9/16	16.020	16	2.010	2	33 3/4	3 3/8	1 13/16
×324	95.3	40.16	40 1/8	1.000	1	1/2	15.905	15 7/8	1.810	1 13/16	33 3/4	3 3/16	1 3/4
×297	87.4	39.84	39 7/8	0.930	15/16	1/2	15.825	15 7/8	1.650	1 5/8	33 3/4	3 1/16	1 11/16
×277	81.3	39.69	39 3/4	0.830	13/16	7/16	15.830	15 7/8	1.575	1 9/16	33 3/4	3	1 5/8
×249	73.3	39.38	39 3/8	0.750	3/4	3/8	15.750	15 3/4	1.420	1 7/16	33 3/4	2 13/16	1 9/16
×215	63.3	38.98	39	0.650	5/8	5/16	15.750	15 3/4	1.220	1 1/4	33 3/4	2 5/8	1 9/16
×199	58.4	38.67	38 5/8	0.650	5/8	5/16	15.750	15 3/4	1.065	1 1/16	33 3/4	2 7/16	1 9/16
W 40×183[b]	53.7	38.98	39	0.650	5/8	5/16	11.810	11 3/4	1.220	1 1/4	33 3/4	2 5/8	1 9/16
×167	49.1	38.59	38 5/8	0.650	5/8	5/16	11.810	11 3/4	1.025	1	33 3/4	2 7/16	1 9/16
×149	43.8	38.20	38 1/4	0.630	5/8	5/16	11.810	11 3/4	0.830	13/16	33 3/4	2 1/4	1 1/2



W SHAPES
Dimensions

Designation	Area A	Depth d		Web Thickness t_w		$\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.
W 36×848[a]	249.0	42.45	42 1/2	2.520	2 1/2	1 1/4	18.130	18 1/8	4.530	4 1/2	31 1/8	5 11/16	2 1/4
×798[a]	234.0	41.97	42	2.380	2 3/8	1 3/16	17.990	18	4.290	4 5/16	31 1/8	5 7/16	2 3/16
×720[a]	211.0	41.19	41 1/4	2.165	2 3/16	1 1/8	17.775	17 3/4	3.900	3 7/8	31 1/8	5 1/16	2 1/16
×650[a]	190.0	40.47	40 1/2	1.970	2	1	17.575	17 5/8	3.540	3 9/16	31 1/8	4 11/16	2
×588[a]	172.0	39.84	39 7/8	1.790	1 13/16	1	17.400	17 3/8	3.230	3 1/4	31 1/8	4 3/8	1 7/8
×527[a]	154.0	39.21	39 1/4	1.610	1 5/8	13/16	17.220	17 1/4	2.910	2 15/16	31 1/8	4 1/16	1 3/4
×485[a]	142.0	38.74	38 3/4	1.500	1 1/2	3/4	17.105	17 1/8	2.680	2 11/16	31 1/8	3 13/16	1 3/4
×439[a]	128.0	38.26	38 1/4	1.360	1 3/8	11/16	16.965	17	2.440	2 7/16	31 1/8	3 9/16	1 5/8
×393[a]	115.0	37.80	37 3/4	1.220	1 1/4	5/8	16.830	16 7/8	2.200	2 3/16	31 1/8	3 5/16	1 5/8
×359[a]	105.0	37.40	37 3/8	1.120	1 1/8	9/16	16.730	16 3/4	2.010	2	31 1/8	3 1/8	1 9/16
×328[a]	96.4	37.09	37 1/8	1.020	1	1/2	16.630	16 5/8	1.850	1 7/8	31 1/8	3	1 1/2
×300	88.3	36.74	36 3/4	0.945	15/16	1/2	16.655	16 5/8	1.680	1 11/16	31 1/8	2 13/16	1 1/2
×280	82.4	36.52	36 1/2	0.885	7/8	7/16	16.595	16 5/8	1.570	1 9/16	31 1/8	2 11/16	1 1/2
×260	76.5	36.26	36 1/4	0.840	13/16	7/16	16.550	16 1/2	1.440	1 7/16	31 1/8	2 9/16	1 1/2
×245	72.1	36.08	36 1/8	0.800	13/16	7/16	16.510	16 1/2	1.350	1 3/8	31 1/8	2 1/2	1 7/16
×230	67.6	35.90	35 7/8	0.760	3/4	3/8	16.470	16 1/2	1.260	1 1/4	31 1/8	2 3/8	1 7/16
W 36×256	75.4	37.43	37 3/8	0.960	1	1/2	12.215	12 1/4	1.730	1 3/4	32 1/8	2 5/8	1 5/16
×232	68.1	37.12	37 1/8	0.870	7/8	7/16	12.120	12 1/8	1.570	1 9/16	32 1/8	2 1/2	1 1/4
×210	61.8	36.69	36 3/4	0.830	13/16	7/16	12.180	12 1/8	1.360	1 3/8	32 1/8	2 5/16	1 1/4
×194	57.0	36.49	36 1/2	0.765	3/4	3/8	12.115	12 1/8	1.260	1 1/4	32 1/8	2 3/16	1 3/16
×182	53.6	36.33	36 3/8	0.725	3/4	3/8	12.075	12 1/8	1.180	1 3/16	32 1/8	2 1/8	1 3/16
×170	50.0	36.17	36 1/8	0.680	11/16	3/8	12.030	12	1.100	1 1/8	32 1/8	2	1 3/16
×160	47.0	36.01	36	0.650	5/8	5/16	12.000	12	1.020	1	32 1/8	1 15/16	1 1/8
×150	44.2	35.85	35 7/8	0.625	5/8	5/16	11.975	12	0.940	15/16	32 1/8	1 7/8	1 1/8
×135	39.7	35.55	35 1/2	0.600	5/8	5/16	11.950	12	0.790	13/16	32 1/8	1 11/16	1 1/8

W SHAPES
Properties

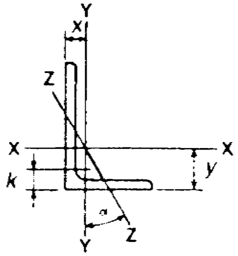


Nominal Wt. per Ft	Compact Section Criteria				r_T	$\frac{d}{A_f}$	Elastic Properties						Plastic Modulus	
	$\frac{b_f}{2t_f}$	F_y'	$\frac{d}{t_w}$	F_y'''			Axis X-X			Axis Y-Y			Z_x	Z_y
							I	S	r	I	S	r		
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{3}	In.^{3}
848	2.0	—	16.8	—	4.84	0.52	67400	3170	16.4	4550	501	4.27	3830	799
798	2.1	—	17.6	—	4.80	0.54	62600	2980	16.4	4200	467	4.24	3570	743
720	2.3	—	19.0	—	4.73	0.59	55300	2690	16.2	3680	414	4.18	3190	656
650	2.5	—	20.5	—	4.67	0.65	48900	2420	16.0	3230	367	4.12	2840	580
588	2.7	—	22.3	—	4.62	0.71	43500	2180	15.9	2850	328	4.07	2550	517
527	3.0	—	24.4	—	4.57	0.78	38300	1950	15.8	2490	289	4.02	2270	454
485	3.2	—	25.8	—	4.53	0.85	34700	1790	15.6	2250	263	3.98	2070	412
439	3.5	—	28.1	—	4.49	0.92	31000	1620	15.6	1990	235	3.95	1860	367
393	3.8	—	31.0	—	4.45	1.02	27500	1450	15.5	1750	208	3.90	1660	325
359	4.2	—	33.4	59.2	4.42	1.11	24800	1320	15.4	1570	188	3.87	1510	292
328	4.5	—	36.4	50.0	4.39	1.21	22500	1210	15.3	1420	171	3.84	1380	265
300	5.0	—	38.9	43.7	4.39	1.31	20300	1110	15.2	1300	156	3.83	1260	241
280	5.3	—	41.3	38.8	4.37	1.40	18900	1030	15.1	1200	144	3.81	1170	223
260	5.7	—	43.2	35.4	4.34	1.52	17300	953	15.0	1090	132	3.78	1080	204
245	6.1	—	45.1	32.5	4.32	1.62	16100	895	15.0	1010	123	3.75	1010	190
230	6.5	—	47.2	29.6	4.30	1.73	15000	837	14.9	940	114	3.73	943	176
256	3.5	—	39.0	43.4	3.14	1.77	16800	895	14.9	528	86.5	2.65	1040	137
232	3.9	—	42.7	36.3	3.11	1.95	15000	809	14.8	468	77.2	2.62	936	122
210	4.5	—	44.2	33.8	3.09	2.21	13200	719	14.6	411	67.5	2.58	833	107
194	4.8	—	47.7	29.0	3.07	2.39	12100	664	14.6	375	61.9	2.56	767	97.7
182	5.1	—	50.1	26.3	3.05	2.55	11300	623	14.5	347	57.6	2.55	718	90.7
170	5.5	—	53.2	23.3	3.04	2.73	10500	580	14.5	320	53.2	2.53	668	83.8
160	5.9	—	55.4	21.5	3.02	2.94	9750	542	14.4	295	49.1	2.50	624	77.3
150	6.4	—	57.4	20.1	2.99	3.18	9040	504	14.3	270	45.1	2.47	581	70.9
135	7.6	—	59.3	18.8	2.93	3.77	7800	439	14.0	225	37.7	2.38	509	59.7

F_y = 46 ksi

COLUMNS
Square structural tubing
Allowable concentric loads in kips

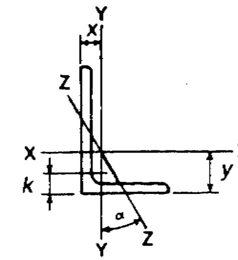
Nominal Size	6 × 6						5 × 5				
Thickness	9/16	1/2	3/8	5/16	1/4	3/16	1/2	3/8	5/16	1/4	3/16
Wt./ft	38.86	35.24	27.48	23.34	19.02	14.53	28.43	22.37	19.08	15.62	11.97
F_y	46 ksi										
Effective length in ft *KL* with respect to radius of gyration											
0	315	287	223	189	154	118	231	182	155	127	97
6	283	257	201	171	140	107	200	159	136	111	86
7	275	251	196	167	137	105	193	153	131	108	83
8	268	244	191	163	133	102	186	148	127	104	80
9	259	237	186	158	130	99	178	142	122	100	77
10	251	229	180	154	126	96	169	135	116	96	74
11	242	221	174	149	122	93	160	129	111	92	71
12	232	212	168	143	117	90	151	122	105	87	67
13	222	203	161	138	113	87	141	115	99	82	64
14	212	194	154	132	108	83	131	107	93	77	60
15	201	185	147	126	104	80	120	99	86	72	56
16	190	175	140	120	99	76	109	90	79	66	52
17	178	164	132	113	94	72	97	82	72	60	47
18	166	153	124	107	88	68	87	73	64	54	43
19	153	142	115	100	83	64	78	65	58	49	39
20	140	131	107	93	77	60	70	59	52	44	35
21	127	119	98	85	71	56	64	54	47	40	32
22	116	108	89	78	65	51	58	49	43	36	29
24	98	91	75	65	55	43	49	41	36	31	24
26	83	77	64	56	47	36	41	35	31	26	21
28	72	67	55	48	40	31	36	30	27	22	18
30	62	58	48	42	35	27	31	26	23	20	15
31	58	54	45	39	33	26		25	22	18	14
32	55	51	42	37	31	24				17	14
34	49	45	37	33	27	21					
36	43	40	33	29	24	19					
37			32	27	23	18					
38				26	22	17					
39						16					
Properties											
A (in.^{2})	11.40	10.40	8.08	6.86	5.59	4.27	8.36	6.58	5.61	4.59	3.52
I (in.^{4})	54.1	50.5	41.6	36.3	30.3	23.8	27.0	22.8	20.1	16.9	13.4
r (in.)	2.18	2.21	2.27	2.30	2.33	2.36	1.80	1.86	1.89	1.92	1.95
B } Bending factor	0.633	0.615	0.583	0.567	0.553	0.539	0.773	0.722	0.699	0.677	0.656
$a/10^6$	8.07	7.52	6.20	5.40	4.52	3.54	4.03	3.39	2.99	2.52	2.00



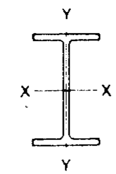
ANGLES
Equal legs and unequal legs
Properties for designing

Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	S	r	y	I	S	r	x	r	Tan α
In.	In.	Lb.	In.²	In.⁴	In.³	In.	In.	In.⁴	In.³	In.	In.	In.	
L 5×3½× 3/4	1 1/4	19.8	5.81	13.9	4.28	1.55	1.75	5.55	2.22	0.977	0.996	0.748	0.464
5/8	1 1/8	16.8	4.92	12.0	3.65	1.56	1.70	4.83	1.90	0.991	0.951	0.751	0.472
1/2	1	13.6	4.00	9.99	2.99	1.58	1.66	4.05	1.56	1.01	0.906	0.755	0.479
7/16	15/16	12.0	3.53	8.90	2.64	1.59	1.63	3.63	1.39	1.01	0.883	0.758	0.482
3/8	7/8	10.4	3.05	7.78	2.29	1.60	1.61	3.18	1.21	1.02	0.861	0.762	0.486
5/16	13/16	8.7	2.56	6.60	1.94	1.61	1.59	2.72	1.02	1.03	0.838	0.766	0.489
1/4	3/4	7.0	2.06	5.39	1.57	1.62	1.56	2.23	0.830	1.04	0.814	0.770	0.492
L 5×3 × 5/8	1	15.7	4.61	11.4	3.55	1.57	1.80	3.06	1.39	0.815	0.796	0.644	0.349
1/2	1	12.8	3.75	9.45	2.91	1.59	1.75	2.58	1.15	0.829	0.750	0.648	0.357
7/16	15/16	11.3	3.31	8.43	2.58	1.60	1.73	2.32	1.02	0.837	0.727	0.651	0.361
3/8	7/8	9.8	2.86	7.37	2.24	1.61	1.70	2.04	0.888	0.845	0.704	0.654	0.364
5/16	13/16	8.2	2.40	6.26	1.89	1.61	1.68	1.75	0.753	0.853	0.681	0.658	0.368
1/4	3/4	6.6	1.94	5.11	1.53	1.62	1.66	1.44	0.614	0.861	0.657	0.663	0.371
L 4×4 × 3/4	1 1/8	18.5	5.44	7.67	2.81	1.19	1.27	7.67	2.81	1.19	1.27	0.778	1.000
5/8	1	15.7	4.61	6.66	2.40	1.20	1.23	6.66	2.40	1.20	1.23	0.779	1.000
1/2	7/8	12.8	3.75	5.56	1.97	1.22	1.18	5.56	1.97	1.22	1.18	0.782	1.000
7/16	13/16	11.3	3.31	4.97	1.75	1.23	1.16	4.97	1.75	1.23	1.16	0.785	1.000
3/8	3/4	9.8	2.86	4.36	1.52	1.23	1.14	4.36	1.52	1.23	1.14	0.788	1.000
5/16	11/16	8.2	2.40	3.71	1.29	1.24	1.12	3.71	1.29	1.24	1.12	0.791	1.000
1/4	5/8	6.6	1.94	3.04	1.05	1.25	1.09	3.04	1.05	1.25	1.09	0.795	1.000
L 4×3½× 1/2	15/16	11.9	3.50	5.32	1.94	1.23	1.25	3.79	1.52	1.04	1.00	0.722	0.750
7/16	7/8	10.6	3.09	4.76	1.72	1.24	1.23	3.40	1.35	1.05	0.978	0.724	0.753
3/8	13/16	9.1	2.67	4.18	1.49	1.25	1.21	2.95	1.17	1.06	0.955	0.727	0.755
5/16	3/4	7.7	2.25	3.56	1.26	1.26	1.18	2.55	0.994	1.07	0.932	0.730	0.757
1/4	11/16	6.2	1.81	2.91	1.03	1.27	1.16	2.09	0.808	1.07	0.909	0.734	0.759

ANGLES
Equal legs and unequal legs
Properties for designing



Size and Thickness	k	Weight per Ft	Area	AXIS X-X				AXIS Y-Y				AXIS Z-Z	
				I	S	r	y	I	S	r	x	r	Tan α
In.	In.	Lb.	In.²	In.⁴	In.³	In.	In.	In.⁴	In.³	In.	In.	In.	
L 4 ×3 × 1/2	15/16	11.1	3.25	5.05	1.89	1.25	1.33	2.42	1.12	0.864	0.827	0.639	0.543
7/16	7/8	9.8	2.87	4.52	1.68	1.25	1.30	2.18	0.992	0.871	0.804	0.641	0.547
3/8	13/16	8.5	2.48	3.96	1.46	1.26	1.28	1.92	0.866	0.879	0.782	0.644	0.551
5/16	3/4	7.2	2.09	3.38	1.23	1.27	1.26	1.65	0.734	0.887	0.759	0.647	0.554
1/4	11/16	5.8	1.69	2.77	1.00	1.28	1.24	1.36	0.599	0.896	0.736	0.651	0.558
L 3½×3½× 1/2	7/8	11.1	3.25	3.64	1.49	1.06	1.06	3.64	1.49	1.06	1.06	0.683	1.000
7/16	13/16	9.8	2.87	3.26	1.32	1.07	1.04	3.26	1.32	1.07	1.04	0.684	1.000
3/8	3/4	8.5	2.48	2.87	1.15	1.07	1.01	2.87	1.15	1.07	1.01	0.687	1.000
5/16	11/16	7.2	2.09	2.45	0.976	1.08	0.990	2.45	0.976	1.08	0.990	0.690	1.000
1/4	5/8	5.8	1.69	2.01	0.794	1.09	0.968	2.01	0.794	1.09	0.968	0.694	1.000
L 3½×3 × 1/2	15/16	10.2	3.00	3.45	1.45	1.07	1.13	2.33	1.10	0.881	0.875	0.621	0.714
7/16	7/8	9.1	2.65	3.10	1.29	1.08	1.10	2.09	0.975	0.889	0.853	0.622	0.718
3/8	13/16	7.9	2.30	2.72	1.13	1.09	1.08	1.85	0.851	0.897	0.830	0.625	0.721
5/16	3/4	6.6	1.93	2.33	0.954	1.10	1.06	1.58	0.722	0.905	0.808	0.627	0.724
1/4	11/16	5.4	1.56	1.91	0.776	1.11	1.04	1.30	0.589	0.914	0.785	0.631	0.727
L 3½×2½× 1/2	15/16	9.4	2.75	3.24	1.41	1.09	1.20	1.36	0.760	0.704	0.705	0.534	0.486
7/16	7/8	8.3	2.43	2.91	1.26	1.09	1.18	1.23	0.677	0.711	0.682	0.535	0.491
3/8	13/16	7.2	2.11	2.56	1.09	1.10	1.16	1.09	0.592	0.719	0.660	0.537	0.496
5/16	3/4	6.1	1.78	2.19	0.927	1.11	1.14	0.939	0.504	0.727	0.637	0.540	0.501
1/4	11/16	4.9	1.44	1.80	0.755	1.12	1.11	0.777	0.412	0.735	0.614	0.544	0.506
L 3 ×3 × 1/2	13/16	9.4	2.75	2.22	1.07	0.898	0.932	2.22	1.07	0.898	0.932	0.584	1.000
7/16	3/4	8.3	2.43	1.99	0.954	0.905	0.910	1.99	0.954	0.905	0.910	0.585	1.000
3/8	11/16	7.2	2.11	1.76	0.833	0.913	0.888	1.76	0.833	0.913	0.888	0.587	1.000
5/16	5/8	6.1	1.78	1.51	0.707	0.922	0.865	1.51	0.707	0.922	0.865	0.589	1.000
1/4	9/16	4.9	1.44	1.24	0.577	0.930	0.842	1.24	0.577	0.930	0.842	0.592	1.000
3/16	1/2	3.71	1.09	0.962	0.441	0.939	0.820	0.962	0.441	0.939	0.820	0.596	1.000

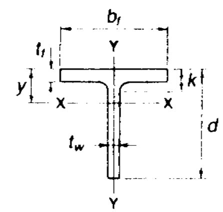


COLUMNS
W shapes
Allowable axial loads in kips

F_y = 36 ksi

F_y = 50 ksi

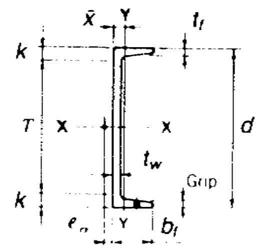
Designation		W14									
Wt./ft		132		120		109		99		90	
F_y		36	50	36	50	36	50	36	50[†]	36	50[†]
Effective length in ft KL with respect to least radius of gyration r_y	0	838	1164	762	1059	691	960	629	873	572	795
	6	801	1101	729	1002	661	908	600	825	547	751
	7	794	1088	722	990	654	897	595	815	541	742
	8	786	1074	714	977	647	885	589	805	536	732
	9	777	1060	707	963	640	873	582	793	530	722
	10	768	1044	699	949	633	860	575	782	524	711
	11	759	1028	690	935	626	847	568	769	517	700
	12	750	1011	682	919	618	833	561	757	511	689
	13	740	994	673	903	609	818	554	743	504	676
	14	730	976	663	887	601	803	546	730	497	664
	15	719	958	654	870	592	788	538	715	489	651
	16	708	938	644	852	583	772	529	701	482	637
	17	697	919	633	834	574	755	521	685	474	624
	18	686	898	623	815	564	738	512	670	466	609
	19	674	877	612	796	554	721	503	654	458	595
	20	662	856	601	776	544	703	494	637	449	580
	22	637	811	578	735	523	665	475	603	432	548
	24	610	764	554	692	501	626	454	567	413	515
	26	583	714	528	647	478	585	433	529	394	481
	28	554	663	502	599	454	541	411	489	374	444
	30	524	608	475	549	429	496	388	448	353	406
	32	493	551	446	497	403	449	365	404	331	366
	34	461	492	416	443	376	399	340	359	308	325
	36	427	439	385	395	348	356	314	320	285	290
	38	392	394	353	355	319	320	287	288	260	261
Properties											
U		2.47	2.47	2.48	2.48	2.49	2.49	2.50	2.28	2.52	2.29
P_{wo} (kips)		196	272	173	240	148	205	125	174	109	151
P_{wi} (kips/in.)		23	32	21	30	19	26	17	24	16	22
P_{wb} (kips)		587	692	449	529	316	373	249	294	186	220
P_{fb} (kips)		239	332	199	276	166	231	137	190	113	158
L_c (ft)		15.5	13.2	15.5	13.1	15.4	13.1	15.4	13.0	15.3	13.0
L_u (ft)		47.7	34.4	44.1	31.7	40.6	29.2	37.0	26.7	34.0	24.5
A (in.^{2})		38.8		35.3		32.0		29.1		26.5	
I_x (in.^{4})		1530		1380		1240		1110		999	
I_y (in.^{4})		548		495		447		402		362	
r_y (in.)		3.76		3.74		3.73		3.71		3.70	
Ratio r_x/r_y		1.67		1.67		1.67		1.66		1.66	
B_x Bending factors		0.186		0.186		0.185		0.185		0.185	
B_y Bending factors		0.521		0.523		0.523		0.527		0.531	
$a_x/10^6$		228.0		204.8		184.5		165.1		148.9	
$a_y/10^6$		81.7		73.6		66.3		59.7		54.1	
$F'_{ex}(K_xL_x)^2/10^2$ (kips)		409		404		401		395		391	
$F'_{ey}(K_yL_y)^2/10^2$ (kips)		147		145		144		143		142	



STRUCTURAL TEES
Cut from W shapes
Dimensions

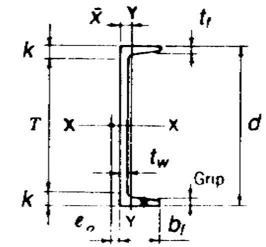
Designation	Area	Depth of Tee d		Stem Thickness t_w		Stem $\frac{t_w}{2}$	Area of Stem	Flange Width b_f		Flange Thickness t_f		Distance k
	In.^{2}	In.		In.		In.	In.^{2}	In.		In.		In.
WT 9×71.5	21.0	9.745	9 3/4	0.730	3/4	3/8	7.11	11.220	11 1/4	1.320	1 5/16	2
×65	19.1	9.625	9 5/8	0.670	11/16	3/8	6.45	11.160	11 1/8	1.200	1 3/16	1 7/8
×59.5	17.5	9.485	9 1/2	0.655	5/8	5/16	6.21	11.265	11 1/4	1.060	1 1/16	1 3/4
×53	15.6	9.365	9 3/8	0.590	9/16	5/16	5.53	11.200	11 1/4	0.940	15/16	1 5/8
×48.5	14.3	9.295	9 1/4	0.535	9/16	5/16	4.97	11.145	11 1/8	0.870	7/8	1 9/16
×43	12.7	9.195	9 1/4	0.480	1/2	1/4	4.41	11.090	11 1/8	0.770	3/4	1 7/16
×38	11.2	9.105	9 1/8	0.425	7/16	1/4	3.87	11.035	11	0.680	11/16	1 3/8
WT 9×35.5	10.4	9.235	9 1/4	0.495	1/2	1/4	4.57	7.635	7 5/8	0.810	13/16	1 1/2
×32.5	9.55	9.175	9 1/8	0.450	7/16	1/4	4.13	7.590	7 5/8	0.750	3/4	1 7/16
×30	8.82	9.120	9 1/8	0.415	7/16	1/4	3.78	7.555	7 1/2	0.695	11/16	1 3/8
×27.5	8.10	9.055	9	0.390	3/8	3/16	3.53	7.530	7 1/2	0.630	5/8	1 5/16
×25	7.33	8.995	9	0.355	3/8	3/16	3.19	7.495	7 1/2	0.570	9/16	1 1/4
WT 9×23	6.77	9.030	9	0.360	3/8	3/16	3.25	6.060	6	0.605	5/8	1 1/4
×20	5.88	8.950	9	0.315	5/16	3/16	2.82	6.015	6	0.525	1/2	1 3/16
×17.5	5.15	8.850	8 7/8	0.300	5/16	3/16	2.65	6.000	6	0.425	7/16	1 1/8
WT 8×50	14.7	8.485	8 1/2	0.585	9/16	5/16	4.96	10.425	10 3/8	0.985	1	1 11/16
×44.5	13.1	8.375	8 3/8	0.525	1/2	1/4	4.40	10.365	10 3/8	0.875	7/8	1 9/16
×38.5	11.3	8.260	8 1/4	0.455	7/16	1/4	3.76	10.295	10 1/4	0.760	3/4	1 7/16
×33.5	9.84	8.165	8 1/8	0.395	3/8	3/16	3.23	10.235	10 1/4	0.665	11/16	1 3/8
WT 8×28.5	8.38	8.215	8 1/4	0.430	7/16	1/4	3.53	7.120	7 1/8	0.715	11/16	1 3/8
×25	7.37	8.130	8 1/8	0.380	3/8	3/16	3.09	7.070	7 1/8	0.630	5/8	1 5/16
×22.5	6.63	8.065	8 1/8	0.345	3/8	3/16	2.78	7.035	7	0.565	9/16	1 1/4
×20	5.89	8.005	8	0.305	5/16	3/16	2.44	6.995	7	0.505	1/2	1 3/16
×18	5.28	7.930	7 7/8	0.295	5/16	3/16	2.34	6.985	7	0.430	7/16	1 1/8
WT 8×15.5	4.56	7.940	8	0.275	1/4	1/8	2.18	5.525	5 1/2	0.440	7/16	1 1/8
×13	3.84	7.845	7 7/8	0.250	1/4	1/8	1.96	5.500	5 1/2	0.345	3/8	1 1/16

CHANNELS MISCELLANEOUS Dimensions

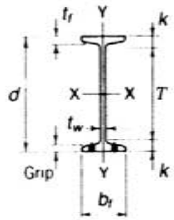


Designation	Area A	Depth d	Web Thickness t_w		$\frac{t_w}{2}$	Flange Width b_f		Flange Average Thickness t_f		Distance T	Distance k	Grip	Max. Flge. Fastener
	In.^{2}	In.	In.		In.	In.		In.		In.	In.	In.	In.
MC 18×58	17.1	18.00	0.700	11/16	3/8	4.200	4 1/4	0.625	5/8	15 1/4	1 3/8	5/8	1
×51.9	15.3	18.00	0.600	5/8	5/16	4.100	4 1/8	0.625	5/8	15 1/4	1 3/8	5/8	1
×45.8	13.5	18.00	0.500	1/2	1/4	4.000	4	0.625	5/8	15 1/4	1 3/8	5/8	1
×42.7	12.6	18.00	0.450	7/16	1/4	3.950	4	0.625	5/8	15 1/4	1 3/8	5/8	1
MC 13×50	14.7	13.00	0.787	13/16	3/8	4.412	4 3/8	0.610	5/8	10 1/4	1 3/8	5/8	1
×40	11.8	13.00	0.560	9/16	1/4	4.185	4 1/8	0.610	5/8	10 1/4	1 3/8	9/16	1
×35	10.3	13.00	0.447	7/16	1/4	4.072	4 1/8	0.610	5/8	10 1/4	1 3/8	9/16	1
×31.8	9.35	13.00	0.375	3/8	3/16	4.000	4	0.610	5/8	10 1/4	1 3/8	9/16	1
MC 12×50	14.7	12.00	0.835	13/16	7/16	4.135	4 1/8	0.700	11/16	9 3/8	1 5/16	11/16	1
×45	13.2	12.00	0.712	11/16	3/8	4.012	4	0.700	11/16	9 3/8	1 5/16	11/16	1
×40	11.8	12.00	0.590	9/16	5/16	3.890	3 7/8	0.700	11/16	9 3/8	1 5/16	11/16	1
×35	10.3	12.00	0.467	7/16	1/4	3.767	3 3/4	0.700	11/16	9 3/8	1 5/16	11/16	1
×31	9.12	12.00	0.370	3/8	3/16	3.670	3 5/8	0.700	11/16	9 3/8	1 5/16	11/16	1
MC 12×10.6	3.10	12.00	0.190	3/16	1/8	1.500	1 1/2	0.309	5/16	10 5/8	11/16	—	—
MC 10×41.1	12.1	10.00	0.796	13/16	3/8	4.321	4 3/8	0.575	9/16	7 1/2	1 1/4	9/16	7/8
×33.6	9.87	10.00	0.575	9/16	5/16	4.100	4 1/8	0.575	9/16	7 1/2	1 1/4	9/16	7/8
×28.5	8.37	10.00	0.425	7/16	3/16	3.950	4	0.575	9/16	7 1/2	1 1/4	9/16	7/8
MC 10×25	7.35	10.00	0.380	3/8	3/16	3.405	3 3/8	0.575	9/16	7 1/2	1 1/4	9/16	7/8
×22	6.45	10.00	0.290	5/16	1/8	3.315	3 3/8	0.575	9/16	7 1/2	1 1/4	9/16	7/8
MC 10× 8.4	2.46	10.00	0.170	3/16	1/16	1.500	1 1/2	0.280	1/4	8 5/8	11/16	—	—
MC 10× 6.5	1.91	10.00	0.152	1/8	1/16	1.127	1 1/8	0.202	3/16	9 1/8	7/16	—	—

CHANNELS MISCELLANEOUS Properties



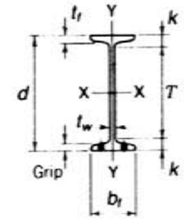
Nominal Wt. per Ft	$\bar{x}$	Shear Center Location e_o	$\frac{d}{A_f}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r
Lb.	In.	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.
58	0.862	0.695	6.86	676	75.1	6.29	17.8	5.32	1.02
51.9	0.858	0.797	7.02	627	69.7	6.41	16.4	5.07	1.04
45.8	0.866	0.909	7.20	578	64.3	6.56	15.1	4.82	1.06
42.7	0.877	0.969	7.29	554	61.6	6.64	14.4	4.69	1.07
50	0.974	0.815	4.83	314	48.4	4.62	16.5	4.79	1.06
40	0.963	1.03	5.09	273	42.0	4.82	13.7	4.26	1.08
35	0.980	1.16	5.23	252	38.8	4.95	12.3	3.99	1.10
31.8	1.00	1.24	5.33	239	36.8	5.06	11.4	3.81	1.11
50	1.05	0.741	4.15	269	44.9	4.28	17.4	5.65	1.09
45	1.04	0.844	4.27	252	42.0	4.36	15.8	5.33	1.09
40	1.04	0.952	4.41	234	39.0	4.46	14.3	5.00	1.10
35	1.05	1.07	4.55	216	36.1	4.59	12.7	4.67	1.11
31	1.08	1.18	4.67	203	33.8	4.71	11.3	4.39	1.12
10.6	0.269	0.284	25.9	55.4	9.23	4.22	0.382	0.310	0.351
41.1	1.09	0.864	4.02	158	31.5	3.61	15.8	4.88	1.14
33.6	1.08	1.06	4.24	139	27.8	3.75	13.2	4.38	1.16
28.5	1.12	1.21	4.40	127	25.3	3.89	11.4	4.02	1.17
25	0.953	1.03	5.11	110	22	3.87	7.35	3.00	1.00
22	0.990	1.13	5.25	103	20.5	3.99	6.50	2.80	1.00
8.4	0.284	0.332	23.8	32.0	6.40	3.61	0.328	0.270	0.365
6.5	0.180	0.167	43.8	22.1	4.42	3.40	0.112	0.118	0.242



S SHAPES
Dimensions

Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Grip	Max. Flge. Fastener
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.	In.
S24×121	35.6	24.50	24½	0.800	13/16	7/16	8.050	8	1.090	1 1/16	20½	2	1⅛	1
×106	31.2	24.50	24½	0.620	⅝	5/16	7.870	7⅞	1.090	1 1/16	20½	2	1⅛	1
S24×100	29.3	24.00	24	0.745	¾	⅜	7.245	7¼	0.870	⅞	20½	1¾	⅞	1
×90	26.5	24.00	24	0.625	⅝	5/16	7.125	7⅛	0.870	⅞	20½	1¾	⅞	1
×80	23.5	24.00	24	0.500	½	¼	7.000	7	0.870	⅞	20½	1¾	⅞	1
S20×96	28.2	20.30	20¼	0.800	13/16	7/16	7.200	7¼	0.920	15/16	16¾	1¾	15/16	1
×86	25.3	20.30	20¼	0.660	11/16	⅜	7.060	7	0.920	15/16	16¾	1¾	15/16	1
S20×75	22.0	20.00	20	0.635	⅝	5/16	6.385	6⅜	0.795	13/16	16¾	1⅝	13/16	⅞
×66	19.4	20.00	20	0.505	½	¼	6.255	6¼	0.795	13/16	16¾	1⅝	13/16	⅞
S18×70	20.6	18.00	18	0.711	11/16	⅜	6.251	6¼	0.691	11/16	15	1½	11/16	⅞
×54.7	16.1	18.00	18	0.461	7/16	¼	6.001	6	0.691	11/16	15	1½	11/16	⅞
S15×50	14.7	15.00	15	0.550	9/16	5/16	5.640	5⅝	0.622	⅝	12¼	1⅜	9/16	¾
×42.9	12.6	15.00	15	0.411	7/16	¼	5.501	5½	0.622	⅝	12¼	1⅜	9/16	¾
S12×50	14.7	12.00	12	0.687	11/16	⅜	5.477	5½	0.659	11/16	9⅛	1 7/16	11/16	¾
×40.8	12.0	12.00	12	0.462	7/16	¼	5.252	5¼	0.659	11/16	9⅛	1 7/16	⅝	¾
S12×35	10.3	12.00	12	0.428	7/16	¼	5.078	5⅛	0.544	9/16	9⅝	1 3/16	½	¾
×31.8	9.35	12.00	12	0.350	⅜	3/16	5.000	5	0.544	9/16	9⅝	1 3/16	½	¾
S10×35	10.3	10.00	10	0.594	⅝	5/16	4.944	5	0.491	½	7¾	1⅛	½	¾
×25.4	7.46	10.00	10	0.311	5/16	3/16	4.661	4⅝	0.491	½	7¾	1⅛	½	¾
S 8×23	6.77	8.00	8	0.441	7/16	¼	4.171	4⅛	0.426	7/16	6	1	7/16	¾
×18.4	5.41	8.00	8	0.271	¼	⅛	4.001	4	0.426	7/16	6	1	7/16	¾
S 7×20	5.88	7.00	7	0.450	7/16	¼	3.860	3⅞	0.392	⅜	5⅛	15/16	⅜	⅝
×15.3	4.50	7.00	7	0.252	¼	⅛	3.662	3⅝	0.392	⅜	5⅛	15/16	⅜	⅝
S 6×17.25	5.07	6.00	6	0.465	7/16	¼	3.565	3⅝	0.359	⅜	4¼	⅞	⅜	⅝
×12.5	3.67	6.00	6	0.232	¼	⅛	3.332	3⅜	0.359	⅜	4¼	⅞	⅜	—
S 5×14.75	4.34	5.00	5	0.494	½	¼	3.284	3¼	0.326	5/16	3⅜	13/16	5/16	—
×10	2.94	5.00	5	0.214	3/16	⅛	3.004	3	0.326	5/16	3⅜	13/16	5/16	—
S 4×9.5	2.79	4.00	4	0.326	5/16	3/16	2.796	2¾	0.293	5/16	2½	¾	5/16	—
×7.7	2.26	4.00	4	0.193	3/16	⅛	2.663	2⅝	0.293	5/16	2½	¾	5/16	—
S 3×7.5	2.21	3.00	3	0.349	⅜	3/16	2.509	2½	0.260	¼	1⅜	11/16	¼	—

S SHAPES
Properties



Nominal Wt. per Ft	Compact Section Criteria $\frac{b_f}{2t_f}$	F_y'	$\frac{d}{t_w}$	F_y'''	r_T	$\frac{d}{A_f}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Torsional constant J	Plastic Modulus Z_x	Plastic Modulus Z_y
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.^{3}
121	3.7	—	30.6	—	1.86	2.79	3160	258	9.43	83.3	20.7	1.53	12.8	306	36.2
106	3.6	—	39.5	42.3	1.86	2.86	2940	240	9.71	77.1	19.6	1.57	10.1	279	33.2
100	4.2	—	32.2	63.6	1.59	3.81	2390	199	9.02	47.7	13.2	1.27	7.58	240	23.9
90	4.1	—	38.4	44.8	1.60	3.87	2250	187	9.21	44.9	12.6	1.30	6.04	222	22.3
80	4.0	—	48.0	28.7	1.61	3.94	2100	175	9.47	42.2	12.1	1.34	4.88	204	20.7
96	3.9	—	25.4	—	1.63	3.06	1670	165	7.71	50.2	13.9	1.33	8.39	198	24.9
86	3.8	—	30.8	—	1.63	3.13	1580	155	7.89	46.8	13.3	1.36	6.64	183	23.0
75	4.0	—	31.5	—	1.43	3.94	1280	128	7.62	29.8	9.32	1.16	4.59	153	16.7
66	3.9	—	39.6	42.1	1.44	4.02	1190	119	7.83	27.7	8.85	1.19	3.58	140	15.3
70	4.5	—	25.3	—	1.36	4.17	926	103	6.71	24.1	7.72	1.08	4.15	125	14.4
54.7	4.3	—	39.0	43.3	1.37	4.34	804	89.4	7.07	20.8	6.94	1.14	2.37	105	12.1
50	4.5	—	27.3	—	1.26	4.28	486	64.8	5.75	15.7	5.57	1.03	2.12	77.1	9.97
42.9	4.4	—	36.5	49.6	1.26	4.38	447	59.6	5.95	14.4	5.23	1.07	1.54	69.3	9.02
50	4.2	—	17.5	—	1.25	3.32	305	50.8	4.55	15.7	5.74	1.03	2.82	61.2	10.3
40.8	4.0	—	26.0	—	1.24	3.46	272	45.4	4.77	13.6	5.16	1.06	1.76	53.1	8.85
35	4.7	—	28.0	—	1.16	4.34	229	38.2	4.72	9.87	3.89	0.980	1.08	44.8	6.79
31.8	4.6	—	34.3	56.2	1.16	4.41	218	36.4	4.83	9.36	3.74	1.00	0.90	42.0	6.40
35	5.0	—	16.8	—	1.10	4.12	147	29.4	3.78	8.36	3.38	0.901	1.29	35.4	6.22
25.4	4.7	—	32.2	63.9	1.09	4.37	124	24.7	4.07	6.79	2.91	0.954	0.60	28.4	4.96
23	4.9	—	18.1	—	0.95	4.51	64.9	16.2	3.10	4.31	2.07	0.798	0.55	19.3	3.68
18.4	4.7	—	29.5	—	0.94	4.70	57.6	14.4	3.26	3.73	1.86	0.831	0.34	16.5	3.16
20	4.9	—	15.6	—	0.88	4.63	42.4	12.1	2.69	3.17	1.64	0.734	0.45	14.5	2.96
15.3	4.7	—	27.8	—	0.87	4.88	36.7	10.5	2.86	2.64	1.44	0.766	0.24	12.1	2.44
17.25	5.0	—	12.9	—	0.81	4.69	26.3	8.77	2.28	2.31	1.30	0.675	0.37	10.6	2.36
12.5	4.6	—	25.9	—	0.79	5.02	22.1	7.37	2.45	1.82	1.09	0.705	0.17	8.47	1.85
14.75	5.0	—	10.1	—	0.74	4.66	15.2	6.09	1.87	1.67	1.01	0.620	0.32	7.42	1.88
10	4.6	—	23.4	—	0.72	5.10	12.3	4.92	2.05	1.22	0.809	0.643	0.11	5.67	1.37
9.5	4.8	—	12.3	—	0.65	4.88	6.79	3.39	1.56	0.903	0.646	0.569	0.12	4.04	1.13
7.7	4.5	—	20.7	—	0.64	5.13	6.08	3.04	1.64	0.764	0.574	0.581	0.07	3.51	0.964
7.5	4.8	—	8.6	—	0.59	4.60	2.93	1.95	1.15	0.586	0.468	0.516	0.09	2.36	0.826

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