Connections and Tension Member Design

Connections

Connections must be able to transfer any axial force, shear, or moment from member to member or from beam to column.

Steel construction accomplishes this with bolt and welds. Wood construction uses nails, bolts, shear plates, and split-ring connectors.

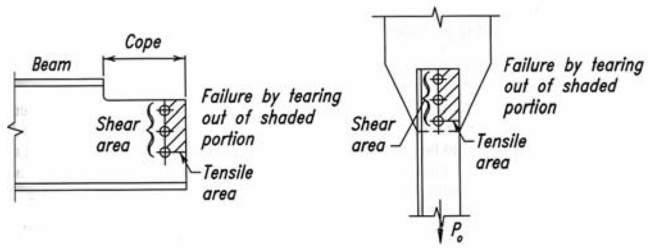


Fig. C-J4.1. Failure for block shear rupture limit state.

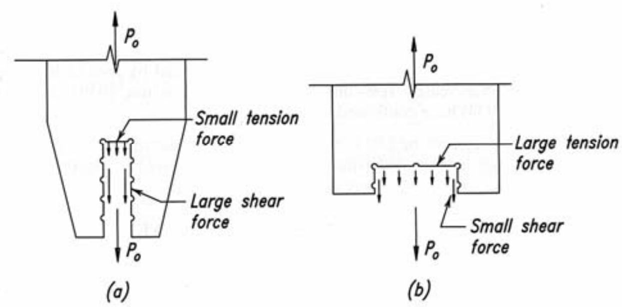


Fig. C-J4.2. Block shear rupture in tension.

Bolted and Welded Connections

The limit state for connections depends on the loads:

1. tension yielding
2. shear yielding
3. bearing yielding
4. bending yielding due to eccentric loads
5. rupture

Welds must resist tension AND shear stress. The design strengths depend on the weld materials.

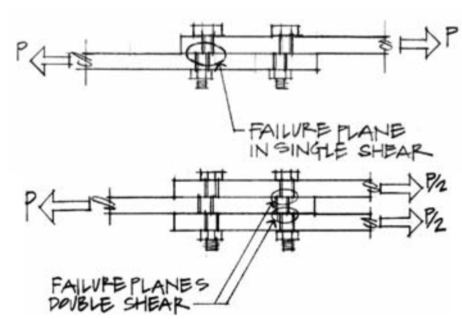
Bolted Connection Design

Bolt designations signify material and type of connection where

SC: slip critical
N: bearing-type connection with bolt threads *included* in shear plane
X: bearing-type connection with bolt threads *excluded* from shear plane

Bolts rarely fail in **bearing**. The material with the hole will more likely yield first.

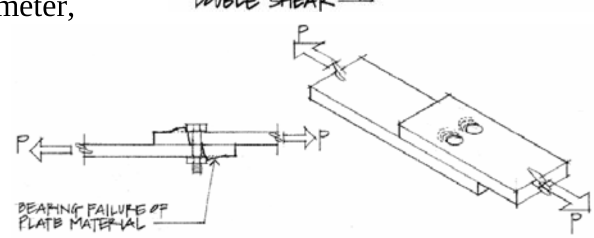
Standard bolt holes are *1/16" larger* than the bolt diameter.



ASD

Allowable shear values are given by bolt type, connection type, hole type, diameter, and loading (Single or Double shear) in AISC manual tables.

Allowable bearing force values are given by bolt diameter, ultimate tensile strength, F_u, of the connected part, and thickness of the connected part in AISC manual tables.



BOLTS, THREADED PARTS AND RIVETS
Shear
Allowable load in kips

TABLE I-D. SHEAR

	ASTM Desig-nation	Conn-ection Type[a]	Hole Type[b]	F_v ksi	Load-ing[c]	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
						Area (Based on Nominal Diameter) in.^{2}							
						.3068	.4418	.6013	.7854	.9940	1.227	1.485	1.767
Bolts	A307	—	STD NSL	10.0	S	3.1	4.4	6.0	7.9	9.9	12.3	14.8	17.7
					D	6.1	8.8	12.0	15.7	19.9	24.5	29.7	35.3
	A325	SC[a] Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9	25.2	30.0
					D	10.4	15.0	20.4	26.7	33.8	41.7	50.5	60.1
			OVS, SSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
			LSL	12.0	S	3.68	5.30	7.22	9.42	11.9	14.7	17.8	21.2
					D	7.36	10.6	14.4	18.8	23.9	29.4	35.6	42.4
		N	STD, NSL	21.0	S	6.4	9.3	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
		X	STD, NSL	30.0	S	9.2	13.3	18.0	23.6	29.8	36.8	44.5	53.0
					D	18.4	26.5	36.1	47.1	59.6	73.6	89.1	106.0
	A490	SC[a] Class A	STD	21.0	S	6.44	9.28	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
			OVS, SSL	18.0	S	5.52	7.95	10.8	14.1	17.9	22.1	26.7	31.8
					D	11.0	15.9	21.6	28.3	35.8	44.2	53.5	63.6
			LSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
		N	STD, NSL	28.0	S	8.6	12.4	16.8	22.0	27.8	34.4	41.6	49.5
					D	17.2	24.7	33.7	44.0	55.7	68.7	83.2	99.0
		X	STD, NSL	40.0	S	12.3	17.7	24.1	31.4	39.8	49.1	59.4	70.7
					D	24.5	35.3	48.1	62.8	79.5	98.2	119.0	141.0
Rivets	A502-1	—	STD	17.5	S	5.4	7.7	10.5	13.7	17.4	21.5	26.0	30.9
					D	10.7	15.5	21.0	27.5	34.8	42.9	52.0	61.8
	A502-2 A502-3	—	STD	22.0	S	6.7	9.7	13.2	17.3	21.9	27.0	32.7	38.9
					D	13.5	19.4	26.5	34.6	43.7	54.0	65.3	77.7
Threaded Parts	A36 (F_u=58 ksi)	N	STD	9.9	S	3.0	4.4	6.0	7.8	9.8	12.1	14.7	17.5
					D	6.1	8.7	11.9	15.6	19.7	24.3	29.4	35.0
		X	STD	12.8	S	3.9	5.7	7.7	10.1	12.7	15.7	19.0	22.6
					D	7.9	11.3	15.4	20.1	25.4	31.4	38.0	45.2
	A572, Gr. 50 (F_u=65 ksi)	N	STD	11.1	S	3.4	4.9	6.7	8.7	11.0	13.6	16.5	19.6
					D	6.8	9.8	13.3	17.4	22.1	27.2	33.0	39.2
		X	STD	14.3	S	4.4	6.3	8.6	11.2	14.2	17.5	21.2	25.3
					D	8.8	12.6	17.2	22.5	28.4	35.1	42.5	50.5
	A588 (F_u=70 ksi)	N	STD	11.9	S	3.7	5.3	7.2	9.3	11.8	14.6	17.7	21.0
					D	7.3	10.5	14.3	18.7	23.7	29.2	35.3	42.1
		X	STD	15.4	S	4.7	6.8	9.3	12.1	15.3	18.9	22.9	27.2
					D	9.4	13.6	18.5	24.2	30.6	37.8	45.7	54.4

Nominal Diameter d, in.

[a]SC = Slip critical connection.
N: Bearing-type connection with threads *included* in shear plane.
X: Bearing-type connection with threads *excluded* from shear plane.
[b]STD: Standard round holes (d + 1/16 in.) OVS: Oversize round holes
LSL: Long-slotted holes normal to load direction SSL: Short-slotted holes
NSL: Long-or short-slotted hole normal to load direction (required in bearing-type connection).
[c]S: Single shear D: Double shear.
For threaded parts of materials not listed, use $F_v = 0.17F_u$ when threads are included in a shear plane, and $F_v = 0.22F_u$ when threads are excluded from a shear plane.
To fully pretension bolts 1 1/8-in. dia. and greater, special impact wrenches may be required.
When bearing-type connections used to splice tension members have a fastener pattern whose length, measured parallel to the line of force, exceeds 50 in., tabulated values shall be reduced by 20%. See AISC ASD Commentary Sect. J3.4.

BOLTS AND THREADED PARTS
Bearing
Allowable loads in kips

TABLE I-E. BEARING
Slip-critical and Bearing-type Connections

Mate-rial Thick-ness	F_u = 58 ksi Bolt dia.			F_u = 65 ksi Bolt dia.			F_u = 70 ksi Bolt dia.			F_u = 100 ksi Bolt dia.		
	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1
1/8	6.5	7.6	8.7	7.3	8.5	9.8	7.9	9.2	10.5	11.3	13.1	15.0
3/16	9.8	11.4	13.1	11.0	12.8	14.6	11.8	13.8	15.8	16.9	19.7	22.5
1/4	13.1	15.2	17.4	14.6	17.1	19.5	15.8	18.4	21.0	22.5	26.3	30.0
5/16	16.3	19.0	21.8	18.3	21.3	24.4	19.7	23.0	26.3	28.1	32.8	37.5
3/8	19.6	22.8	26.1	21.9	25.6	29.3	23.6	27.6	31.5	33.8	39.4	45.0
7/16	22.8	26.6	30.5	25.6	29.9	34.1	27.6	32.2	36.8		45.9	52.5
1/2	26.1	30.5	34.8	29.3	34.1	39.0	31.5	36.8	42.0			60.0
9/16	29.4	34.3	39.2	32.9	38.4	43.9		41.3	47.3			
5/8	32.6	38.1	43.5		42.7	48.8		45.9	52.5			
11/16		41.9	47.9		46.9	53.6			57.8			
3/4		45.7	52.2			58.5						
13/16			56.6									
7/8			60.9									
15/16												
1	52.2	60.9	69.6	58.5	68.3	78.0	63.0	73.5	84.0	90.0	105.0	120.0

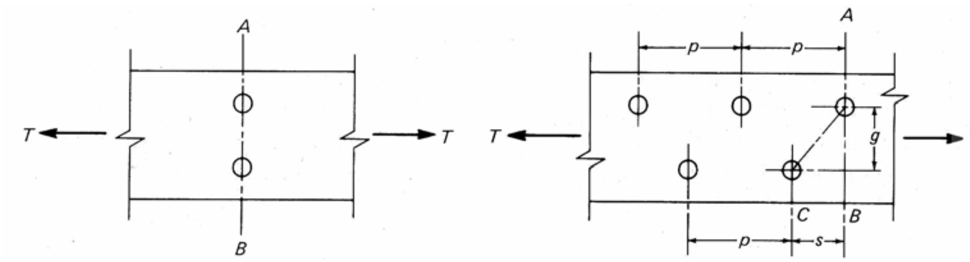
Notes:
This table is applicable to all mechanical fasteners in both slip-critical and bearing-type connections utilizing standard holes. Standard holes shall have a diameter nominally 1/16-in. larger than the nominal bolt diameter (d + 1/16 in.).
Tabulated bearing values are based on $F_p = 1.2\ F_u$.
F_u = specified minimum tensile strength of the connected part.
In connections transmitting axial force whose length between extreme fasteners measured parallel to the line of force exceeds 50 in., tabulated values shall be reduced 20%.
Connections using high-strength bolts in slotted holes with the load applied in a direction other than approximately normal (between 80 and 100 degrees) to the axis of the hole and connections with bolts in oversize holes shall be designed for resistance against slip at working load in accordance with AISC ASD Specification Sect. J3.8.
Tabulated values apply when the distance l parallel to the line of force from the center of the bolt to the edge of the connected part is not less than 1 1/2 d and the distance from the center of a bolt to the center of an adjacent bolt is not less than 3d. See AISC ASD Commentary J3.8.
Under certain conditions, values greater than the tabulated values may be justified under Specification Sect. J3.7.
Values are limited to the double-shear bearing capacity of A490-X bolts.
Values for decimal thicknesses may be obtained by multiplying the decimal value of the unlisted thickness by the value given for a 1-in. thickness.

Tension Member Design

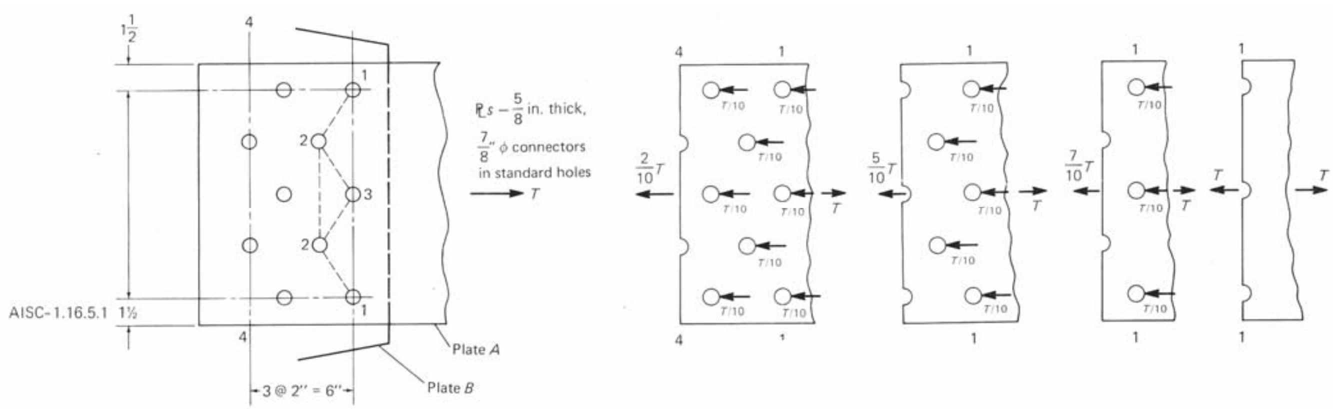
In steel tension members, there may be bolt holes that reduce the size of the cross section.

Effective Net Area:

The smallest effective are must be determined by subtracting the bolt hole areas. With staggered holes, the shortest length must be evaluated.



A series of bolts can also transfer a portion of the tensile force, and some of the effective net areas see reduced stress.



ASD

For other than pin connected members: $F_t = 0.60F_y$ *on gross area*

$F_t = 0.50F_u$ *on net area*

For pin connected members: $F_t = 0.45F_y$ *on net area*

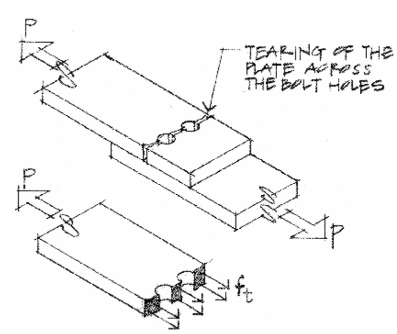
For threaded rods of approved steel: $F_t = 0.33F_u$ *on major diameter (static loading only)*

LRFD

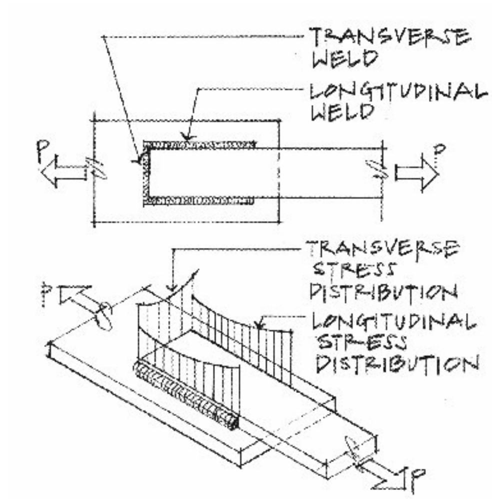
The limit state for tension members are: $P_u \le \phi_t P_n$

1. yielding $\phi_t = 0.9 \quad P_n = F_y A_g$
2. rupture $\phi_t = 0.75 \quad P_n = F_u A_e$

where A_g = the gross area of the member (excluding holes)
A_e = the effective net area (with holes, etc.)
F_u = the tensile strength of the steel (ultimate)



Welded Connections



Weld designations include the strength in the name, i.e. E70XX has F_y = 70 ksi.

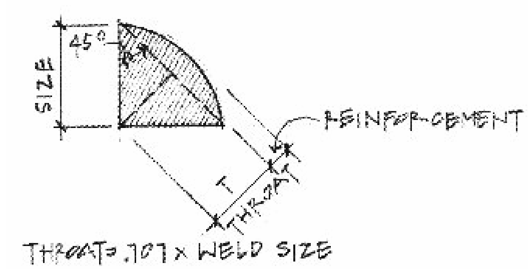
The throat size, T, of a fillet weld is determined trigonometry by: $T = 0.707 \times \text{weld size}$

<u>ASD</u>

Allowable shear stress of a weld is limited to 30% of the nominal strength.

F_v = 18 ksi for E60XX

F_v = 21 ksi for E70XX



Weld sizes are limited by the size of the parts being put together and are given in AISC manual table J2.4 along with the allowable strength per length of fillet weld, referred to as *S*.

The *maximum* size of a fillet weld:

a) can't be greater than the material thickness if it is ¼" or less

b) is permitted to be 1/16" less than the thickness of the material if it is over ¼"

The *minimum length* of a fillet weld is 4 times the nominal size. If it is not, then the weld size used for design is ¼ the length.

Intermittent fillet welds can not be less that four times the weld size, not to be less than 1 ½".

Allowable Strength of Fillet Welds per inch of weld (*S*)

Weld Size (in.)	E60XX (k/in.)	E70XX (k/in.)
3/16	2.39	2.78
¼	3.18	3.71
5/16	3.98	4.64
3/8	4.77	5.57
7/16	5.57	6.94
½	6.36	7.42
5/8	7.95	9.27
¾	9.55	11.13

TABLE J2.4
Minimum Size of Fillet Welds

Material Thickness of Thicker Part Joined (in.)	Minimum Size of Fillet Weld[a] (in.)
To ¼ inclusive	1/8
Over ¼ to ½	3/16
Over ½ to ¾	¼
Over ¾	5/16

[a]Leg dimension of fillet welds. Single-pass welds must be used.

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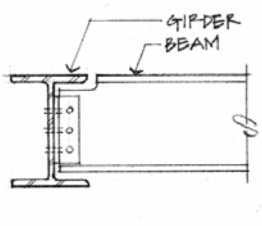
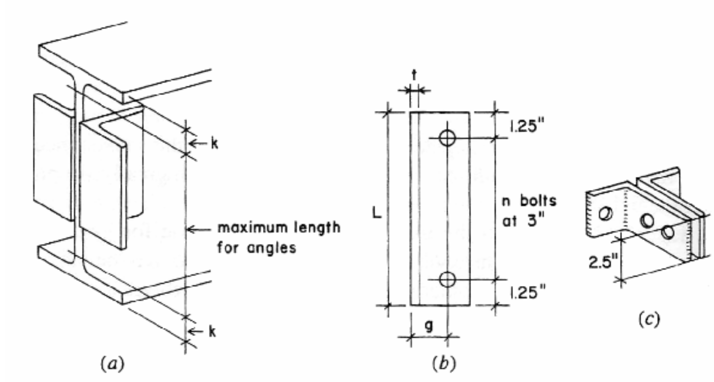
Framed Beam Connections



Coping is the term for cutting away part of the flange to connect a beam to another beam using welded or bolted angles.

AISC provides tables that give angle sizes knowing bolt type, bolt diameter, angle leg thickness, and number of bolts (determined by *shear* capacity).

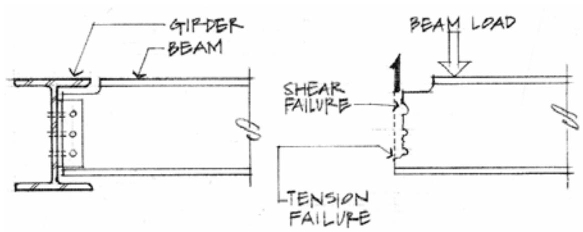


Load and Factor Resistance Design

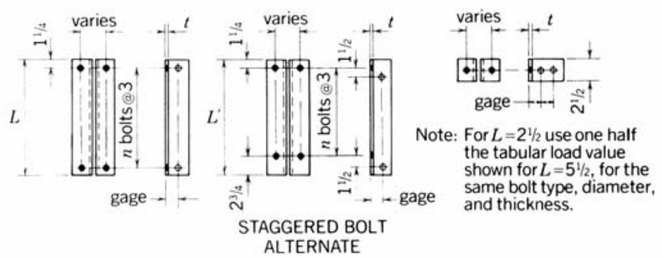
In addition to resisting shear and tension in bolts and shear in welds, the connected materials may be subjected to shear, bearing, tension, flexure and even prying action. Coping can significantly reduce design strengths and may require web reinforcement. All the following must be considered:

- shear yielding
- shear rupture
- block shear rupture -

  failure of a block at a beam as a result of shear and tension
- tension yielding
- tension rupture
- local web buckling
- lateral torsional buckling



FRAMED BEAM CONNECTIONS
Bolted
TABLE II Allowable loads in kips



Note: For $L = 2\frac{1}{2}$ use one half the tabular load value shown for $L = 5\frac{1}{2}$, for the same bolt type, diameter, and thickness.

TABLE II-A Bolt Shear[a]

For A307 bolts in standard or slotted holes and for A325 and A490 bolts in **slip-critical** connections with standard holes and Class A, clean mill scale surface condition.

Bolt Type			A307			A325-SC			A490-SC		
F_v, Ksi			10.0			17.0			21.0		
Bolt Dia., d In.			¾	⅞	1	¾	⅞	1	¾	⅞	1
Angle Thickness t, In.			¼	¼	¼	¼	5/16	½	5/16	½	⅝
L In.	L' In.	n									
29½	31	10	88.4	120	157	150	204	267	186	253	330
26½	28	9	79.5	108	141	135	184	240	167	227	297
23½	25	8	70.7	96.2	126	120	164	214	148	202	264
20½	22	7	61.9	84.2	110	105	143	187	130	177	231
17½	19	6	53.0	72.2	94.2	90.1	123	160	111	152	198
14½	16	5	44.2	60.1	78.5	75.1	102	134	92.8	126	165
11½	13	4	35.3	48.1	62.8	60.1	81.8	107	74.2	101	132
8½	10	3	26.5	36.1	47.1[b]	45.1	61.3	80.1	55.7	75.8	99.0
5½	7	2	17.7	24.1	31.4[b]	30.0	40.9	53.4	37.1	50.5	66.0

Note: For slip-critical connections with oversize or slotted holes, see Table II-B.

Notes:

[a]Tabulated load values are based on double shear of bolts unless noted. See RCSC Specification for other surface conditions.

[b]Capacity shown is based on double shear of the bolts; however, for length L, net shear on the angle thickness specified is critical. See Table II-C.

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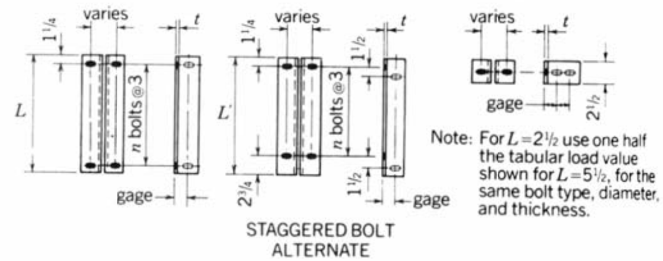
FRAMED BEAM CONNECTIONS
Bolted
TABLE II Allowable loads in kips



Note: For $L = 2\frac{1}{2}$ use one half the tabular load value shown for $L = 5\frac{1}{2}$, for the same bolt type, diameter, and thickness.

TABLE II-A Bolt Shear

For bolts in **bearing-type** connections with standard or slotted holes.

Bolt Type			A325-N			A490-N			A325-X			A490-X		
F_v, Ksi			21.0			28.0			30.0			40.0		
Bolt Dia., d In.			¾	⅞	1	¾	⅞	1	¾	⅞	1	¾	⅞	1
Angle Thickness t, In.			5/16	⅜	⅝	⅜	½	⅝	⅜	⅝	⅝	½	⅝	⅝
L In.	L' In.	n												
29½	31	10	186	253	330	247	337	440	265	361		353		
26½	28	9	167	227	297	223	303	396	239	325		318		
23½	25	8	148	202	264	198	269	352	212	289		283		
20½	22	7	130	177	231	173	236	308	186	253		247		
17½	19	6	111	152	198	148	202	264	159	216		212	289	
14½	16	5	92.8	126	165	124	168	220	133	180		177	242	
11½	13	4	74.2	101	132	99.0	135	176	106	144	188	141	192	
8½	10	3	55.7	75.8	99.0	74.2	101	132	79.5	108	141	106	144	
5½	7	2	37.1	50.5	66.0	49.5	67.3	88.0	53.0	72.2	94	70.7	96	

Tabulated load values are based on double shear of bolts.

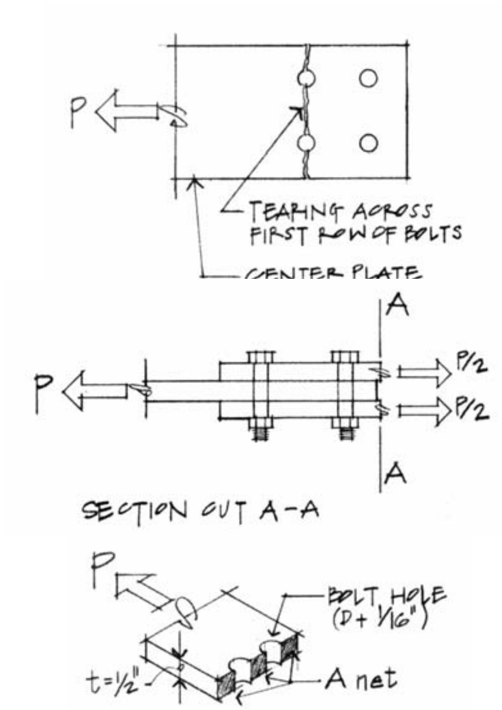
Shaded values are based on double shear of the bolts; however, for length L, net shear on the angle thickness specified is critical. See Table II-C.

For shaded cells without values, shear rupture is critical for lengths L and L' on angle thickness specified. See Table II-C.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

Example 1

10.2 The butt splice shown in Figure 10.22 uses two 8 × ⅜″ plates to "sandwich" in the 8 × ½″ plates being joined. Four ⅞″ϕ A325-SC bolts are used on both sides of the splice. Assuming A36 steel and standard round holes, determine the allowable capacity of the connection.



Solution:

Shear, bearing, and net tension will be checked to determine the critical condition that governs the capacity of the connection.

(Table I-D)

Shear: Using the AISC allowable shear in Table 10.1:

$$P_v = 20.4\,\text{k/bolt} \times 4 \text{ bolts} = 81.6\,\text{k} \quad \text{(double shear)}$$

(Table I-E)

Bearing: Using the AISC bearing in Table 10.2:

The thinner material with the largest proportional load governs, therefore, the ½″ center plate governs. Assume the bolts are at a *3d* spacing, center to center.

$$P_b = 30.5\,\text{k/bolt} \times 4 \text{ bolts} = 122\,\text{k}$$

Tension: The center plate is critical since its thickness is less than the combined thickness of the two outer plates.

Hole diameter = (bolt diameter) + 1⁄16″ = ⅞″ + 1⁄16″ = 15⁄16″.

$$A_{net} = (8'' - 2 \times 15/16'') \times (1/2'') = 3.06\,\text{in.}^2$$

$$P_t = F_t \times A_{\text{net}}$$

where:

$$F_t = 0.5F_u = 0.5(58\,\text{ksi}) = 29\,\text{ksi}$$

$$P_t = 29\,\text{k/in.}^2 \times 3.06\,\text{in.}^2 = 88.7\,\text{k}$$

For yielding in the cross section without holes:

$$A_{gross} = (8'') \times (1/2'') = 4.0\,\text{in.}^2$$

$$P_t = F_t \times A_{gross}$$

where:

$$F_t = 0.6F_y = 0.6(36\,\text{ksi}) = 21.6\,\text{ksi}$$

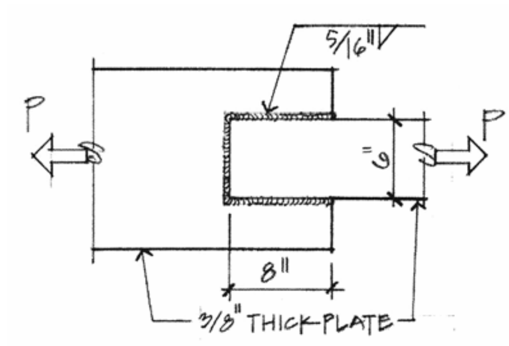
$$P_t = 21.6\,\text{k/in.}^2 \times 4.0\,\text{in.}^2 = 86.4\,\text{k}$$

The maximum connection capacity is governed by shear.

$$P_{\text{allow}} = 81.6\,\text{k}$$

Example 2

10.7 Determine the capacity of the connection in Figure 10.44 assuming A36 steel with E70XX electrodes.



Solution:

Capacity of weld:

For a 5⁄16″ fillet weld, S = 4.64 k/in

Weld length = 22″

Weld capacity = 22″ × 4.64 k/in = 102.1 k

Capacity of plate:

$$F_{t\,\text{allow}} = 0.6F_y = 22\,\text{ksi}$$

Plate capacity = 3⁄8″ × 6″ × 22 k/in.^{2} = 49.5 k

∴ Plate capacity governs, $P_{\text{allow}} = 49.5$ k

The weld size used is obviously too strong. What size, then, can the weld be reduced to so that the weld strength is more compatible to the plate capacity? To make the weld capacity ≈ plate capacity:

22″ × (weld capacity per in.) = 49.5 k

$$\text{Weld capacity per inch} = \frac{49.5\,\text{k}}{22\,\text{in.}} = 2.25\,\text{k/in.}$$

(page 4)

From Table 10.5, use 3⁄16″ weld ($S = 2.78$ k/in.).

Minimum size fillet = 3⁄16″ based on a 3⁄8″ thick plate.

FRAMED BEAM CONNECTIONS
BOLTED
TABLE II Allowable loads in kips

TABLE II-C
Allowable Shear in Connection Angles for A36 Material

Bolt Dia., *d* In.		¾				⅞					1				
Angle Thickness, *t* In.		¼	5⁄16	⅜	½	¼	5⁄16	⅜	½	⅝	¼	5⁄16	⅜	½	⅝
L In.	*n*														
29½	10	186	232	279	372	175	219	263	350	438	164	205	246	328	411
26½	9	167	209	250	334	157	196	236	314	393	147	184	221	295	368
23½	8	148	185	222	296	139	174	209	278	348	131	163	196	261	326
20½	7	129	161	193	258	121	152	182	243	303	114	142	170	227	284
17½	6	110	137	165	220	103	129	155	207	258	96.8	121	145	194	242
14½	5	90.8	114	136	182	85.4	107	128	171	213	79.9	99.9	120	160	200
11½	4	71.8	89.7	108	144	67.4	84.3	101	135	169	63.1	78.8	94.6	126	158
8½	3	52.7	65.9	79.1	105	49.5	61.9	74.2	99.0	124	46.2	57.8	69.3	92.4	116
5½	2	33.7	42.1	50.6	67.4	31.5	39.4	47.3	63.1	78.8	29.4	36.7	44.0	58.7	73.4
L′ In.	*n*														
31	10	199	249	299	398	188	235	282	376	470	177	222	266	355	443
28	9	180	225	270	360	170	213	255	340	425	160	201	241	321	401
25	8	161	201	241	322	152	190	228	305	381	144	179	215	287	359
22	7	142	177	213	284	134	168	201	269	336	127	158	190	253	317
19	6	123	154	184	246	116	145	175	233	291	110	137	165	220	275
16	5	104	130	156	208	98.4	123	148	197	246	93.0	116	139	186	232
13	4	84.8	106	127	170	80.5	101	121	161	201	76.1	95.2	114	152	190
10	3	65.8	82.2	98.7	132	62.5	78.2	93.8	125	156	59.3	74.1	88.9	119	148
7	2	46.8	58.5	70.1	93.5	44.6	55.7	66.9	89.2	111	42.4	53.0	63.6	84.8	106

NOTES: Table based on an allowable shear of $0.3F_u$ (17.4 ksi for A36 angles) of the net section of two angles.
Net section based on diameter of fastener + 1⁄16 in.

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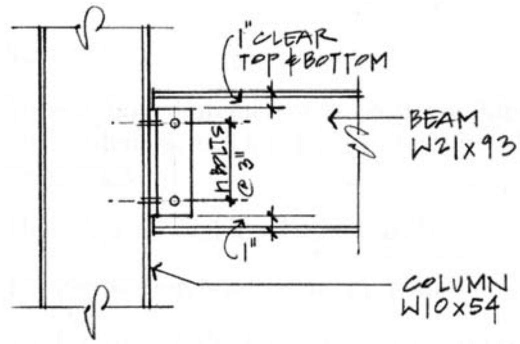
Example 3



The steel used in the connection and beams is A992 with F_y = 50 ksi, and F_u = 65 ksi. Using A490-N bolt material, determine the maximum capacity of the connection based on shear in the bolts, bearing in all materials and pick the number of bolts and angle length (not staggered). Use A36 steel for the angles.

W21x93: d = 21.62 in, t_w = 0.58 in, t_f = 0.93 in
W10x54: t_f = 0.615 in

SOLUTION:

The maximum length the angles can be depends on how it fits between the top and bottom flange with some clearance allowed for the fillet to the flange, and getting an air wrench in to tighten the bolts. This example uses 1" of clearance:

Available length = beam depth – both flange thicknesses – 1" clearance at top & 1" at bottom

= 21.62 in – 2(0.93 in) – 2(1 in) = 17.76 in.

The standard lengths for non-staggered holes (L) and staggered holes (L') are shown in Table II-A. The closest size within the available length is 17 ½ in. This will fit 6 bolts (n) with a standard spacing.

We have a choice of bolt diameters of ¾", 7/8" and 1" in Table II-A. These have allowable loads for **shear** (double) of 148 kips, 202 kips, and 264 kips. But the last two values are shaded and the note says that "net shear on the angle thickness specified is critical" and to see Table II-C. The angle thickness (t) is listed below the bolt diameter.

Table II-C gives a value of 207 kips for a 7/8" bolt diameter, ½" angle thickness, and 17.5" length. It gives a value of 242 kips for a 1" bolt diameter, 5/8" angle thickness, and 17.5" length. Therefore, 242 kips is the maximum value limited by shear in the *angle*.

P_p = 264 kips for double shear of 1" bolts (Table I-D: 6 bolts·(44 k/bolt) = 264 kips)

P_v = 242 kips for net shear in angle

We also need to evaluate **bearing** of bolts on the angles, beam web, and column flange where there are bolt holes. Table I-E provides allowable bearing load for the material type, bolt diameter and some material thicknesses. The last note states that "Values for decimal thicknesses may be obtained by multiplying the decimal value of the unlisted thickness by the value given for a 1-in. thickness". This comes from the definition for bearing stress:

$$f_P = \frac{P}{td} \le F_p, \text{ where } P_p = t\cdot d\cdot F_p \text{ at the allowable bearing stress}$$

For a constant diameter and allowable stress, the allowable load depends only on the thickness.

a) Bearing for 5/8" thick angle: There are 12 bolt holes through two angle legs to the column, and 12 bolt holes through two angle legs either side of the beam. The material is A36 (F_u = 58 ksi), with 1" bolt diameters.

P_p = 12 bolts·(43.5 k/bolt) = 522 kips

b) Bearing for column flange: There are 12 bolt holes through two angle legs to the column. The material is A992 (F_u = 65 ksi), 0.615" thick, with 1" bolt diameters.

P_p = 12 bolts·(78 k/bolt/1")·(0.615 in) = 576 kips.

c) Bearing for beam web: There are *6* bolt holes through two angle legs either side of the beam. The material is A992 (F_u = 65 ksi), 0.58" thick, with 1" bolt diameters

P_p = 6 bolts·(78 k/bolt/1")·(0.58 in) = 271 kips.

Although, the bearing in the beam web is the smallest at 271 kips, with the shear on the bolts even smaller at 264 kips, *the maximum capacity for the simple-shear connector is 242 kips* limited by net shear in the angles.