Lateral Systems for Light Gauge Steel

SEAONC 5/13/09

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Walnut Creek, CA

Lateral Systems for Light Gauge Steel

- Presentation is based primarily upon Seismic loading and conditions in California and they might not be accurate outside of California.

- Some examples use rough numbers to illustrate the example – actual values will depend upon specifics.

- Not all systems are presented.

- In an effort to save time, please keep questions to the end.   Thank you.

Basis of Design

2006 International Building Code
(2007 California Building Code)

SECTION 2210
COLD-FORMED STEEL
LIGHT-FRAMED CONSTRUCTION

2210.1 General. The design, installation and construction of cold-formed carbon or low-alloy steel, structural and nonstructural steel framing shall be in accordance with AISI-General and AISI-NAS.

2210.2 Headers. The design and installation of cold-formed steel box headers, back-to-back headers and single and double L-headers used in single-span conditions for load-carrying purposes shall be in accordance with AISI-Header, subject to the limitations therein.

2210.3 Trusses. The design, quality assurance, installation and testing of cold-formed steel trusses shall be in accordance with AISI-Truss, subject to the limitations therein.

2210.4 Wall stud design. The design and installation of cold-formed steel studs for structural and nonstructural walls shall be in accordance with AISI-WSD.

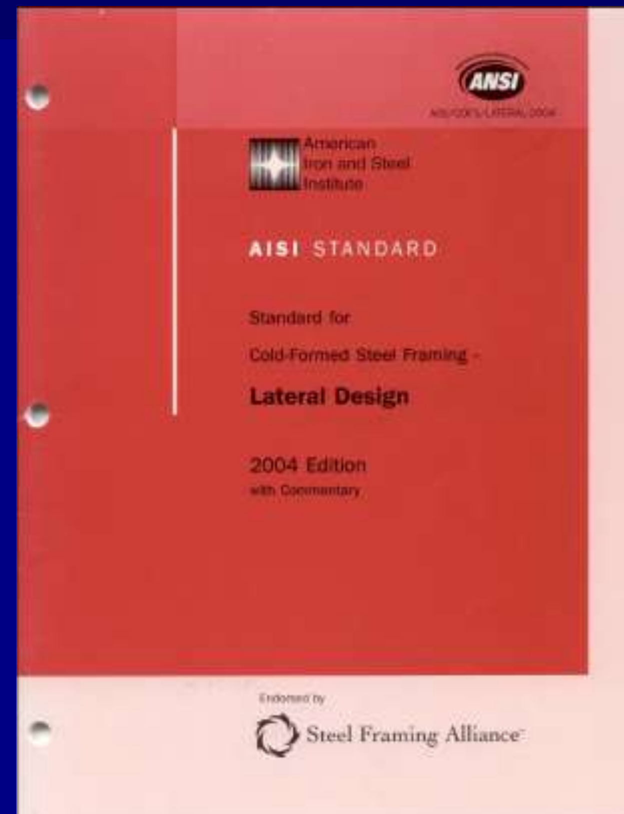
2210.5 Lateral design. The design of light-framed cold-formed steel walls and diaphragms to resist wind and seismic loads shall be in accordance with AISI-Lateral.

2210.6 Prescriptive framing. Detached one- and two-family dwellings and townhouses, up to two stories in height, shall be permitted to be constructed in accordance with AISI-PM, subject to the limitations therein.

Basis of Design

American Iron and Steel Institute (AISI)

2001 North American Specification (NAS) with 2004 Amendments



2004 Lateral Design

Outline

I. Shear Walls
   A. Stud Framing
   B. Sheathing Materials
II. Diaphragms
   A. Joist Framing
   B. Sheathing Materials
III. Selection of Systems
   A. Complete Light Gauge Buildings
   B. Components of Larger Buildings

Shear Walls – Response Modification

R Values per ASCE 7-05:

A. BEARING WALL SYSTEM

13.	Light-framed walls sheathed with wood framed structural panels rated for shear resistance or sheet steel	**6.5**
14.	Light framed walls with shear panels of all other materials	**2.0**
15.	Light-framed wall systems using flat strap bracing	**4.0**

Shear Walls – Stud Framing

C2.2 – Lateral

1. Stud: C – shape, 33 mil min, 1.625 inch flange min., 3.5 inch depth min., 0.375 inch edge stiffener min.
2. Track: 33 mil min, 1.25 inch flange min.
3. Maximum spacing of studs is 24 inches on center

Shear Walls – Sheathing

- Diagonal Straps
- Sheet Steel
- Narrow Piers
- Plywood
- SureBoard

Shear Walls – Sheathing

- For ASD divide nominal shear strength given in tables by 2.5
- h/w – 2.0 maximum, some materials allow 4.0 if modifications to allowable shear strength are made
- Different materials or fasteners on the same wall are not additive
- Same material and fasteners on both sides doubles values

Shear Walls – Capacities (Diagonal Straps)

Diagonal Straps – Strengths are limited. Must be installed taut. Single sided installations should be limited to low load situations or eccentricity in hold down connection must be accounted for. Connections must be designed for amplified seismic loads.

Shear Walls – Capacities (Sheet Steel)

TABLE C2.1-3
NOMINAL SHEAR STRENGTH, (R_n), FOR SEISMIC LOADS FOR SHEAR WALLS [1,4,7]
(Pounds Per Foot)

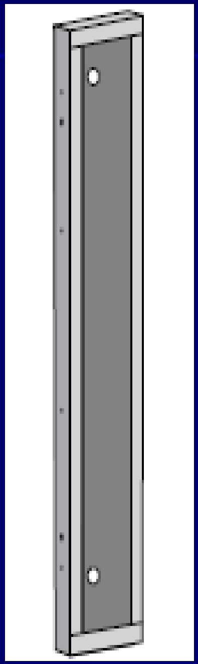
Assembly Description	Max. Aspect Ratio (h/w)	Fastener Spacing at Panel Edges[2] (Inches)				Designation Thickness[5,6] of Stud and Track (mils)	Required Sheathing Screw Size
		6	4	3	2		
15/32" Structural 1 sheathing (4-ply), one side	2:1[3]	780	990	-	-	33 or 43	8
	2:1	890	1330	1775	2190	43 or 54	8
7/16" OSB, one side	2:1[3]	700	915	-	-	33	8
	2:1[3]	825	1235	1545	2060	43 or 54	8
	2:1	940	1410	1760	2350	54	8
	2:1	1232	1848	2310	3080	68	10
0.018" steel sheet, one side	2:1	390	-	-	-	33 (min.)	8
0.027" steel sheet, one side	4:1	-	1000	1085	1170	33 (min.)	8

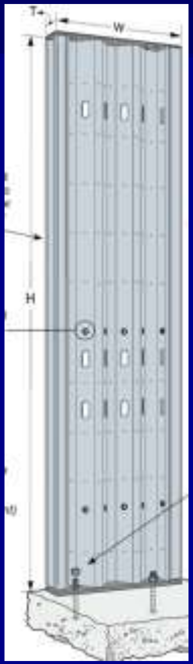
1 *Nominal* shear strength shall be multiplied by the *resistance factor* (ϕ) to determine *design strength* or divided by the *safety factor* (Ω) to determine *allowable* shear strength as set forth in Section C2.1.
2 Screws in the field of the panel shall be installed 12 inches (305 mm) o.c. unless otherwise shown.
3 *Shear wall* height to width aspect ratios (h/w) greater than 2:1, but not exceeding 4:1, are permitted provided the *nominal* shear strength are multiplied by 2w/h. See Section C2.1.
4 See Section C2.1 for requirements for sheathing applied to both sides of wall.

Values for Sheet Steel vary with thickness and fastener spacing.

Maximum Values – 468 plf (ASD) for 27 mil sheet, 33 mil studs, #8 @ 2" o/c

Shear Walls – Capacities (Narrow Piers)





Narrow Piers are Proprietary – Values vary with manufacturer and configuration

Care should be taken with respect to values for products using the 2006 IBC a some have not been tested per AC 322-07. Some modifications to published values may be required depending upon jurisdiction.

Shear Walls – Capacities (Plywood)

TABLE C2.1-3
NOMINAL SHEAR STRENGTH, (R_n), FOR SEISMIC LOADS FOR SHEAR WALLS [1,4,7]
(Pounds Per Foot)

Assembly Description	Max. Aspect Ratio (h/w)	Fastener Spacing at Panel Edges[2] (Inches)				Designation Thickness[5,6] of Stud and Track (mils)	Required Sheathing Screw Size
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4 See Section C2.1 for requirements for sheathing applied to both sides of wall.

Values for plywood vary depending upon thickness, gauge of studs and fastener spacing.

Maximum Values – 1232 plf (ASD) for 7/16 OSB, 68 mil studs, #10 @ 2" o/c

Shear Walls – Capacities (Sure-Board)

SURE-BOARD®
Series 200 For Shear

ICBO ER-5762
www.sureboard.com

◄STEEL►
Framing

TABLE 1 - NOMINAL SHEAR RESISTANCE TO WIND OR EARTHQUAKE FORCES AND DEFLECTION (inches) FOR SHEAR WALLS WITH SURE-BOARD® SERIES 200 STRUCTURAL PANELS ATTACHED TO LIGHT GAGE STEEL STUDS WITH SCREWS (pounds per foot) [1234]

STEEL FRAMING	FASTENER SPACING AT PANEL EDGES (Inches)[6, 7]											
	6			4			3			2		
Minimum Gage[5]	Load (lb/linear foot)	Δ_n (inch)	Δ_s (inch)	Load (lb/linear foot)	Δ_n (inch)	Δ_s (inch)	Load (lb/linear foot)	Δ_n (inch)	Δ_s (inch)	Load (lb/linear foot)	Δ_n (inch)	Δ_s (inch)
20 (0.033 inch)	1,085	0.55	0.10	1,545	0.70	0.11	1,730	0.70	0.14	1,915	0.70	0.12
18 (0.043 inch)	1,405	0.82	0.11	1,925	0.97	0.13	2,145	0.97	0.16	2,360	0.83	0.13
16 (0.057 inch)	-	-	-	-	-	-	2,895	1.01	0.20	3,460	1.24	0.18

For SI: 1 inch = 25.4 mm, 1 lb/linear = 0.0146 N/mm.

[1] These values are for short-term loads due to wind or earthquake.
[2] The screws are described in Section 2.2.2 and are installed in accordance with Section 2.4 in ICC ES ER-5762.
[3] Tabulated values are for panels applied to one side of a wall.
[4] For allowable stress design (ASD) loads, the tabulated load values must be divided by the safety factor $\Omega = 2.5$. For load and resistance factor design (LRFD) loads, the tabulated load values must be multiplied by the resistance factor $\Phi = 0.55$.
[5] Section 2.2.3 in ICC ES ER-5762, describes minimum base metal thickness associated with gages.
[6] All panel edges must be blocked. Panels are installed vertically. Fasteners must be spaced a maximum of 12 inches on center along intermediate framing members.
[7] Δ_n = approximate deflection at nominal load; Δ_s = approximate deflection at design load.

CEMCO

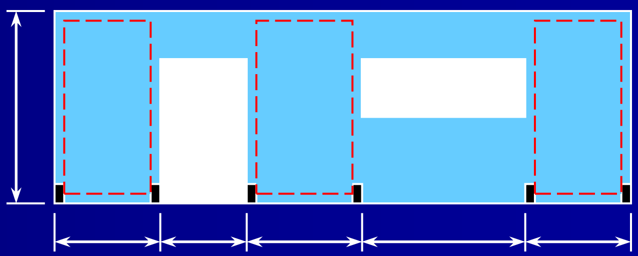
California Expanded Metal Products Co. **Technical Services** **800.416.2278**
www.cemcosteel.com
263 N. Covina Lane • City of Industry, CA 91744 800.775.2362
1001-A Pittsburg Antioch Hwy • Pittsburg, CA 94565 925.473.9340
490 Osage Street • Denver, CO 80204 303.572.3626

Values for Sure-Board vary with stud gauge and fastener spacing.

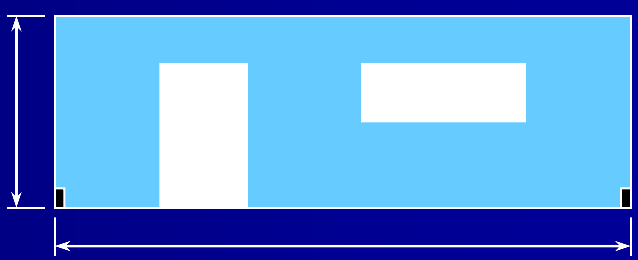
Maximum Values – 1384 plf (ASD) for 54 mil studs and #6 @ 2" o/c

Shear Walls – Type I and II

- Segmented shearwalls
  - TYPE I



- Perforated shearwalls
  - Designed for load transfer around opening
  - No design for load transfer around openings: TYPE II



Shear Walls – Type I and II

- Perforated shear walls (Type II)
  - No design for load transfer around openings: TYPE II
  - Not to be based upon screw spacing of less than 4” o/c
  - h/w (2:1) ratio walls on each end unless the shear values are adjusted by 2w/h
  - Uplift anchorage at ends and uniform uplift anchorage must be provided

Table C3.2-1
SHEAR RESISTANCE ADJUSTMENT FACTOR-C_a

Wall Height (h)	Maximum Opening Height Ratio[1] and Height				
	h/3	h/2	2h/3	5h/6	h
8'-0" (2440 mm)	2'-8" (810 mm)	4'-0" (1220 mm)	5'-4" (1630 mm)	6'-8" (2030 mm)	8'-0" (2440 mm)
10'-0" (3050 mm)	3'-4" (1020 mm)	5'-0" (1530 mm)	6'-8" (2030 mm)	8'-4" (2540 mm)	10'-0" (3050 mm)
Percent Full-Height Sheathing[2]	**Shear Resistance Adjustment Factor**				
10%	1.00	0.69	0.53	0.43	0.36
20%	1.00	0.71	0.56	0.45	0.38
30%	1.00	0.74	0.59	0.49	0.42
40%	1.00	0.77	0.63	0.53	0.45
50%	1.00	0.80	0.67	0.57	0.50
60%	1.00	0.83	0.71	0.63	0.56
70%	1.00	0.87	0.77	0.69	0.63
80%	1.00	0.91	0.83	0.77	0.71
90%	1.00	0.95	0.91	0.87	0.83
100%	1.00	1.00	1.00	1.00	1.00

1 See Section C3.2.2
2 See Section C3.2.1

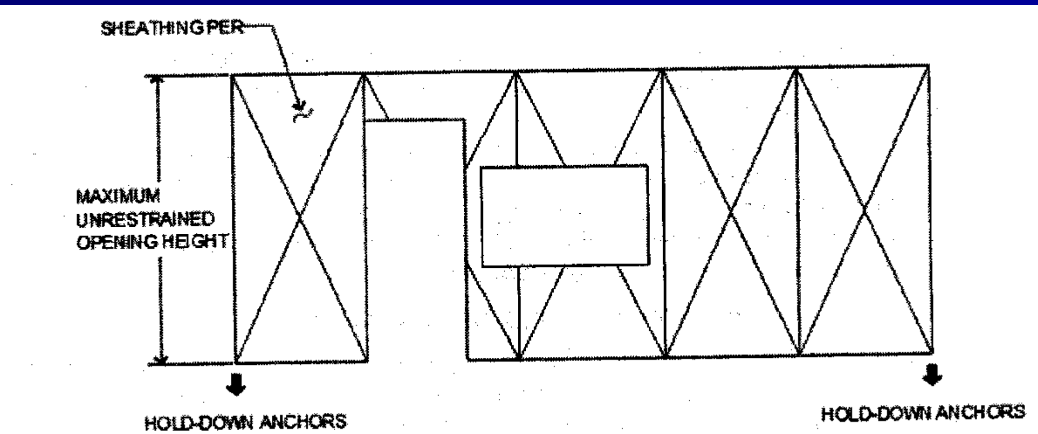


Figure C3-1 – Typical Type II Shear Wall

Shear Walls – Aspect Ratios

- Sheet Steel – 2:1 or 4:1 depending upon type
- Narrow Piers – Based upon test Results up to 8:1
- Plywood – 2:1 without reduction some can go to 4:1 with reductions in allowable shear (Table C2.1-3)
- SureBoard – 2.5:1

Shear Walls –
Jambs and Boundary Elements

C5.3 – Studs or vertical boundary members at the ends of wall elements and anchorage thereto shall have the nominal strength to resist the amplified seismic loads, but need not be greater than the loads the system can deliver.

Shear Walls –
Jambs and Boundary Elements

In multistory situations:

- Compression loads quickly exceed cold formed steel capacities

- Hold down connection demands exceed screw capacities

Shear Walls –
Jambs and Boundary Elements

Example:
10 foot floor heights:

Floor	Shear	Jamb Load	Amplified Load	Cumulative Load	Equiv. ASD
4th	500 plf	5.0 k	15 k	15 k	9 k
3rd	750 plf	7.5 k	23 k	38 k	23 k
2nd	1000 plf	10.0 k	30 k	68 k	41 k
1st	1250 plf	12.5 k	38 k	116 k	69 k

Shear Walls –
Jambs and Boundary Elements

Detailing:

Double Studs – lower load levels

PACO Members – can be combined with studs

Tube Sections – with stud "nailers"

40 k (ASD) Practical Limit

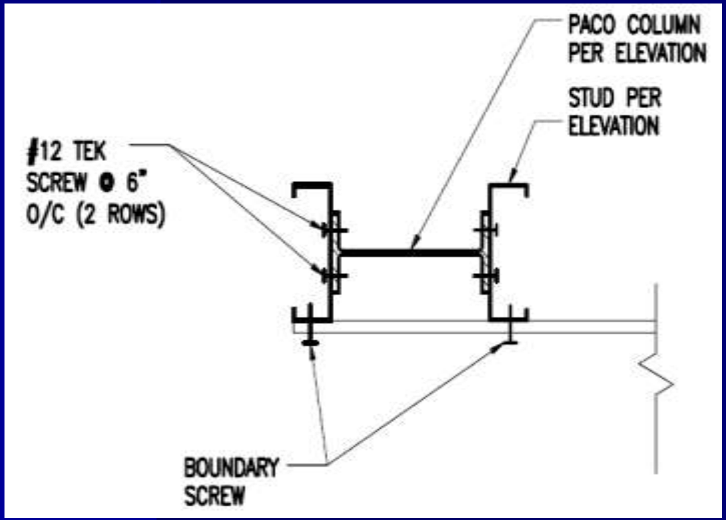
Shear Walls –
Jambs and Boundary Elements

Detailing:

Double Studs – lower load levels

PACO Members – can be combined with studs

Tube Sections – with stud "nailers"



100 k (ASD) Practical Limit

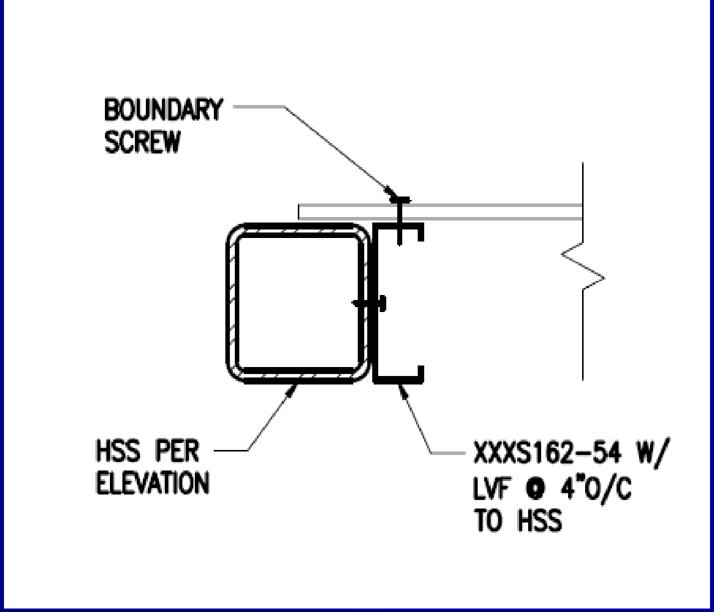
Shear Walls –
Jambs and Boundary Elements

Detailing:

Double Studs – lower load levels

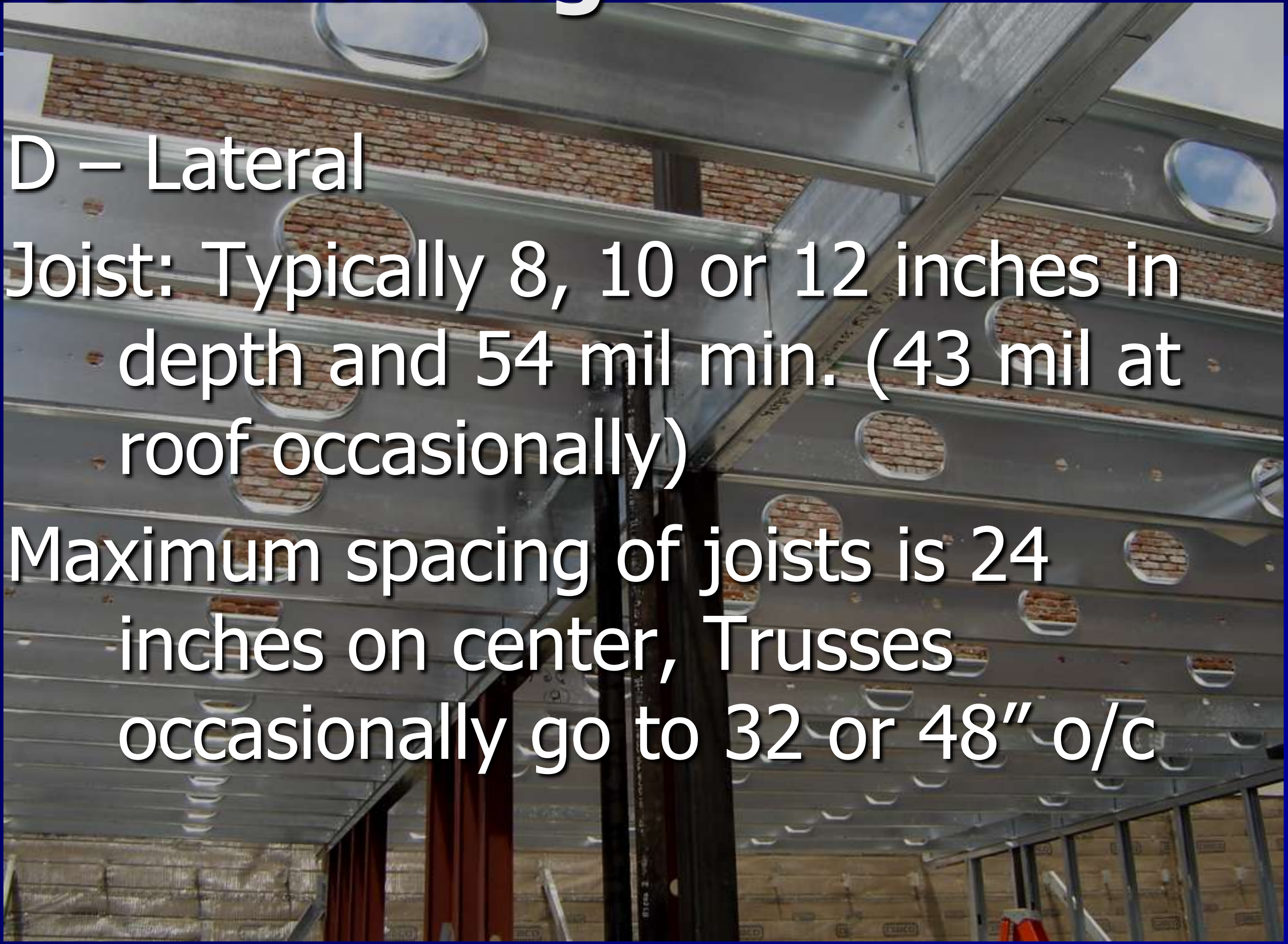
PACO Members – can be combined with studs

Tube Sections – with stud "nailers"



180 k (ASD) Practical Limit

Diaphragms – Joist Framing



D – Lateral

Joist: Typically 8, 10 or 12 inches in depth and 54 mil min. (43 mil at roof occasionally)

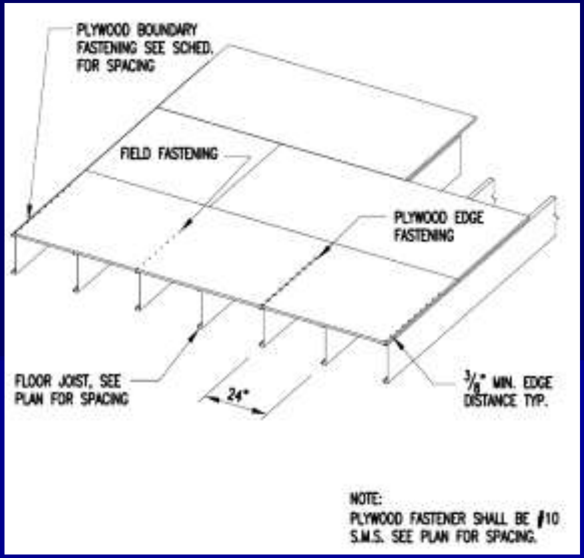
Maximum spacing of joists is 24 inches on center, Trusses occasionally go to 32 or 48” o/c

Diaphragms – Sheathing Materials

- Plywood
- Metal Deck
- Cement Board

Diaphragms – Sheathing Materials

- Plywood -D2.2 Wood Diaphragms



Capacity of Unblocked Plywood varies from 222 plf to 330 plf and Blocked varies from 333 plf to 986 plf

Table D2-1
NOMINAL SHEAR STRENGTH FOR DIAPHRAGMS WITH WOOD SHEATHING [1]
(Pounds Per Foot)

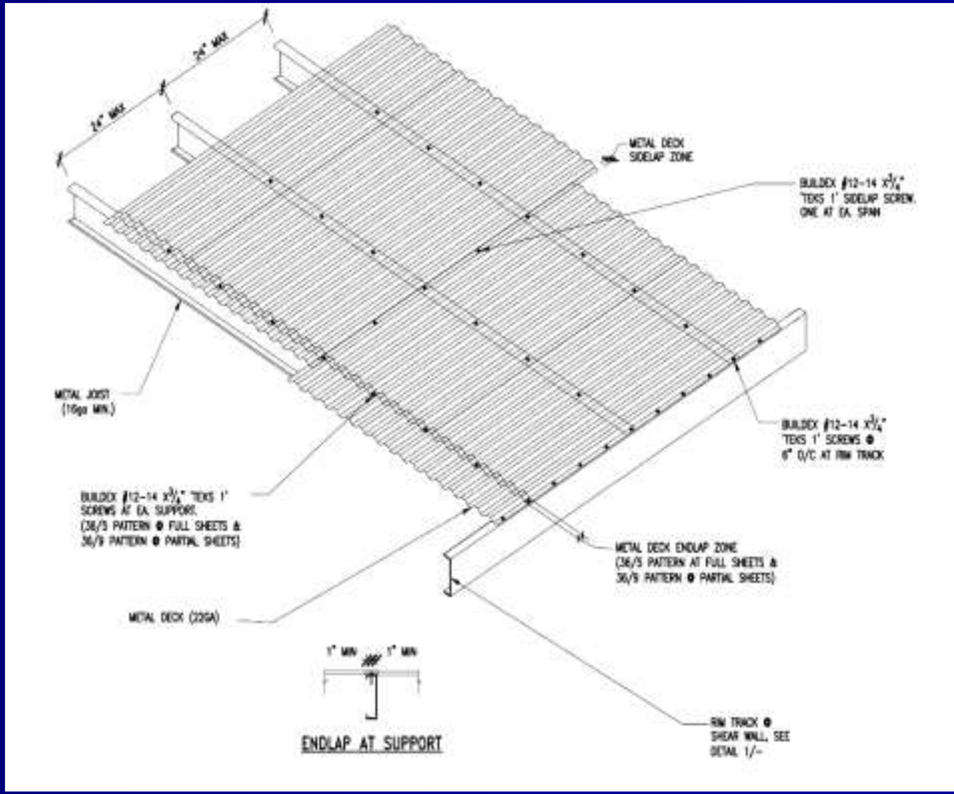
Membrane Material	Screw Size	Thickness (in)	Blocked				Unblocked	
			Screw spacing at diaphragm boundary edges and at all continuous panel edges				Screws spaced maximum of 6" on all supported edges	
			6	4	2.5	2	Load perpendicular to unblocked edges and continuous panel joints	All other configurations
			Screw spacing at all other panel edges					
			6	6	4	3		
Structural I	See note 2	3/8	768	1022	1660	2045	685	510
		7/16	768	1127	1800	2255	755	565
		15/32	925	1232	1970	2465	825	615
C-D, C-C and other graded wood structural panels in DOC PS-1 and PS-2	See note 2	3/8	690	920	1470	1840	615	460
		7/16	760	1015	1620	2030	680	505
		15/32	832	1110	1770	2215	740	555

1 For SI: 1" = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N

Diaphragms – Sheathing Materials

- Metal Deck – Steel Deck Institute DDM03

Capacity of 9/16 metal deck with minimal fastening is 466 plf and can go up to 1200 plf with increased fastening



Diaphragms – Sheathing Materials

- Cement Board (Fortacrete and others)

Capacity varies up to about 540 plf. Products are proprietary

Diaphragms – Diaphragm Flexibility

- Plywood deflection per D2.1.1

$$\delta = \frac{5vL^3}{8E_s A_c b} + \omega_1 \omega_2 \frac{vL}{\rho G t_{sheathing}} + \omega_1^{5/4} \omega_2 (\alpha) \left(\frac{v}{2\beta} \right)^2 + \frac{\sum_{j=1}^{n} \Delta_{ci} X_i}{2b}$$

- Metal Deck deflection per Steel Deck Institute DDM03

- Cement Board deflection per manufacturer

Diaphragms – Chords and Drags

- ASCE 7-05 (12.10) for requirements 12.10.2.1 – overstrength factors not required in structures braced entirely by light-framed shear walls.
- AISI Lateral has no specific requirements for diaphragm chords or collectors, but does require special loading at chord and collector **connections**

Diaphragms – Chords and Drags

- Interconnection of cold formed steel floor joists, ledgers, deck, and walls top tracks frequently have in-plane tensile and compression capacities that can be used for chord and collectors. Specific detailing may be required at highly loaded areas.

Selection of Systems –
Advantages and Disadvantages

- Complete Light Gauge Buildings

Cost Concerns:

Shear Walls ($ to $$$) -
- Strap Bracing
- Sheet Steel
- Plywood
- Sure-Board

Diaphragms ($ to $$$) -
- Plywood
- Metal Deck
- Cement Board

Selection of Systems – Advantages and Disadvantages

- Complete Light Gauge Buildings

Fire Ratings: Type II, III, or V

Shear Walls -

Strap Bracing (II)

Sheet Steel (II)

Sure-Board (II)

Fire Treated Plywood (III)

Plywood (V)

Diaphragms -

Metal Deck (II)

Cement Board (II)

Fire Treated Plywood (III)

Plywood (V)

Selection of Systems – Advantages and Disadvantages

- Complete Light Gauge Buildings

Strength:

Shear Walls -

Strap Bracing (1 or 2 story)

Sheet Steel (1 or 2 story or top floor of 3 or more)

Sure-Board (5 or 6 floors depending upon conditions)

Plywood (4 or 5 floors depending upon conditions)

Selection of Systems – Advantages and Disadvantages

- Complete Light Gauge Buildings

Strength:

Diaphragms – (based upon Diaphragm force of 10 psf)

Plywood – (up to 30′ to 40′ between walls / 20′ cant.)

Cement Board – (up to 60′ to 80′ between walls / 30′ cant.)

Metal Deck – (up to 60′ to 100′ between walls / 40′ cant.)

Numbers are approximate and assume ideal geometry for cantilevers. Blocking can increase above numbers.

Selection of Systems – Advantages and Disadvantages

- Complete Light Gauge Buildings

Analysis:

Per ASCE 12.3.1 Diaphragms with plywood or untopped steel decking are permitted to be idealized as flexible

Diaphragm calculations typically show the diaphragm to be rigid when compared to light framed shear walls

Choosing a shear wall system and diaphragm to fulfill the Rigid Diaphragm assumption will likely result in a more economical structure

Selection of Systems – Advantages and Disadvantages

Hybrid Systems – Light Gauge with Structural Steel

- Moment Frames
- Braced Frames
- Concrete Shear walls

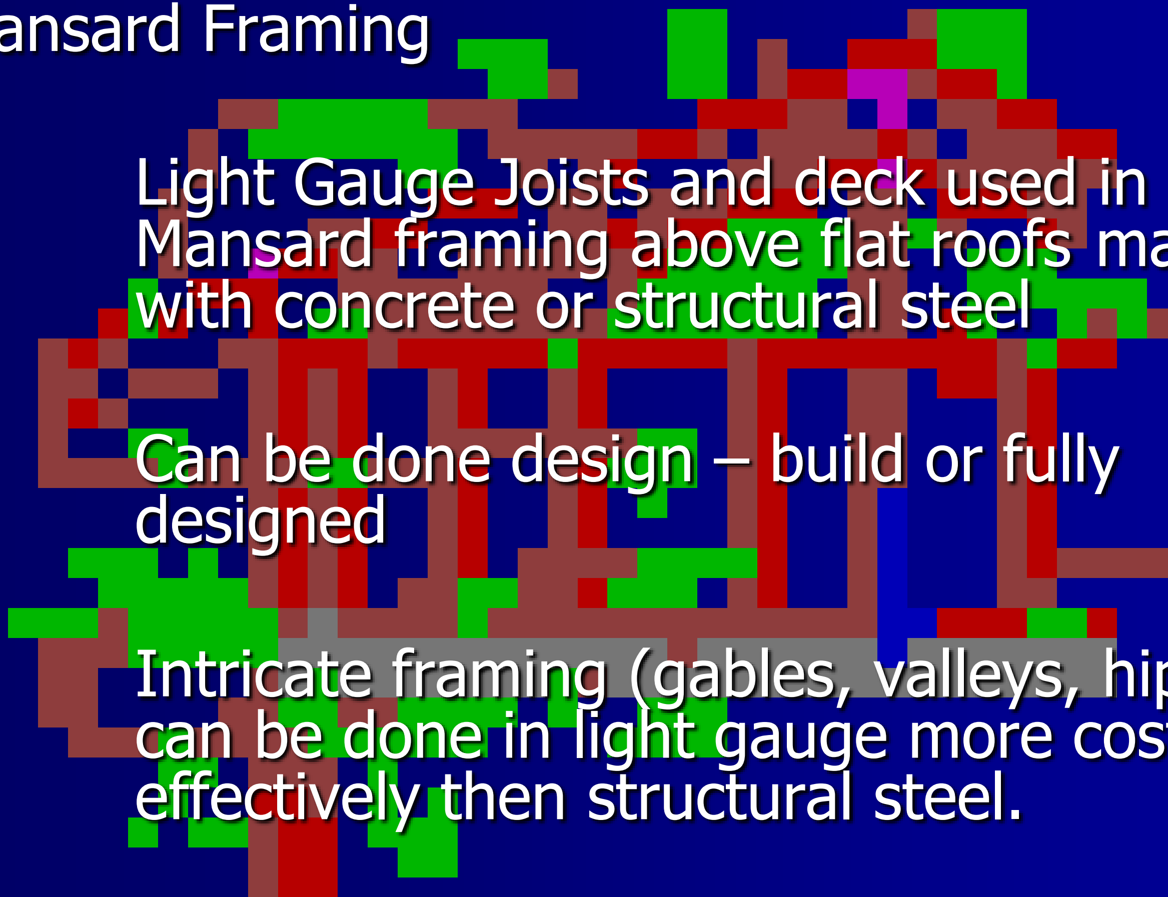
Selection of Systems – Advantages and Disadvantages

Items to watch out for:

- Anchorage of Hold downs can be difficult in thin Podium Decks
- In Residential design care must be taken to coordinate MEP with structural elements
- Mixing Structural Steel and Light Gauge can cause difficulties in the field

Selection of Systems – Components of Larger Structures

Mansard Framing



- Light Gauge Joists and deck used in Mansard framing above flat roofs made with concrete or structural steel
- Can be done design – build or fully designed
- Intricate framing (gables, valleys, hips, … can be done in light gauge more cost effectively then structural steel.

Selection of Systems – Components of Larger Structures

Penthouses and Mechanical Rooms

- Light gauge framing can be used to frame ancillary structures at the top of heavier structural systems
- Can be done design-build or fully designed
- Light weight and economical
- May not be appropriate for support of heavy equipment

- Provisions for wall anchorage must be present