STRUCTURES CONGRESS 2017

Denver, Colorado | April 6-8

Structures Congress 2017

NAVIGATING THE NEW AISC

STEEL CONSTRUCTION MANUAL

Presented by Cynthia J. Duncan, AISC

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Committee on Manuals

Mission

Update and maintain AISC manuals and accompanying design examples in response to revisions in AISC standards and inquiries from within the Committee and the steel construction industry

Roster

28 Members (fabricators, connection designers, detailers, educators, consulting engineers)

5 Emeritus Members

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Steel Solutions Center

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or

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Part 1. Dimensions and Properties

- New shapes:
  - W-shapes (& corresponding WT-shapes)
  - HP-shape
  - Angles
  - HSS
  - Pipe

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Part 1. Dimensions and Properties

W-Shapes	HP-Shapes	Angles
W40x655	HP12x89	L12x12x1-3/8
W36x925		L12x12x1-1/4
W36x853		L12x12x1-1/8
W36x802		L12x12x1
W36x723		L10x10x1-3/8
W21x275		L10x10x1-1/4
W21x248		L10x10x1-1/8
W21x223		L10x10x1
W14x873		L10x10x7/8
W14x808		L10x10x3/4

& corresponding WT-shapes

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Part 1. Dimensions and Properties

HSS22x22x7/8, 3/4
HSS20x20x7/8, 3/4, 5/8, 1/2
HSS18x18x7/8, 3/4, 5/8, 1/2
HSS16x16x7/8, 3/4
HSS14x14x7/8, 3/4
HSS16x16x7/8, 3/4
HSS14x14x7/8, 3/4
HSS12x12x3/4
HSS10x10x3/4

HSS24x12x3/4, 5/8, 1/2
HSS20x12x3/4
HSS16x12x3/4

Pipe 26, 24, 20, 18, 16, 14 (std and x-strong)
& Pipe 12, 10 (xx-strong)

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Part 1. Dimensions and Properties

- New shapes
- Updated fillet radii → k_{det}, k_1, T affected

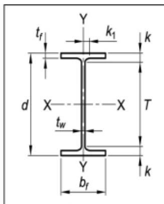

Table 1-1
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $t_w/2$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335[c]	98.5	44.0	44	1.03	1	1/2	15.9	16	1.77	1 3/4	2.56	3	1 3/4	38	5 1/2
×290[c]	85.4	43.6	43 5/8	0.865	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.36	2 13/16	1 5/8	↓	↓
×262[c]	77.2	43.3	43 1/4	0.785	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.20	2 5/8	1 5/8	↓	↓
×230[c,v]	67.8	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 7/16	1 9/16	↓	↓

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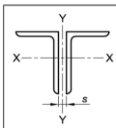
Part 1. Dimensions and Properties

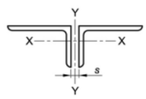
- New shapes
- Updated fillet radii ⟶ k_{det}, k_1, T affected
- Larger separation for new double angles (2L12 and 2L10)

Part 1. Dimensions and Properties



LLBB

Table 1-15
Double Angles
Properties



SLBB

Shape	Area, A	Radius of Gyration							
		LLBB				SLBB			
		r_y Separation, s, in.			r_x	r_y Separation, s, in.			r_x
		0	3/4	1 1/2		0	3/4	1 1/2	
	in.²	in.	in.	in.	in.	in.	in.	in.	in.
2L12×12×1 3/8	62.2	5.06	5.32	5.60	3.64	5.06	5.32	5.60	3.64
×1 1/4	56.8	5.04	5.29	5.57	3.66	5.04	5.29	5.57	3.66
×1 1/8	51.6	5.02	5.28	5.55	3.68	5.02	5.28	5.55	3.68
×1	46.0	5.00	5.25	5.54	3.70	5.00	5.25	5.54	3.70

Part 1. Dimensions and Properties

- New shapes
- Updated fillet radii
- Larger separation for double angles (2L12 and 2L10)
- Check material availability: See www.aisc.org
- V15.0 Database

Part 2. General Design Considerations

- Table 2-4: Applicable ASTM Specifications for Various Structural Shapes
- Table 2-5: Applicable ASTM Specifications for Plate
- Table 2-7: Summary of Surface Preparation Stds

Part 2. General Design Considerations

Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation		F_y Yield Stress[a] (ksi)	F_u Tensile Stress[a] (ksi)	Applicable Shape Series: W	M	S	HP	C	MC	L	HSS: Rect.	HSS: Round	Pipe
	A36		36	58–80[b]										
	A53 Gr. B		35	60										
	A500	Gr. B	42	58										
			46	58										
		Gr. C	46	62										
			50	62										
		Gr. A	36	58										

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Part 2. General Design Considerations

Table 2-5
Applicable ASTM Specifications for Plates and Bars

Steel Type	ASTM Designation		F_y Yield Stress[a] (ksi)	F_u Tensile Stress[a] (ksi)	Plates and Bars, in.: to 0.75 incl.	over 0.75 to 1.25 incl.	over 1.25 to 1.5 incl.	over 1.5 to 2 incl.	over 2 to 2.5 incl.	over 2.5 to 4 incl.	over 4 to 5 incl.	over 5 to 6 incl.	over 6 to 8 incl.	over 8
Carbon	A36		32	58–80										
			36	58–80										
	A283[e]	Gr. C	30	55–75					d					
		Gr. D	33	60–80					d					
	A529	Gr. 50	50	65–100		b	b	b	b	b				
		Gr. 55	55	70–100		c	c	c	c	c				
	A709	Gr. 36	36	58–80										
High-	A572	Gr. 42	42	60										
		Gr. 50	50	65										
		Gr. 55	55	70										
		Gr. 60	60	75										
		Gr. 65	65	80										

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Part 2. General Design Considerations

Table 2-7
Summary of Surface Preparation Standards

SSPC Standard No.	Title	Description
SSPC-SP 14/NACE No. 8*	Industrial Blast Cleaning	Between SP 7 (brush-off) and SP 6 (commercial); the intent is to remove as much coating as possible; tightly adhering contaminants can remain….
SSPC-SP 15	Commercial-Grade Power-Tool Cleaning	Between SP 3 AND SP 11; complete removal of all visible oil, grease, dirt, rust, coating, mill scale, ….
SSPC-SP 16	Brush-Off Blast Cleaning of Coated and Uncoated Galv.	Requirements for removing loose contaminants and coating from coated and uncoated galvanized steel, stainless steels, and non-ferrous metals; cleaned surface is

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Part 3. Design of Flexural Members

- Incorporates new W-shapes in all existing tables (50 ksi)

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Part 3. Design of Flexural Members

- Incorporates new W-shapes in all existing tables
- Footnote for noncompact or slender sections:
  "…tabulated values have been adjusted accordingly"
  (also in Part 4 tables)

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Part 3. Design of Flexural Members

- Incorporates new W-shapes in all existing tables
- Footnote for noncompact or slender sections:
  "…tabulated values have been adjusted accordingly"
- Table 3-19, Composite beam table footnote:
  " Ductility (slip capacity) of shear connection at the beam/concrete interface may control minimum ΣQ_n value per AISC *Spec.* Sect. I3.2d."

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Part 3. Design of Flexural Members

- Incorporates new W-shapes in all existing tables
- Footnote for noncompact or slender sections:
  "…tabulated values have been adjusted accordingly"
- Table 3-19, Composite beam table footnote:
  " Ductility (slip capacity) of shear connection at the beam/concrete interface may control minimum ΣQ_n value per AISC *Spec.* Sect. I3.2d."
- Tables 3-16 and 3-17, Available Shear Stress, plate girders

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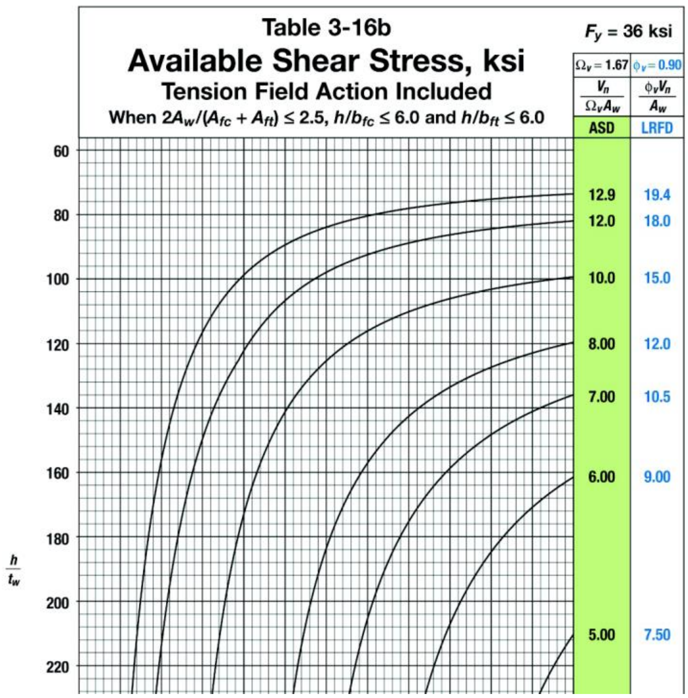

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Part 4. Design of Compression Members

- Eliminated K factor in tables/discussion → L_c
- Clarifies $C_w = 0$ is used in WT column tables
- Chapter E revisions reflected in tables
  - Slender members
  - Double angles use more general F_{cry} equation
- Removed Tables 4-13 to 4-20: Composite Columns
- W-shape column tables: added 65 and 70 ksi for some

Part 4. Design of Compression Members

- W-shape column tables: added 65 and 70 ksi for some

Table 4-1b
Available Strength in Axial Compression, kips
W-Shapes

$F_y = 65$ ksi — W14

Shape		W14×							
lb/ft		873h		808h		730h		665h	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
	0	10000	15000	9260	13900	8370	12600	7630	11500

Table 4-1c
Available Strength in Axial Compression, kips
W-Shapes

$F_y = 70$ ksi — W14

Shape		W14×							
lb/ft		873h		808h		730h		665h	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
	0	10800	16200	9980	15000	9010	13500	8220	12300

Part 6. Design of Members Subject to Combined Forces

- New Tables 6-1a & 6-1b: *Limiting Width-to-Thickness Ratios*

Table 6-1a
Width-to-Thickness Ratios: Compression Elements Members Subject to Axial Compression

	Case	Description of Element	Width-to-Thickness Ratio	F_y, ksi 32	36	42	46	50
				λ_r	λ_r	λ_r	λ_r	λ_r
Elements	1	Flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections, outstanding legs of pairs of angles connected with continuous contact, flanges of channels, and flanges of tees	b/t	–	15.9	14.7	–	13.5
		Flanges of built-up I-shaped						

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Part 6. Design of Members Subject to Combined Forces

- New Tables 6-1a & 6-1b: *Limiting Width-to-Thickness Ratios*
- New Table 6-2: *Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces, W-Shapes*

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The Super Table

Table 6-2
Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces
W-Shapes

F_y = 50 ksi
F_u = 65 ksi

W44

W44× 335[c] P_n/Ω_c ASD	335[c] $\phi_c P_n$ LRFD	290[c] P_n/Ω_c ASD	290[c] $\phi_c P_n$ LRFD	262[c] P_n/Ω_c ASD	262[c] $\phi_c P_n$ LRFD	Shape lb/ft / Design: Effective length, L_c, ft, with respect to least radius of gyration, r_y, or unbraced length, L_b, ft, for X-X axis bending	W44× 335 M_{nx}/Ω_b ASD	335 $\phi_b M_{nx}$ LRFD	290 M_{nx}/Ω_b ASD	290 $\phi_b M_{nx}$ LRFD	262 M_{nx}/Ω_b ASD	262 $\phi_b M_{nx}$ LRFD
Available Compressive Strength, kips							Available Flexural Strength, kip-ft					
2900	4360	2400	3610	2110	3180	0	4040	6080	3520	5290	3170	4760
2830	4250	2340	3520	2060	3090	6	4040	6080	3520	5290	3170	4760
2800	4210	2320	3480	2040	3060	7	4040	6080	3520	5290	3170	4760
2770	4160	2290	3440	2010	3030	8	4040	6080	3520	5290	3170	4760
2730	4110	2260	3400	1990	2990	9	4040	6080	3520	5290	3170	4760
2690	4050	2230	3350	1960	2950	10	4040	6080	3520	5290	3170	4760
2650	3990	2200	3300	1930	2900	11	4040	6080	3520	5290	3170	4760
2600	3910	2160	3240	1900	2850	12	4040	6080	3520	5290	3170	4760
2550	3830	2120	3180	1860	2800	13	4000	6010	3480	5230	3130	4700
2490	3740	2080	3120	1820	2740	14	3940	5930	3430	5150	3080	4620
2430	3650	2030	3050	1780	2680	15	3880	5840	3370	5070	3020	4550
2360	3550	1990	2980	1740	2620	16	3820	5750	3320	4980	2970	4470
2300	3450	1940	2910	1700	2560	17	3760	5660	3260	4900	2920	4390
2230	3350	1890	2840	1660	2490	18	3700	5570	3210	4820	2870	4310
2160	3240	1840	2760	1610	2420	19	3640	5480	3150	4740	2810	4230
2090	3140	1780	2680	1560	2350	20	3590	5390	3100	4650	2760	4150
1940	2920	1670	2520	1470	2210	22	3470	5210	2990	4490	2660	3990
1790	2690	1550	2340	1370	2060	24	3350	5030	2880	4320	2550	3840
1640	2470	1430	2140	1270	1910	26	3230	4850	2770	4160	2450	3680
1500	2250	1300	1950	1160	1750	28	3110	4670	2660	3990	2340	3520
1350	2040	1170	1770	1050	1580	30	2990	4490	2550	3830	2240	3360
1220	1830	1060	1590	944	1420	32	2870	4320	2440	3660	2130	3200
1080	1630	939	1410	839	1260	34	2750	4140	2330	3500	2030	3050
966	1450	838	1260	749	1130	36	2630	3960	2220	3330	1910	2870
867	1300	752	1130	672	1010	38	2510	3780	2070	3110	1750	2630
783	1180	679	1020	606	911	40	2360	3550	1920	2880	1620	2430
710	1070	616	925	550	827	42	2200	3310	1780	2680	1500	2260
647	972	561	843	501	753	44	2060	3100	1660	2500	1400	2100
592	890	513	771	459	689	46	1940	2910	1560	2350	1310	1970
544	817	471	708	421	633	48	1830	2750	1470	2210	1230	1850
501	753	434	653	388	583	50	1730	2600	1390	2090	1160	1740

Properties

Available Strength in Tensile Yielding, kips					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
2950	4430	2560	3840	2310	3470
Available Strength in Tensile Rupture ($A_e = 0.75A_g$), kips					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
2400	3600	2080	3120	1880	2820
Available Strength in Shear, kips					
V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$
906	1360	754	1130	680	1020
Available Strength in Flexure about Y-Y Axis, kip-ft					
M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$
589	885	511	769	454	683

Limiting Unbraced Lengths, ft					
L_p	L_r	L_p	L_r	L_p	L_r
12.3	38.9	12.3	36.9	12.3	35.7
Area, in.^{2}					
98.5		85.4		77.2	
Moment of Inertia, in.^{4}					
I_x	I_y	I_x	I_y	I_x	I_y
31100	1200	27000	1040	24100	923
r_y, in.					
3.49		3.49		3.47	
r_x/r_y					
5.10		5.10		5.10	

[c] Shape is slender for compression with F_y = 50 ksi.

Example—Table 6-2

Given: W14x99, ASTM A992, pinned ends (K = 1.0),

$L_{cx} = L_{cy} = L_b$ = 14 ft

Check shape for combined loading using LRFD, with required strengths as follows:

LRFD
P_u = 400 kips M_{ux} = 250 kip-ft M_{uy} = 80.0 kip-ft

Example— Table 6-2

Solution:

$\phi_c P_n = 1130$ kips

$\phi_b M_{nx} = 642$ kip-ft

Table 6-2 (continued)
Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces
W-Shapes

$F_y = 50$ ksi
$F_u = 65$ ksi

W14

W14× 109 P_n/Ω_c ASD	109 $\phi_c P_n$ LRFD	99 P_n/Ω_c ASD	99 $\phi_c P_n$ LRFD	90 P_n/Ω_c ASD	90 $\phi_c P_n$ LRFD	Shape lb/ft Design	W14× 109 M_{nx}/Ω_b ASD	109 $\phi_b M_{nx}$ LRFD	99[f] M_{nx}/Ω_b ASD	99[f] $\phi_b M_{nx}$ LRFD	90[f] M_{nx}/Ω_b ASD	90[f] $\phi_b M_{nx}$ LRFD
Available Compressive Strength, kips						Effective length, L_c, ft, with respect to least radius of gyration, r_y, or unbraced length, L_b, ft, for X-X axis bending	Available Flexural Strength, kip-ft					
913	1370	830	1250	755	1140	8	479	720	430	646	382	574
901	1350	819	1230	745	1120	9	479	720	430	646	382	574
888	1340	807	1210	735	1100	10	479	720	430	646	382	574
874	1310	794	1190	723	1090	11	479	720	430	646	382	574
859	1290	780	1170	710	1070	12	479	720	430	646	382	574
843	1270	766	1150	697	1050	13	479	720	430	646	382	574
826	1240	750	1130	682	1030	14	475	714	427	642	382	574
808	1210	733	1100	667	1000	15	470	706	422	635	382	574
789	1190	716	1080	652	979	16	465	699	417	627	378	568
770	1160	698	1050	635	955	17	460	691	413	620	373	560
750	1130	680	1020	618	929	18	455	684	408	613	368	553
729	1100	661	994	601	903	19	450	676	403	605	363	546
708	1060	642	964	583	877	20	445	669	398	598	358	539
664	998	602	904	547	822	22	435	654	388	583	349	524
620	931	561	843	509	766	24	425	639	378	569	339	510
574	863	519	781	472	709	26	415	623	369	554	329	495
529	796	478	719	434	653	28	405	608	359	539	320	481
485	729	438	658	397	597	30	395	593	349	524	310	466
441	663	398	598	361	543	32	385	578	339	510	300	452
399	600	360	541	326	490	34	375	563	329	495	291	437
359	539	323	485	292	439	36	365	548	320	480	281	423
322	484	290	435	262	394	38	355	533	310	466	271	408
290	437	261	393	237	356	40	345	518	300	451	262	394
263	396	237	356	215	323	42	335	503	290	436	252	379
240	361	216	325	196	294	44	325	488	280	422	239	359

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Example—Table 6-2

Solution:

$\phi_b M_{ny} = 311$ kip-ft

Table 6-2 (continued)
Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces
W-Shapes

$F_y = 50$ ksi
$F_u = 65$ ksi

W14

W14× 109 P_n/Ω_c ASD	109 $\phi_c P_n$ LRFD	99 P_n/Ω_c ASD	99 $\phi_c P_n$ LRFD	90 P_n/Ω_c ASD	90 $\phi_c P_n$ LRFD	Shape lb/ft Design	W14× 109 M_{nx}/Ω_b ASD	109 $\phi_b M_{nx}$ LRFD	99[f] M_{nx}/Ω_b ASD	99[f] $\phi_b M_{nx}$ LRFD	90[f] M_{nx}/Ω_b ASD	90[f] $\phi_b M_{nx}$ LRFD
Available Compressive Strength, kips							Available Flexural Strength, kip-ft					

Properties

Available Strength in Tensile Yielding, kips					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
958	1440	871	1310	793	1190
Available Strength in Tensile Rupture ($A_e = 0.75A_g$), kips					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
780	1170	709	1060	647	970
Available Strength in Shear, kips					
V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$
150	225	138	207	123	185
Available Strength in Flexure about Y-Y Axis, kip-ft					
M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$
231	348	207	311	181	273

Limiting Unbraced Lengths, ft					
L_p	L_r	L_p	L_r	L_p	L_r
13.2	48.5	13.5	45.3	15.1	42.5
Area, in.^{2}					
32.0		29.1		26.5	
Moment of Inertia, in.^{4}					
I_x	I_y	I_x	I_y	I_x	I_y
1240	447	1110	402	999	362
r_y, in.					
3.73		3.71		3.70	
r_x/r_y					
1.67		1.66		1.66	

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.

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Example—Table 6-2

Solution:

$$\frac{P_u}{P_c} = \frac{400 \text{ kips}}{1130 \text{ kips}}$$
$$= 0.354$$

Because $\dfrac{P_u}{P_c} \geq 0.2,$ use *Spec.* Eq. H1-1a:

$$\frac{P_r}{P_c} + \frac{8}{9}\left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1.0$$

$$\frac{400 \text{ kips}}{1130 \text{ kips}} + \frac{8}{9}\left(\frac{250 \text{ kip-ft}}{642 \text{ kip-ft}} + \frac{80.0 \text{ kip-ft}}{311 \text{ kip-ft}}\right) = 0.928 < 1.0 \quad \textbf{o.k.}$$

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Part 6. Design of Members Subject to Combined Forces

- New Tables 6-1a & 6-1b: *Limiting Width-to-Thickness Ratios*
- New Table 6-2: *Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces, W-Shapes*
- Tables 6-3, 6-4 and 6-5: *Cross-Section Strength Equations & Properties for Encased W-Shapes, Filled Rectangular HSS, Filled Round HSS*

L.F. Geschwindner, *Engineering Journal*, 2010

M. Denavit et al., *Engineering Journal*, 2015

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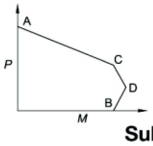
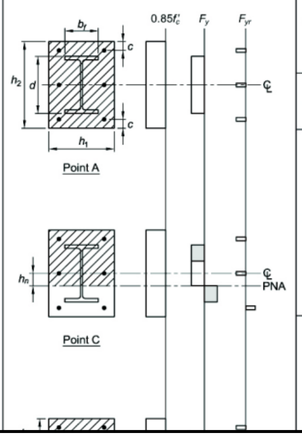


Table 6-3a
Cross-Section Strength for Rectangular Encased W-Shapes
Subject to Flexure about the Major Axis



Section	Stress Distribution	Pt.	Defining Equation
Point A		A	$P_A = F_yA_s + F_{yr}A_{sr} + 0.85f'_cA_c$ $M_A = 0$ A_s = area of steel shape A_{sr} = area of all continuous reinforcing bars $A_c = h_1h_2 - A_s - A_{sr}$
		C	$P_C = 0.85f'_cA_c$ $M_C = M_B$
Point C		D	$P_D = \frac{0.85f'_cA_c}{2}$ $M_D = F_yZ_s + F_{yr}Z_r + 0.85f'_c\left(\frac{Z_c}{2}\right)$ Z_s = full *x*-axis plastic section modulus of steel shape A_{srs} = area of continuous reinforcing bars at the centerline $Z_r = (A_{sr} - A_{srs})\left(\frac{h_2}{2} - c\right)$ $Z_c = \frac{h_1h_2^2}{4} - Z_s - Z_r$
			$P_B = 0$ $M_B = M_D - F_yZ_{sn} - 0.85f'_c\left(\frac{Z_{cn}}{2}\right)$ $Z_{cn} = h_1h_n^2 - Z_{sn}$ For h_n below the flange $\left(h_n \le \frac{d}{2} - t_f\right)$

Part 7. Design Considerations for Bolts

- *Figure 7-10. Permitted coatings for structural fasteners*

ASTM Designation		Fastener Description	Coating Type: Mechanical Galvanizing, ASTM B695	Coating Type: Hot Dip Galvanizing, ASTM F2329	Coating Type: Zinc/ Aluminum
ASTM F3125	Gr. A325	Heavy hex, F_u = 120 ksi	Class 55	50 µm	[a]
ASTM F3125	Gr. F1852	Tension control, F_u = 120 ksi	Class 55	–	–
ASTM F3125	Gr. A490	Heavy hex, F_u = 150 ksi	–	–	[a]
ASTM F3125	Gr. F2280	Tension control, F_u = 150 ksi	–	–	–
A449		Heavy hex, F_u = 90, 105 and 120 ksi	Class 55	50 µm	–
A354 BC		Heavy hex, F_u = 115 ksi and 125 ksi	Class 55	50 µm	–
A354 BD		Heavy hex, F_u = 140 ksi and 150 ksi	[b]	[b]	–

– Indicates this coating is not qualified.

[a] See ASTM F3125 Table 1.1 for approved zinc/aluminum coating standards and grades.

[b] Galvanizing of ASTM A354 BD is not prohibited but may cause susceptibility to hydrogen embrittlement. Precautions to avoid embrittlement, such as those in ASTM A143, should be considered.

Part 7. Design Considerations for Bolts

- Figure 7-10. Permitted coatings for structural fasteners
- Tables 7-1, 7-2 and 7-3 incorporate the Group C (200 ksi) bolts

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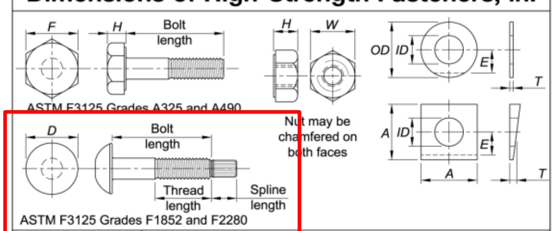
Part 7. Design Considerations for Bolts

- Figure 7-10. Permitted coatings for structural fasteners
- Tables 7-1, 7-2 and 7-3 includes the Group C (200 ksi) bolts
- Tables 7-14 includes tension-control bolts

Table 7-14

Dimensions of High-Strength Fasteners, in.



Measurement		Nominal Bolt Diameter, in								
		1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
F1852, A490, 80 Bolts[a]	Width Across Flats, F	7/8	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16	2 3/8
	Head Diameter, D[e]	1 1/8	1 5/16	1 9/16	1 7/8	2 3/16	2 3/8	–	–	–
	Height, H	5/16	25/64	15/32	35/64	39/64	11/16	25/32	27/32	15/16
	Thread Length	1	1 1/4	1 3/8	1 1/2	1 3/4	2	2	2 1/4	2 1/4

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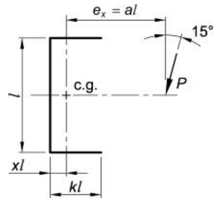
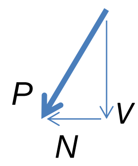
Part 8. Design Considerations for Welds

ECCENTRICALLY LOADED WELD GROUPS

Eccentricity in the Plane of the Faying Surface





1) Instantaneous Center of Rotation Method
2) Elastic Method
3) Plastic Method - new

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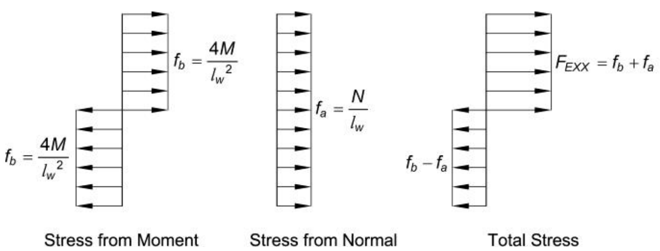
Part 8. Design Considerations for Welds

ECCENTRICALLY LOADED WELD GROUPS

Eccentricity in the Plane of the Faying Surface

Plastic Method:



$$f_v = \frac{V}{l_w} \quad (8\text{-}12)$$

$$f_a = \frac{N}{l_w} \quad (8\text{-}13)$$

$$f_b = \frac{4M}{l_w^2} \quad (8\text{-}14)$$

$$f_w = \sqrt{f_v^2 + (f_a + f_b)^2} \quad (8\text{-}15)$$

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Part 9. Design of Connecting Elements

- Connecting elements subject to combined loading

2010: $$f_e = \sqrt{f_x^2 - f_x f_y + f_y^2 + 3f_{xy}^2} \le F_y \qquad (9\text{-}1)$$

2016: $$\frac{M_r}{M_c} + \left(\frac{P_r}{P_c}\right)^2 + \left(\frac{V_r}{V_c}\right)^4 \le 1.0 \qquad (9\text{-}1)$$

See Dowswell, 2015; Neal, 1961; Astaneh, 1998

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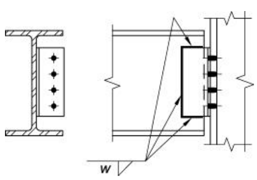
Part 9. Design of Connecting Elements

- Connecting elements subject to combined loading
- Connecting element rupture strength at welds

Fillet weld on one side of element, $F_{EXX} = 70$ ksi

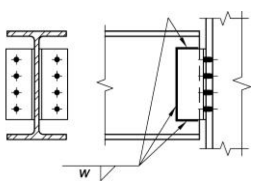
$$t_{min} = \frac{0.60F_{EXX}\left(\frac{\sqrt{2}}{2}\right)\left(\frac{D}{16}\right)}{0.6F_u}$$

$$= \frac{3.09D}{F_u} \qquad (9\text{-}2)$$



Fillet weld on both sides of element, $F_{EXX} = 70$ ksi

$$t_{min} = \frac{6.19D}{F_u} \qquad (9\text{-}3)$$



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Part 9. Design of Connecting Elements

- Connecting elements subject to combined loading
- Coped beam strength
  - ➢ No limits on cope length or cope depth
  - ➢ Post-yield strength explicitly accounted for

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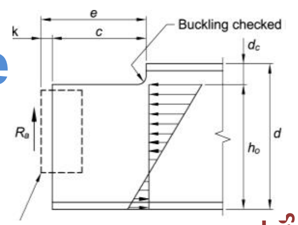
Part 9. Design of Connecting Eleme



- Coped beam strength—*top flange only*

When $\lambda \le \lambda_p$

$$M_n = M_p \qquad (9\text{-}6)$$

When $\lambda_p < \lambda \le 2\lambda_p$

$$M_n = M_p - (M_p - M_y)\left(\frac{\lambda}{\lambda_p} - 1\right) \qquad (9\text{-}7)$$

When $\lambda > 2\lambda_p$

$$M_n = F_{cr} S_{net} \qquad (9\text{-}8)$$

where

$$\lambda = \frac{h_o}{t_w}$$

$$\lambda_p = 0.475\sqrt{\frac{k_1 E}{F_y}}$$

$$k_1 = fk \ge 1.61$$

$$F_{cr} = \frac{0.903 E k_1}{\lambda^2}$$

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Part 9. Design of Connecting Elements

- Coped beam strength—*top & bottom flange*

Use *Spec.* Section F11

When $c_b \geq c_t$:

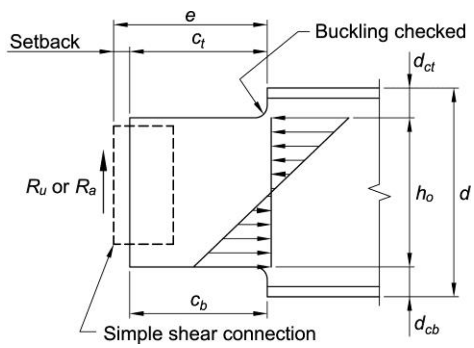
$= c_t$

$$C_b = \left[3 + \ln\left(\frac{L_b}{d}\right)\right]\left(1 - \frac{d_{ct}}{d}\right) \leq 1.84 \qquad (9\text{-}15)$$

$= \dfrac{c_t + c_b}{2}$

When $c_t > c_b$:

$$C_b = \left(\frac{c_b}{c_t}\right)\left[3 + \ln\left(\frac{L_b}{d}\right)\right]\left(1 - \frac{d_{ct}}{d}\right) \leq 1.84 \qquad (9\text{-}16)$$



Dowswell& Whyte, *Engineering Journal*, No. 1, 2014

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Part 9. Design of Connecting Elements

- Connecting elements subject to combined loading
- Connecting element rupture strength at welds
- Coped beam strength
- Other Spec. requirements and design considerations
  - Prying action
  - Plate elements subjected to out-of-plane bending

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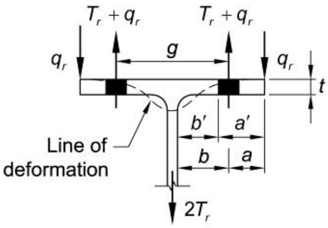
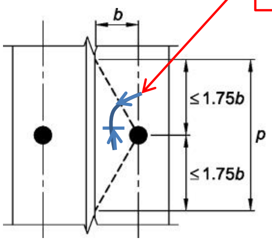
Part 9. Design of Connecting Elements

- Prying action

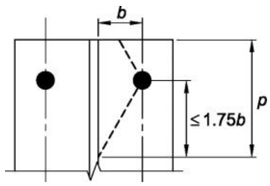
14th Ed: max 45°
15th Ed: max 60°



Prying forces in tee



Typical bolt location



Edge bolt

Refs: Thornton, 1992; Swanson, 2002;

Part 9. Design of Connecting Elements

- Prying action

LRFD	ASD
$t_{min} = \sqrt{\dfrac{4T_u b'}{\phi p F_u (1+\delta\alpha')}}$ (9-19a)	$t_{min} = \sqrt{\dfrac{\Omega 4T_a b'}{p F_u (1+\delta\alpha')}}$ (9-19b)

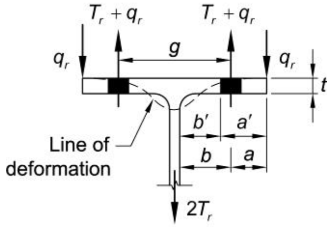
$$\delta = 1 - \frac{d'}{p}$$

$$\alpha' = 1.0 \text{ if } \beta \geq 1 \text{ or lesser of 1 and } \frac{1}{\delta}\left(\frac{\beta}{1-\beta}\right) \text{ if } \beta<1$$

$$\beta = \frac{1}{\rho}\left(\frac{B_c}{T_r} - 1\right)$$

$$\rho = \frac{b'}{a'}$$

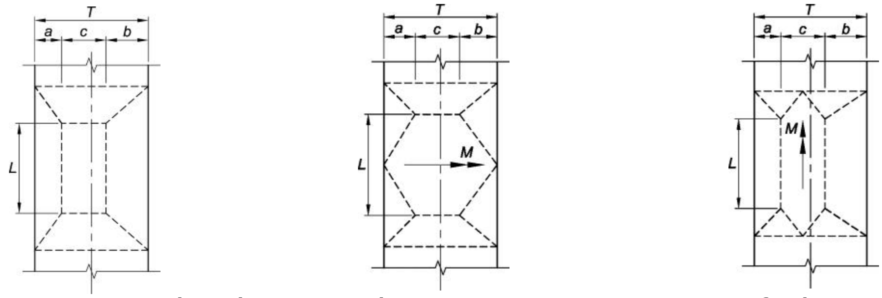
B_c = available tension per bolt based on tension only or combined tension & shear rupture



Part 9. Design of Connecting Elements

- Plate elements subjected to out-of-plane loads

Also see *Spec.* Section J10.10.



Transverse load *In-plane moment* *Out-of-plane moment*

Yield-Line Analysis Models

Part 10. Design of Simple Shear Connections

14^{th} Edition Manual

Bolt and Angle Limit States:

Minimum of:

- Total bolt shear on bolt group
- Total slip resistance for slip-critical bolts on bolt group
- Bolt bearing on the angles
- Bolt tearout on the angles
- Shear yielding of the angles
- Shear rupture of the angles
- Block shear rupture of the angles

Table 10-1
All-Bolted Double-Angle Connections — $^3/_4$-in. Bolts

Beam: F_y = 50 ksi, F_u = 65 ksi
Angle: F_y = 36 ksi, F_u = 58 ksi

Bolt and Angle Available Strength, kips

12 Rows W44	Bolt Group	Thread Cond.	Hole Type	1/4 ASD	1/4 LRFD	5/16 ASD	5/16 LRFD	3/8 ASD	3/8 LRFD	1/2 ASD	1/2 LRFD
	Group A	N	STD	197	295	246	369	286	430	286	430
		X	STD	197	295	246	369	295	443	361	541
		SC Class A	STD	152	228	152	228	152	228	152	228
			OVS	129	194	129	194	129	194	129	194
			SSLT	152	228	152	228	152	228	152	228
		SC Class B	STD	197	295	246	369	253	380	253	380
			OVS	196	294	216	323	216	323	216	323
			SSLT	195	293	244	366	253	380	253	380
	Group B	N	STD	197	295	246	369	295	443	361	541
		X	STD	197	295	246	369	295	443	393	590
		SC Class A	STD	190	285	190	285	190	285	190	285
			OVS	162	242	162	242	162	242	162	242
			SSLT	190	285	190	285	190	285	190	285
		SC Class B	STD	197	295	246	369	295	443	316	475
			OVS	196	294	245	367	270	403	270	403
			SSLT	195	293	244	366	293	440	316	475

Beam Web Available Strength per Inch Thickness, kips/in.

Hole Type / L_{eh}*, in.	L_{ev}, in.	STD 1 1/2 ASD	STD 1 1/2 LRFD	STD 1 3/4 ASD	STD 1 3/4 LRFD	OVS 1 1/2 ASD	OVS 1 1/2 LRFD	OVS 1 3/4 ASD	OVS 1 3/4 LRFD	SSLT 1 1/2 ASD	SSLT 1 1/2 LRFD	SSLT 1 3/4 ASD	SSLT 1 3/4 LRFD
Coped at Top Flange Only	1 1/4	498	747	506	759	468	702	476	714	495	743	503	755
	1 3/8	501	751	509	763	470	706	479	718	497	746	506	758
	1 1/2	503	754	511	767	473	709	481	722	500	750	508	762
	1 5/8	505	758	514	770	475	713	483	725	502	753	510	766
	2	513	769	521	781	483	724	491	736	510	764	518	777
	3	532	798	540	810	502	753	510	765	529	794	537	806
	1 1/4	488	731	488	731	458	687	458	687	488	731	488	731

Part 10. Design of Simple Shear Connections

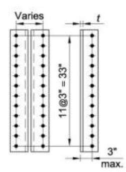
15th Ed. Manual

Bolt and Angle Limit States:
Minimum of:

- Σ(Effective strengths of individual bolts)
  where
  Effective strength = MIN: bolt shear, slip resistance for slip-critical bolts, bolt bearing, bolt tearout
- Shear yielding -- angles
- Shear rupture -- angles
- Block shear rupture -- angles

Table 10-1
All-Bolted Double-Angle Connections

F_y = 36 ksi Angles — ¾-in. Bolts



12 Rows W44	Bolt Group	Thread Cond.	Hole Type	¼ ASD	¼ LRFD	5/16 ASD	5/16 LRFD	⅜ ASD	⅜ LRFD	½ ASD	½ LRFD
			Bolt and Angle Available Strength, kips — Angle Thickness, in.								
	Group A	N	STD/SSLT	197	296	246	370	284	427	286	429
		X	STD/SSLT	197	296	246	370	296	444	360	540
		SC Class A	STD	152	228	152	228	152	228	152	228
			OVS	129	194	129	194	129	194	129	194
			SSLT	152	228	152	228	152	228	152	228
		SC Class B	STD	197	296	246	370	253	380	253	380
			OVS	197	296	215	321	216	323	216	323
			SSLT	197	296	246	370	253	380	253	380
	Group B	N	STD/SSLT	197	296	246	370	296	444	360	540
		X	STD/SSLT	197	296	246	370	296	444	394	592
		SC Class A	STD	189	283	190	285	190	285	190	285
			OVS	162	242	162	242	162	242	162	242
			SSLT	189	283	190	285	190	285	190	285
		SC Class B	STD	197	296	246	370	296	444	316	475
			OVS	197	296	246	370	268	400	270	403
			SSLT	197	296	246	370	296	444	316	475

Part 10. Design of Simple Shear Connections

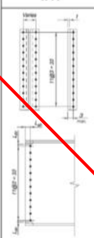
14th Edition Manual

Beam Web Limit States (kip/in.):

- Bolt bearing on the web
- Bolt tearout on the web
- Shear yielding of the web
- Shear rupture of the web
- Block shear rupture of the web

Table 10-1
All-Bolted Double-Angle Connections

Beam: F_y = 50 ksi, F_u = 65 ksi; Angle: F_y = 36 ksi, F_u = 58 ksi — ¾-in. Bolts



12 Rows W44	Bolt Group	Thread Cond.	Hole Type	¼ ASD	¼ LRFD	5/16 ASD	5/16 LRFD	⅜ ASD	⅜ LRFD	½ ASD	½ LRFD
			Bolt and Angle Available Strength, kips — Angle Thickness, in.								
	Group A	N	STD	197	295	246	369	286	430	286	430
		X	STD	197	295	246	369	295	443	361	541
		SC Class A	STD	152	228	152	228	152	228	152	228
			OVS	129	194	129	194	129	194	129	194
			SSLT	152	228	152	228	152	228	152	228
		SC Class B	STD	197	295	246	369	253	380	253	380
			OVS	196	294	216	323	216	323	216	323
			SSLT	195	293	244	366	253	380	253	380
	Group B	N	STD	197	295	246	369	295	443	361	541
		X	STD	197	295	246	369	295	443	393	590
		SC Class A	STD	190	285	190	285	190	285	190	285
			OVS	162	242	162	242	162	242	162	242
			SSLT	190	285	190	285	190	285	190	285
		SC Class B	STD	197	295	246	369	295	443	316	475
			OVS	196	294	245	367	270	403	270	403
			SSLT	195	293	244	366	293	440	316	475

Beam Web Available Strength per Inch Thickness, kips/in.

Hole Type / L_{ev}, in.		STD 1½ ASD	STD 1½ LRFD	STD 1¾ ASD	STD 1¾ LRFD	OVS 1½ ASD	OVS 1½ LRFD	OVS 1¾ ASD	OVS 1¾ LRFD	SSLT 1½ ASD	SSLT 1½ LRFD	SSLT 1¾ ASD	SSLT 1¾ LRFD
		L_{eh}*, in.											
Coped at Top Flange Only	1¼	498	747	506	759	468	702	476	714	495	743	503	755
	1⅜	501	751	509	763	470	706	479	718	497	746	506	758
	1½	503	754	511	767	473	709	481	722	500	750	508	762
	1⅝	505	758	514	770	475	713	483	725	502	753	510	766
	2	513	769	521	781	483	724	491	736	510	764	518	777
	3	532	798	540	810	502	753	510	765	529	794	537	806
	1¼	488	731	488	731	458	687	458	687	488	731	488	731

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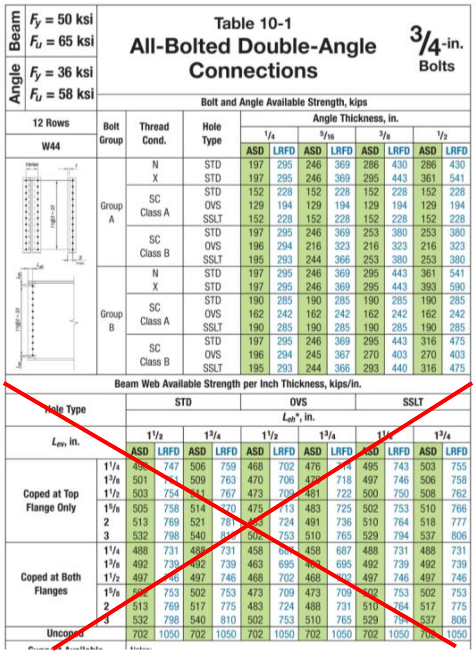
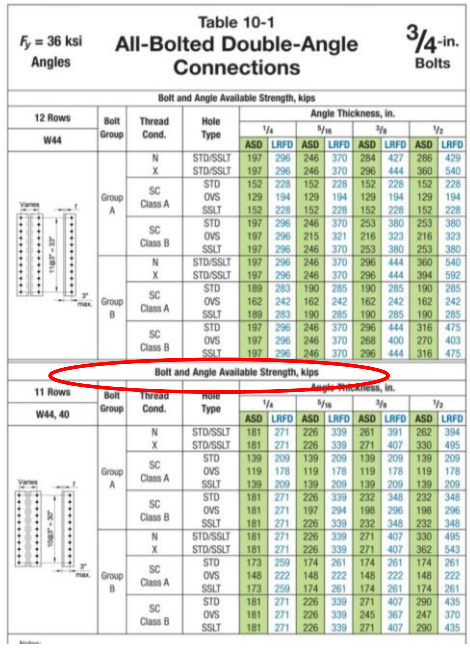
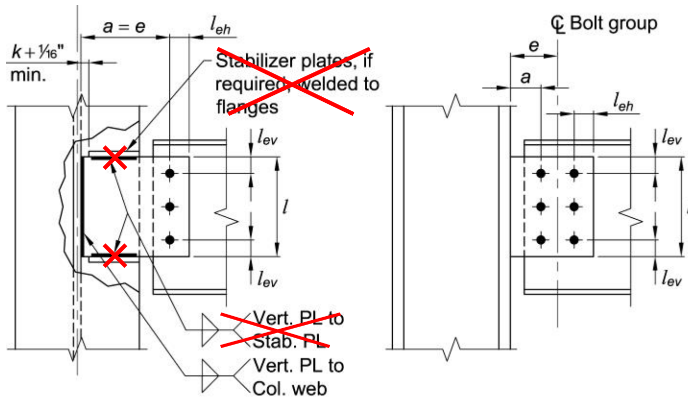


15TH Ed.



Part 10. Design of Simple Shear Connections

- Table 10-1 revised
- Extended single-plate connections: Removed stabilizer plate provision



Thornton and Fortney, *Engineering Journal*, 2011, 2016

Part 10. Design of Simple Shear Connections

- Table 10-1 revised
- Single-plate connections: Stabilizer plate requirement
- Table 10-14C: Weld details for skewed single-plate connections

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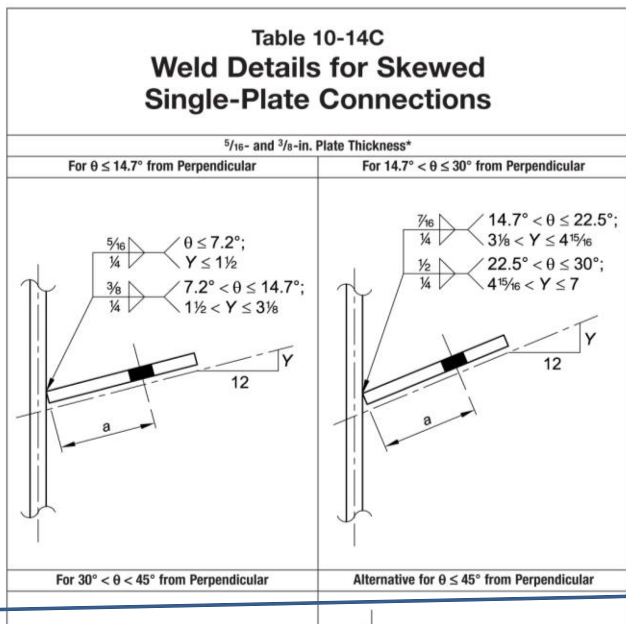
Part 10. Design of Simple Shear Connections

- This is "One acceptable design aid for skewed welds…."
- Works for 36- or 50-ksi plates
- Added 5/8-in. plate



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Part 14. Design of Beam Bearing Plates, Column Base Plates, Anchor Rods and Column Splices

Table 14-2
Recommended Sizes for Washers and Anchor Rod Holes in Base Plates

Anchor Rod Diameter	Hole Diameter	Washer Size	Min. Washer Thickness	Anchor Rod Diameter	Hole Diameter	Washer Size	Min. Washer Thickness
in.	in.	in.	in.	in.	in.	in.	in.
3/4	1 5/16	2	1/4	1 1/2	2 3/8	4	1/2
7/8	1 9/16	2 1/2	5/16	1 3/4	2 7/8	4 1/2	5/8
1	1 7/8	3	3/8	2	3 1/4	5	3/4
1 1/4	2 1/8	3 1/2	1/2	2 1/2	3 3/4	5 1/2	7/8

14th Ed: 3 1/2, 4

14th Ed: 3

14th Ed: 1 13/16, 2 1/16

14th Ed: 2 5/16, 2 3/4

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Part 14. Design of Beam Bearing Plates, Column Base Plates, Anchor Rods and Column Splices

Table 14-2 Notes:

1. Hole sizes provided are based on anchor rod size and correlate with ACI 117 (ACI, 2010).

…

4. ASTM F844 washer are permitted instead of plate washers when hole clearances are limited to 5/16 in. for rod diameters up to 1 in., 1/2 in. for rod diameters over 1 in. to 2 in., and 1 in. for rod diameters over 2 in. This exception should not be used unless the general contractor has agreed to meet smaller tolerances for anchor rod placement than those permitted in ACI 117.

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In Summary

Part 1…New shape sizes and detailing dimensions
Part 2…ASTM A500 Grade C is preferred for HSS
Part 3…New footnotes
Part 4…W-Shape column tables for 65 and 70 ksi
Part 6…New Super Table 6-2
Part 7…Table 7-14 includes TC bolts dimensions
Part 8…New plastic method for eccentrically loaded bolt groups
Part 9…Increased permitted tributary length for prying
Part 10…Removal of stabilizer plate provisions
Part 13…Additional considerations for HSS-to-HSS truss connections
Part 14…Updated Table 14-2 for improved anchor-rod installation

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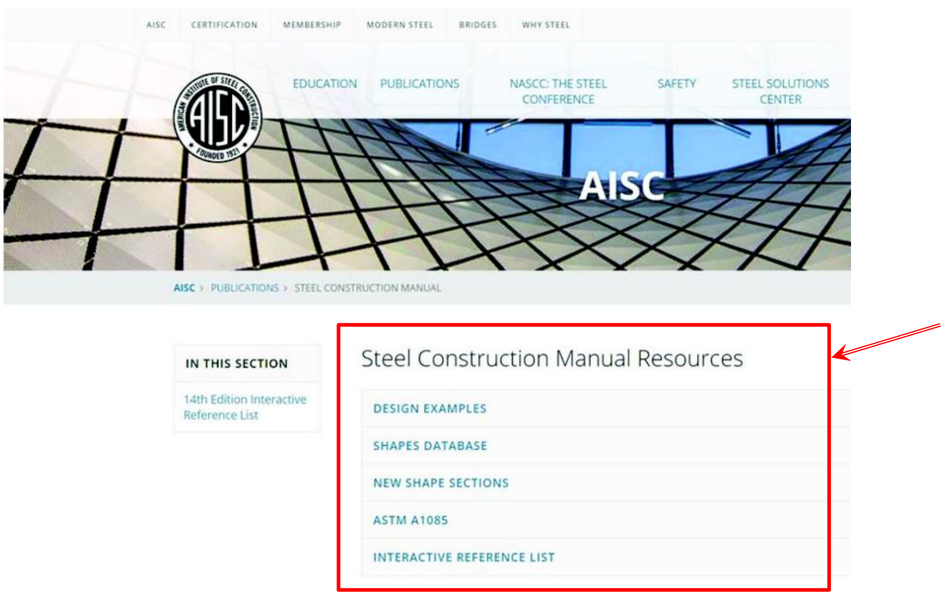

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Design Examples V15.0

Part IV: Additional Resources

- Combined Flexure and Axial Force, W-shapes (Table 6-1, 14th Ed. Manual)
- Filled HSS Column Tables, A500 Gr. C (Tables 4-13 to 4-20, 14th Ed. Manual)
- New Super Table 6-2: W-Shapes, 65 and 70 ksi
HSS, ASTM A1085
HSS, A500 Gr. C
Pipe
- New Z_{net} Table for Coped W-shapes

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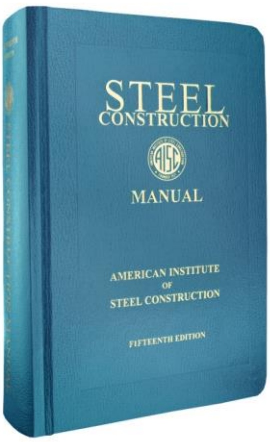

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