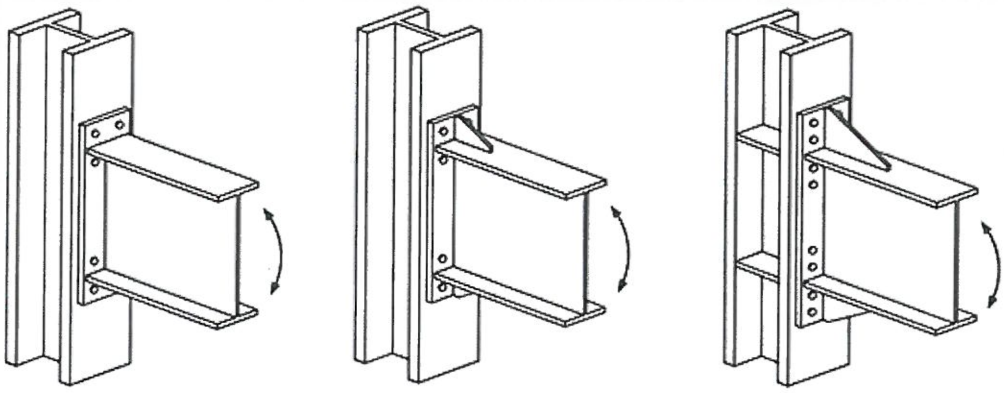
STRUCTURAL CONNECTIONS



(a) Four-Bolt Unstiffened, 4E

(b) Four-Bolt Stiffened, 4ES

(c) Eight-Bolt Stiffened, 8ES

LECTURE # 10

CONNECTIONS

CHAPTER 16-1 / Pg.324, J1, J2 & J3

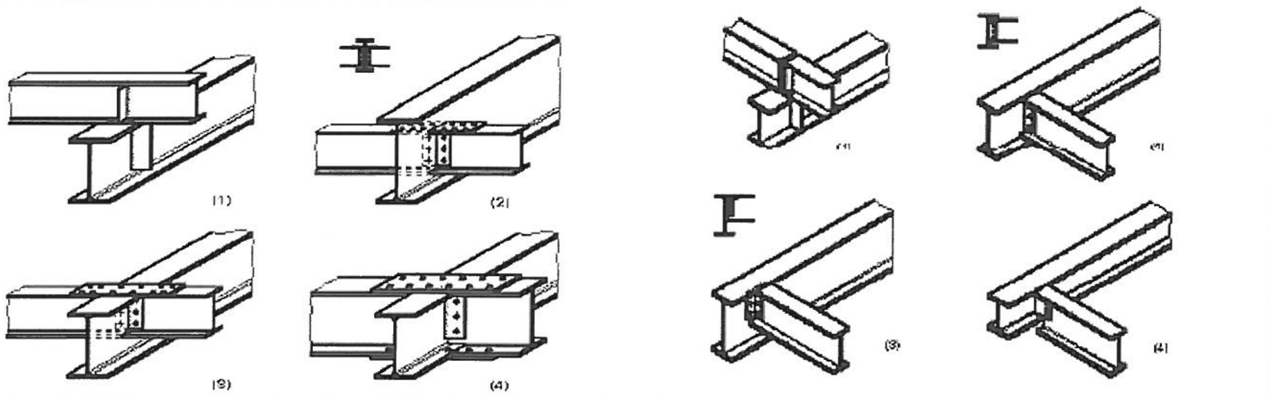
Objectives:

Through the following 3 lectures, we shall study together the steel connections. Our main objectives will be:

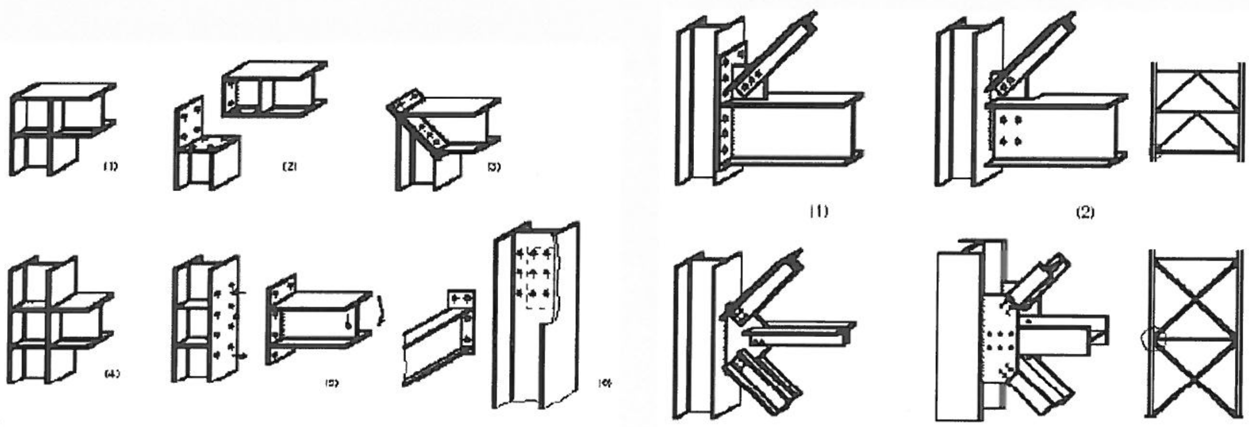
1. Identify the different types of steel connections.

2. Understanding the force transfer through steel connections.

3. Practicing the design of riveted, bolted and welded connections through neat self-explained calculations and full drawings details.



Some types of connections (a)



Some types of connections (b)

Generally the area of any connection is represented by a connector, connected elements & some type of assistant elements such as splice plate or gusset plate.

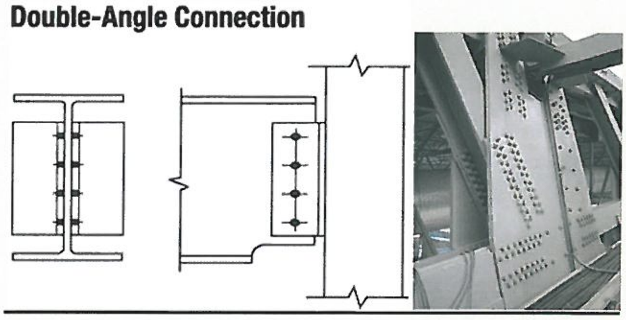


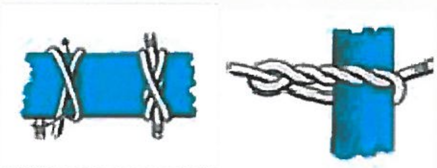
Fig. shows connectors, connected element & web angles

Structural connections types:

1- Simple (flexible) connection type.
2- Semi rigid connection type.
3- Rigid connection type.

Types of connectors or fasteners:

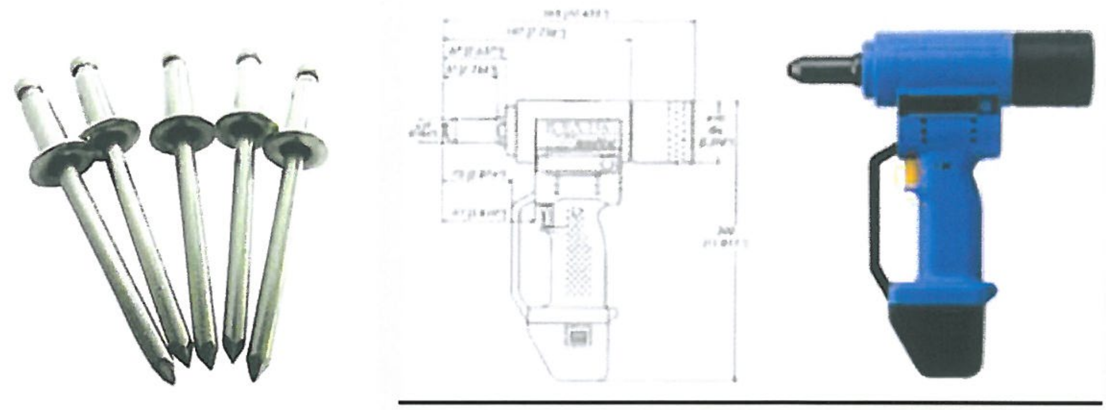
1- Ropes.
2- Cables.
3- Nails
4- Pins.
5- Rivets.
6- Bolts.
7- Welds.



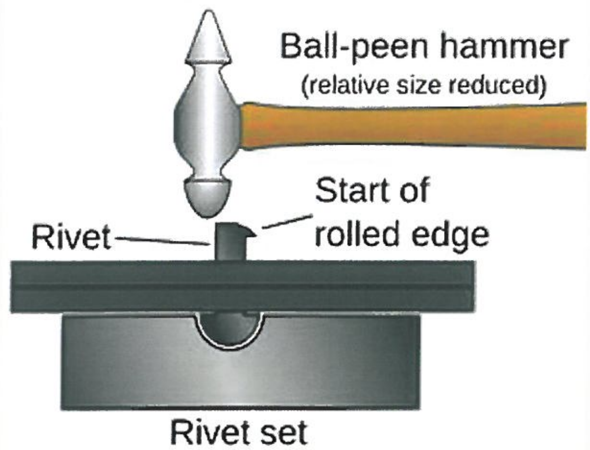
Rivets types:

- Cold type driven rivets: used for secondary & finishing works.

- Hot type driven rivets: used for structural works.



Cold driven rivets types & driven tool



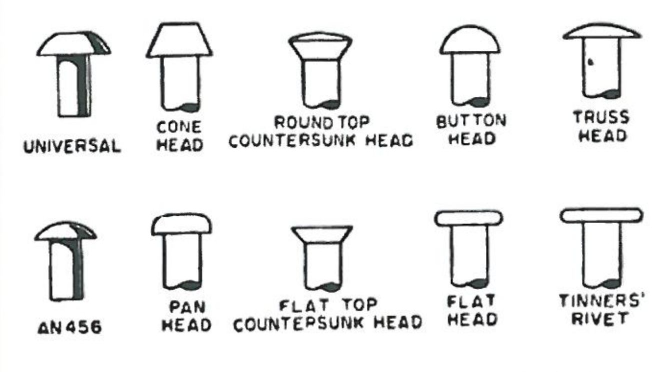


Figure 4-18.—Some common types of rivets.

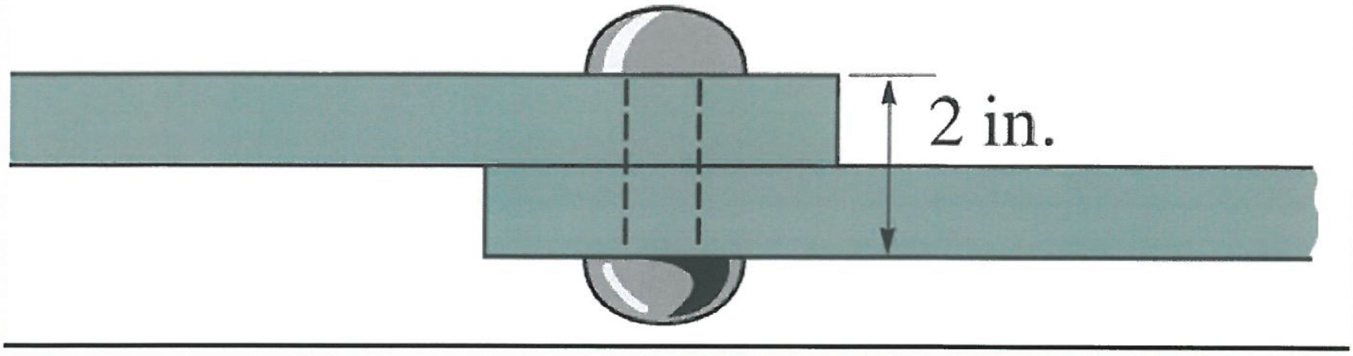
Hot driven rivets types & process

<u>ASTM HOT DRIVEN RIVETS TYPES:</u>

A502, 1: Of low carbon, so weaker than the ordinary structural carbon steel, easy to driven & have a higher ductility.

A502, 2: of low carbon & manganese alloyes, with higher strength, where developed for higher steel strength. So the connection will have fewer number of rivets.

A502, 3: they are of same specification of grade 2 above but has good resistance to atmospheric corrosion



Lap riveted connection

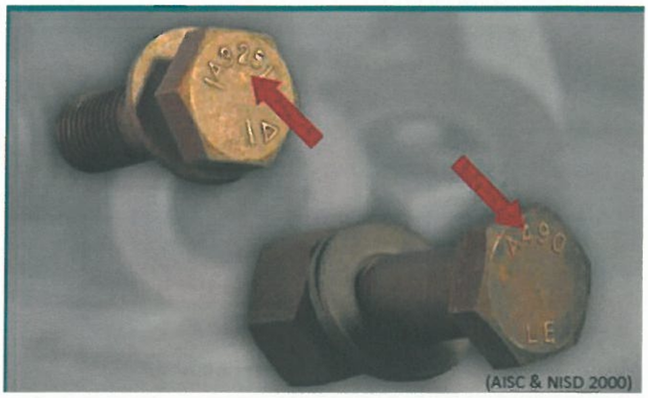
ASTM Bolts Types (AISC):

- ✓ A307 – Low carbon steel
- Not commonly used.
- Only used for secondary members.

- ✓ A325 – High-strength medium carbon steel.
- Most common bolts used in building construction.

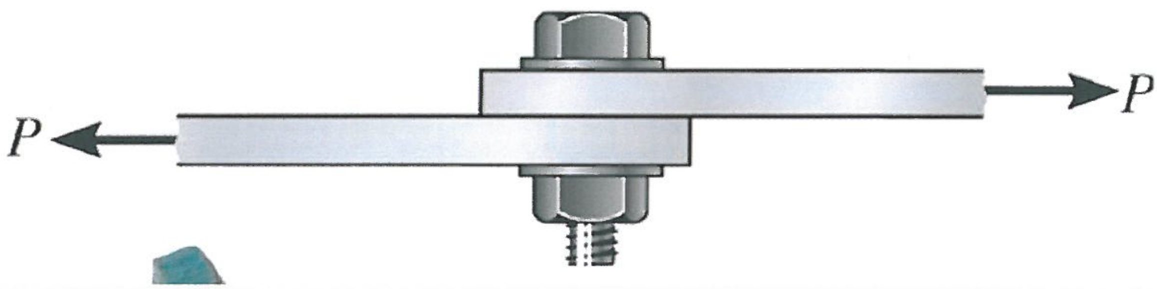
- ✓ A490 – High-strength heat treated steel.
  - Cost more than A325's, but are stronger so fewer bolts may be necessary.

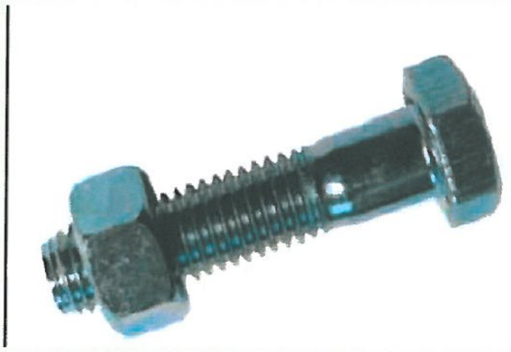
Note that the ASTM designation is indicated on the head of the bolts shown below:

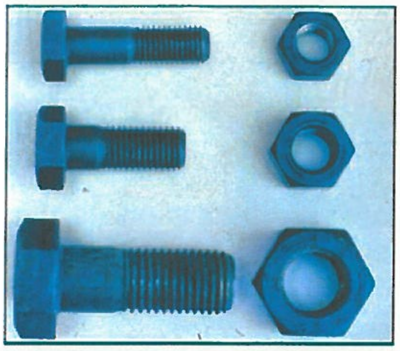


(AISC & NISD 2000)

ASTM F1554 threaded rods are preferred to be used as threaded rods.







Common Bolt Sizes (AISC):

- ✓ A325 and A490 bolts are available in diameters ranging from 1/2″ to 1-1/2″.
- ✓ The most common sizes are 3/4″, 7/8″, and 1″.
- ✓ High-strength bolts are commonly available in incremental lengths up to 8″.

Washers (AISC):

- ✓ Hardened steel washers are used in many structural connections to spread pressure from the bolt tightening process over a larger area.
- ✓ Washers may also be used to cover an oversized or slotted hole (RCSC 2000).
- ✓ Flat washers are most commonly used.
- ✓ Tapered washers (above left) are used when the surface being bolted has a sloped surface, such as the flange of a channel or an S shape.
- ✓ A325 bolts require a washer under the element (head or nut) being turned to tighten the bolt (shown under the nut, above right).
- ✓ A490 bolts require a washer under both the head and nut (AISC & NISD 2000).

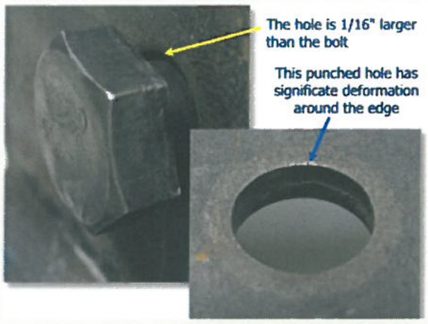


Table 2.1. Acceptable ASTM A563 Nut Grade and Finish and ASTM F436 Washer Type and Finish

ASTM Desig.	Bolt Type	Bolt Finish[d]	ASTM A563 nut grade and finish[d]	ASTM F436 washer type and finish[a,d]
A325	1	Plain (uncoated)	C, C3, D, DH[c] and DH3; plain	1; plain
		Galvanized	DH[c]; galvanized And lubricated	1; galvanized
	3	Plain	C3 and DH3; plain	3; plain
F1852	1	Plain (uncoated)	C, C3, DH[c] and DH3; plain	1; plain[b]
		Mechanically Galvanized	DH[c]; mechanically galvanized and lubricated	1; mechanically galvanized[b]
	3	Plain	C3 and DH3; plain	3; plain[b]
A490	1	Plain	DH[c] and DH3; plain	1; plain
	3	Plain	DH3; plain	3; plain

[a] Applicable only if washer is required in Section 6.

[b] Required in all cases under nut per Section 6.

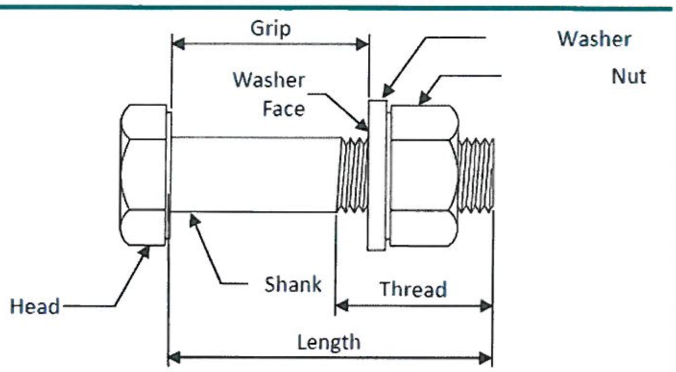
[c] The substitution of ASTM A194 grade 2H nuts in place of ASTM A563 grade DH nuts is permitted.

[d] "Galvanized" as used in this table refers to hot-dip galvanizing in accordance with ASTM A153 or mechanical galvanizing in accordance with ASTM B695.

<table>
<tr><th>Bolt / Nut</th><th colspan="3">Type 1</th><th colspan="3">Type 3</th></tr>
<tr><td>ASTM A325 bolt</td><td colspan="3">
Three radial line 120°apart are optional</td><td colspan="3"></td></tr>
<tr><td>ASTM F1852 bolt</td><td colspan="3">
Three radial line 120°apart are optional</td><td colspan="3"></td></tr>
<tr><td>ASTM A490 bolt</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td rowspan="2">ASTM A563 nut</td><td colspan="2">
Arcs indicate grade C</td><td colspan="2">
Arcs with "3" indicate grade C3</td><td colspan="2">
Grade mark D</td></tr>
<tr><td colspan="3">
Grade mark DH</td><td colspan="3">
Grade mark DH3</td></tr>
</table>

Notes:
1. XYZ represents the manufacturer's identification mark.
2. ASTM F1852 twist-off-type tension-control bolt assemblies are also produced with heavy-hex head that has similar markings.

Parts of the Bolt Assembly (AISC):



- ✓ Grip is the distance from behind the bolt head to the back of the nut or washer.
- ✓ It is the sum of the thicknesses of all the parts being joined exclusive of washers.
- ✓ Thread length is the threaded portion of the bolt.
- ✓ Bolt length is the distance from behind the bolt head to the end of the bolt.

Threads in or out of the shear plane (AISC): as (threads included A325N bolt) & (threads excluded A325X bolt) respectively.

- ✓ The shear plane is the plane between two or more pieces under load where the pieces tend to move parallel from each other, but in opposite directions.
- ✓ The threads of a bolt may either be included in the shear plane or excluded from the shear plane Threads.
- ✓ The capacity of a bolt is greater with the threads excluded Included in the Shear Plane from the shear plane.
- ✓ The most commonly used bolt is an ASTM A325 3/4″ bolt with the threads included in the shear plane.

Table C-2.1. Bolt and Nut Dimensions

Nominal Bolt Diameter d_b, in.	Heavy Hex Structural Bolt Dimensions			Heavy Hex Nut Dimensions	
	Width across flats F, in.	Height H_1, in.	Thread Length T, in.	Width across flats W, in.	Height H_2, in.
$^1/_2$	$^7/_8$	$^5/_{16}$	1	$^7/_8$	$^{31}/_{64}$
$^5/_8$	$1^1/_{16}$	$^{25}/_{64}$	$1^1/_4$	$1^1/_{16}$	$^{39}/_{64}$
$^3/_4$	$1^1/_4$	$^{15}/_{32}$	$1^3/_8$	$1^1/_4$	$^{47}/_{64}$
$^7/_8$	$1^7/_{16}$	$^{35}/_{64}$	$1^1/_2$	$1^7/_{16}$	$^{55}/_{64}$
1	$1^5/_8$	$^{39}/_{64}$	$1^3/_4$	$1^5/_8$	$^{63}/_{64}$
$1^1/_8$	$1^{13}/_{16}$	$^{11}/_{16}$	2	$1^{13}/_{16}$	$1^7/_{64}$
$1^1/_4$	2	$^{25}/_{32}$	2	2	$1^7/_{32}$
$1^3/_8$	$2^3/_{16}$	$^{27}/_{32}$	$2^1/_4$	$2^3/_{16}$	$1^{11}/_{32}$
$1^1/_2$	$2^3/_8$	$^{15}/_{16}$	$2^1/_4$	$2^3/_8$	$1^{15}/_{32}$

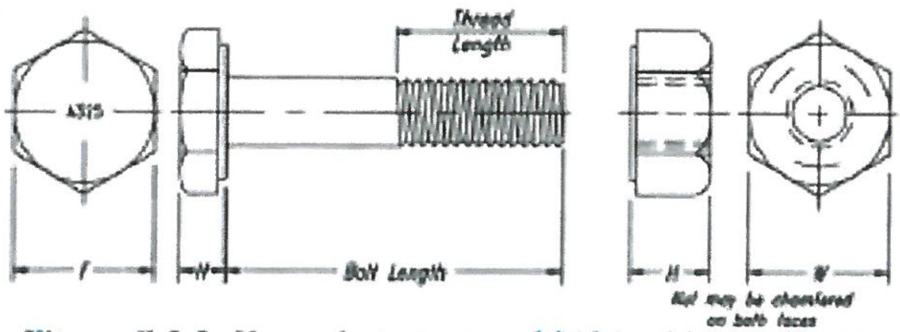
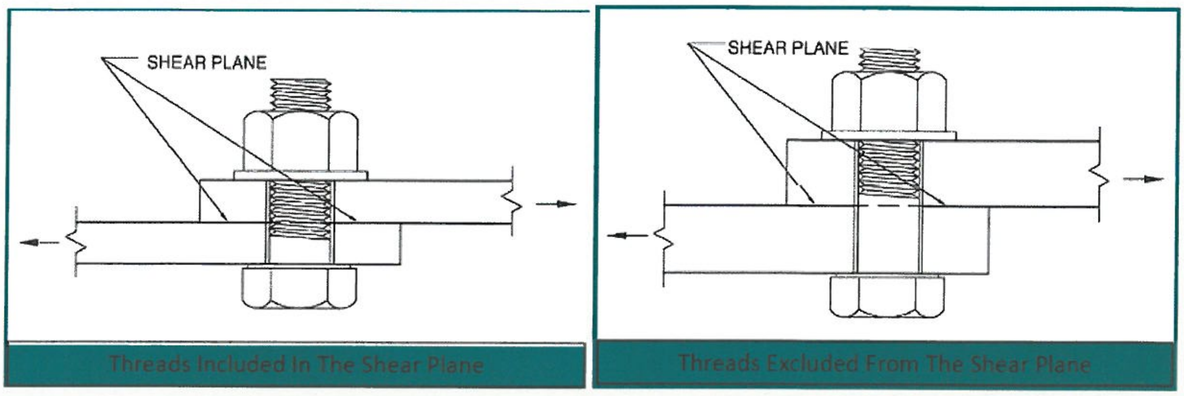


Figure C-2.2. Heavy-hex structural bolt and heavy-hex nut.



Threads included & excluded from shear plane

According to AISC Sec B3.1:

Design of Connections

Connection elements shall be designed in accordance with the provisions of Chapters J and K. The forces and deformations used in design shall be consistent with the intended performance of the connection and the assumptions used in the structural analysis. Self-limiting inelastic deformations of the connections are permitted. At points of support, beams, girders and trusses shall be restrained against rotation about their longitudinal axis unless it can be shown by analysis that the restraint is not required.

User Note: Section 3.1.2 of the Code of Standard Practice addresses communication of necessary information for the design of connections.

Simple Connections

A simple connection transmits a negligible moment. In the analysis of the structure, simple connections may be assumed to allow unrestrained relative rotation between the framing elements being connected. A simple connection shall have sufficient rotation capacity to accommodate the required rotation determined by the analysis of the structure.

Moment Connections

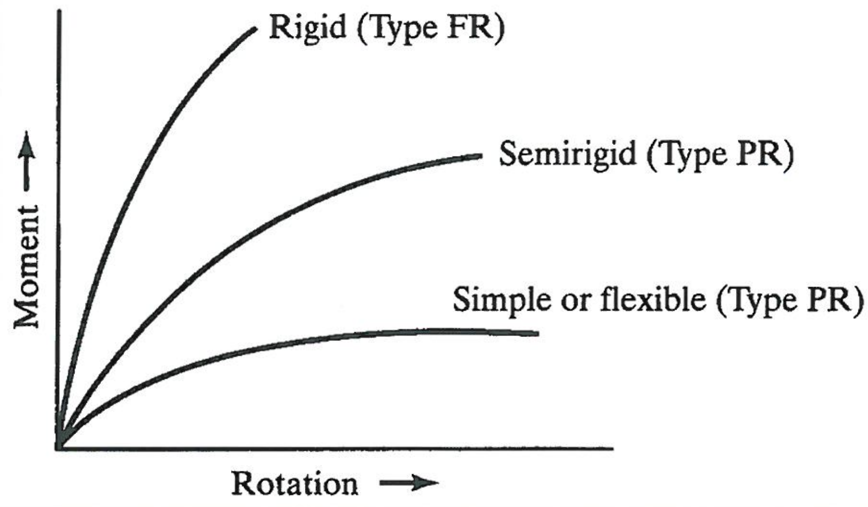
Two types of moment connections, fully restrained and partially restrained, are permitted, as specified below.

(a) Fully Restrained (FR) Moment Connections

A fully restrained (FR) moment connection transfers moment with a negligible rotation between the connected members. In the analysis of the structure, the connection may be assumed to allow no relative rotation. An FR connection shall have sufficient strength and stiffness to maintain the angle between the connected members at the strength limit states.

(b) Partially Restrained (PR) Moment Connections

Partially restrained (PR) moment connections transfer moments, but the rotation between connected members is not negligible. In the analysis of the structure, the force-deformation response characteristics of the connection shall be included. The response characteristics of a PR connection shall be documented in the technical literature or established by analytical or experimental means. The component elements of a PR connection shall have sufficient strength, stiffness and deformation capacity at the strength limit states.

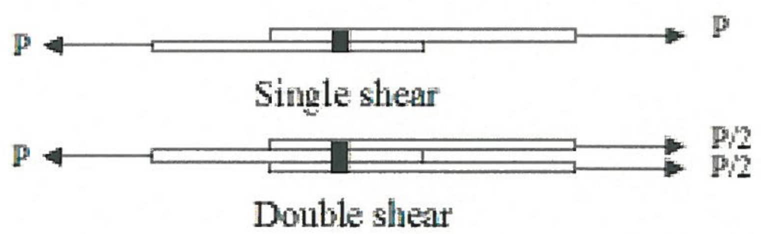


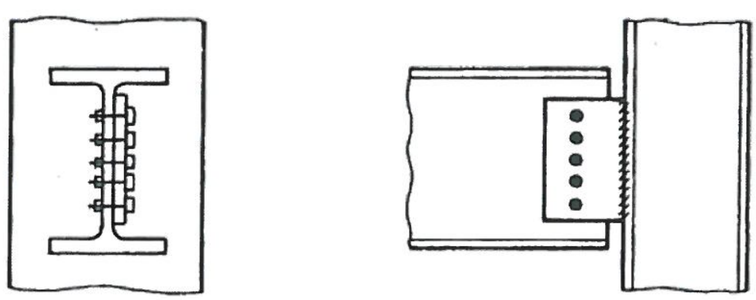
Typical moment – rotation curves for connections

Type of connections:

Simple type connection or shear type connection such as:

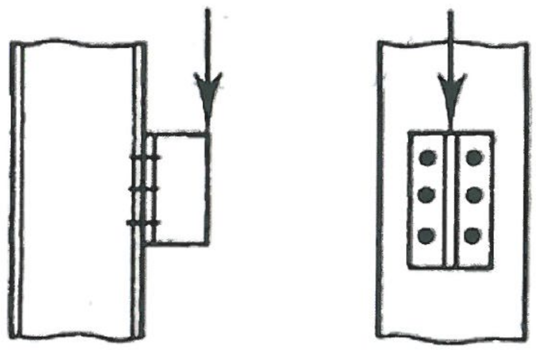
- ✓ Lap connection of single shear plane.
- ✓ Butt connection of double shear planes.
- ✓ Web angles for framed building connection.
- ✓ Tension type connection.



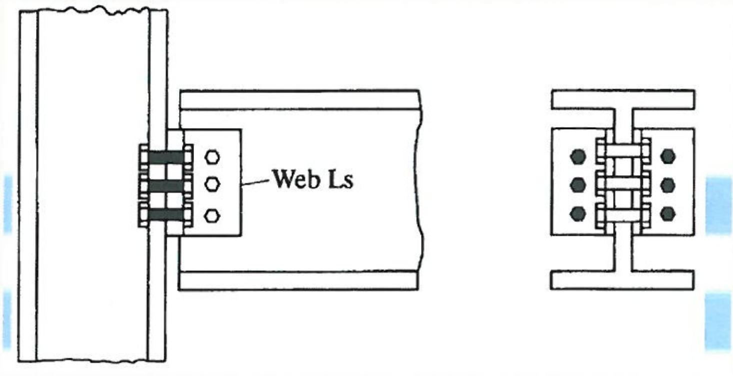


Single or double web angles for beam column connection

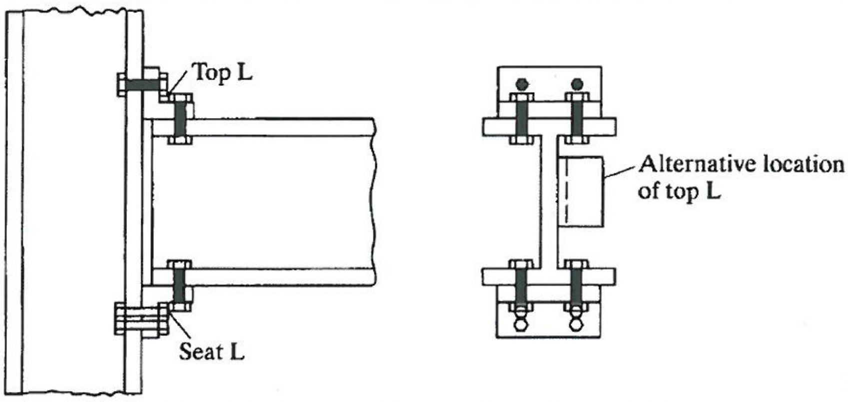
Tension connection (hangar)



Eccentric beam column connection

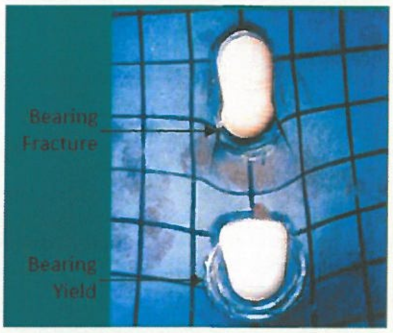


Framed simple connection

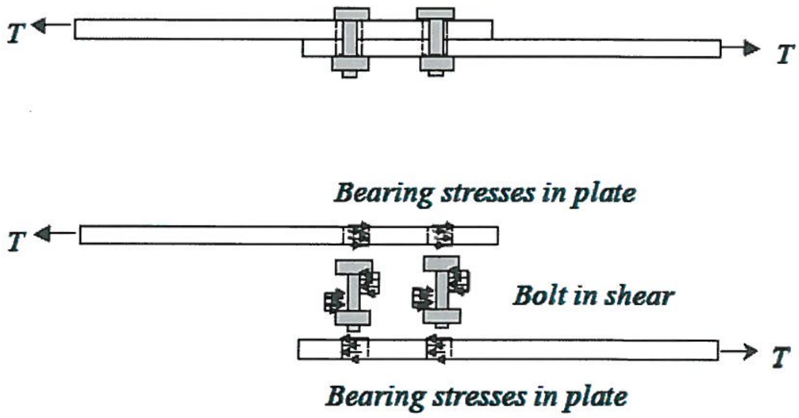


Seated simple type angle connection

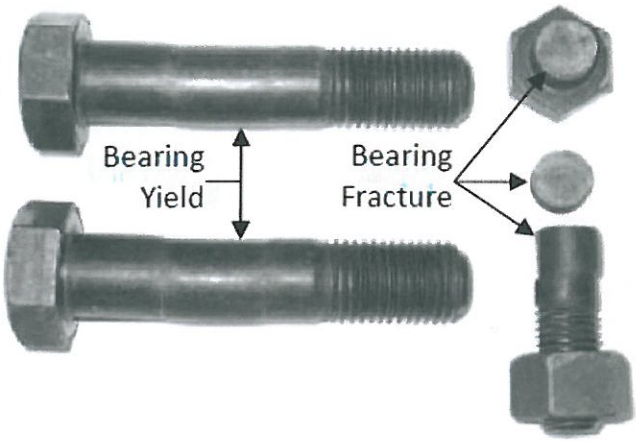
Failure mode: The failure mode may be in element or in connector & this depend on unsuitable design of edge distance or thickness of element or size of connector.



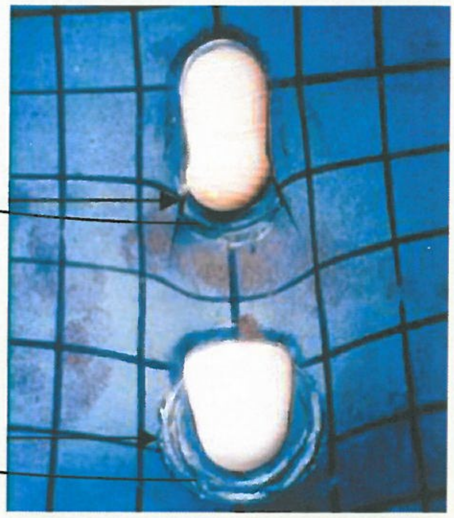
Bearing in plate (fracture or yield)



Tensile failure of bolt



Bearing failure of bolt



Fracture failure in element

Yielding failure in element

DESIGN STRENGTH FOR:

- Bearing type connection.
- Slip critical connection.

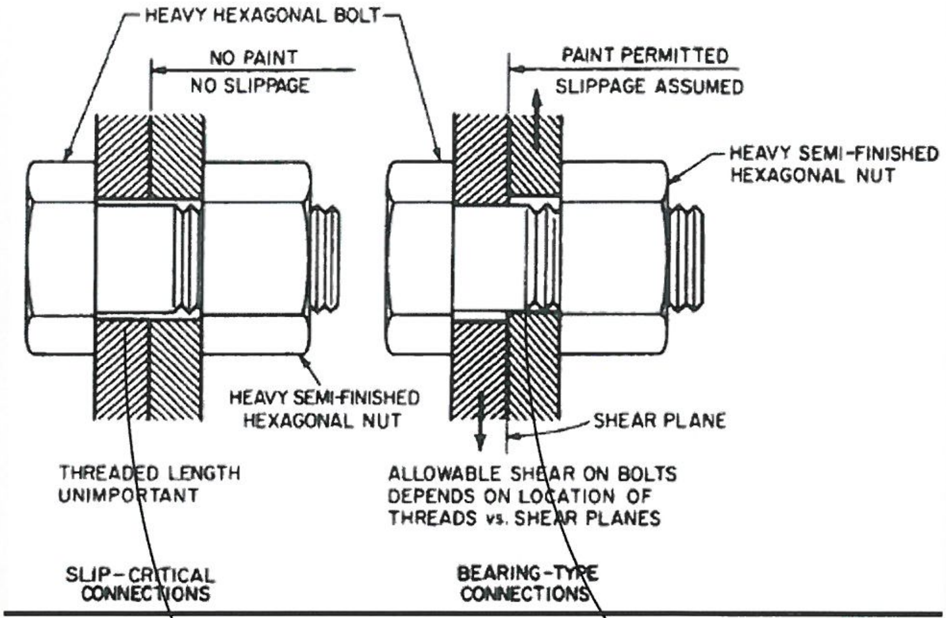


Figure show the both types of connections

See no bearing on shank

See bearing on shank

BEARING TYPE CONNECTIONS:

- Tensile and Shear Strength of Bolts and Threaded Parts:

LRFD	ASD
ØRn	Rn/ Ω

ØRn is the design tensile or shear strength.

Rn/ Ω is the allowable tensile or shear strength, of a snug-tightened or pretension high-strength bolt or threaded part shall be determined according to the limit states of tension rupture and shear rupture as follows:

$R_n = F_n A_b$ ………………………………………………… (J3-1)

LRFD	ASD
Ø = 0.75	Ω = 2.0

Where:

Ab = nominal unthreaded body area of bolt or threaded part, in^2.
Fn = nominal tensile stress, Fnt, or shear stress, Fnv, from Table J3.2, ksi.

Strength of Elements in Tension:
The design strength, ØRn, and the allowable strength, Rn /Ω, of affected and connecting elements loaded in tension shall be the lower value obtained according to the limit states of tensile yielding and tensile rupture.

(a) For tensile yielding of connecting elements:

Rn = Fy Ag .... (J4-1)

LRFD	ASD
Ø = 0.9	Ω = 1.67

(b) For tensile rupture of connecting elements:
Rn = Fu Ae .... (J4-2)

LRFD	ASD
Ø = 0.75	Ω = 2.0

where
Ae = effective net area as defined in Section D3, in^2; for bolted splice plates, Ae = An ≤ 0.85 Ag.

Strength of Elements in Shear:
The available shear strength of affected and connecting elements in shear shall be the lower value obtained according to the limit states of shear yielding and shear rupture:

(a) For shear yielding of the element:

$R_n = 0.60\ F_y\ A_{gv}$ .... (J4-3)

LRFD	ASD
$Ø = 1.0$	$\Omega = 1.5$

Where:

A_{gv} = gross area subject to shear, in^2 (mm^2)

(b) For shear rupture of the element:

$R_n = 0.60\ F_u\ A_{nv}$ .... (J4-4)

LRFD	ASD
$Ø = 0.75$	$\Omega = 2.0$

Where:

A_{nv} = net area subject to shear, in^2

- Strength of Elements in Compression:

The available strength of connecting elements in compression for the limit states of yielding and buckling shall be determined as follows:

(a) When $KL/r \leq 25$

$P_n = F_y\ A_g$ .... (J4-6)

LRFD	ASD
$Ø= 0.90$	$\Omega = 1.67$

(b) When $kL/r > 25$ chapter E should be applied.

- Bearing strength on bolt hole wall:

The available bearing strength, $\emptyset R_n$ and R_n/Ω, at bolt holes shall be determined for the limit state of bearing as follows:

LRFD	ASD
$\emptyset = 0.75$	$\Omega = 2.0$

The nominal bearing strength of the connected material, Rn, is determined as follows:

(a) For a bolt in a *connection* with standard, oversized and short-slotted holes, independent of the direction of loading, or a long-slotted hole with the slot parallel to the direction of the bearing *force,*

(i) When deformation at the bolt hole at *service load* is a design consideration;

$$R_n = 1.2\, l_c\, t\, F_u \leq 2.4\, d\, t\, F_u \quad \text{................} \quad (J3\text{-}6a)$$

(ii) When deformation at the bolt hole at service load is not a design consideration;

$$R_n = 1.5\, l_c\, t\, F_u \leq 3.0\, d\, t\, F_u \quad \text{..................} \quad (J3\text{-}6b)$$

(b) For a bolt in a connection with long-slotted holes with the slot perpendicular to the direction of force;

$$R_n = 1.0\, l_c\, t\, F_u \leq 2.0\, d\, t\, F_u \quad \text{................} \quad (J3\text{-}6c)$$

Where:

Fu = *specified minimum tensile strength* of the connected material, ksi.

d = nominal bolt diameter, in.

lc = clear distance, in the direction of the force, between the edge of the hole and the edge of the adjacent hole or edge of the material, in.

t = thickness of connected material, in.

TABLE J3.1
Minimum Bolt Pretension, kips*

Bolt Size, in.	A325 Bolts	A490 Bolts
$^{1}/_{2}$	12	15
$^{5}/_{8}$	19	24
$^{3}/_{4}$	28	35
$^{7}/_{8}$	39	49
1	51	64
$1^{1}/_{8}$	56	80
$1^{1}/_{4}$	71	102
$1^{3}/_{8}$	85	121
$1^{1}/_{2}$	103	148

* Equal to 0.70 times the minimum *tensile strength* of bolts, rounded off to nearest kip, as specified in ASTM specifications for A325 and A490 bolts with UNC threads.

TABLE J3.2
Nominal Stress of Fasteners and Threaded Parts, ksi (MPa)

Description of Fasteners	Nominal Tensile Stress, F_{nt}, ksi (MPa)	Nominal Shear Stress in Bearing-Type Connections, F_{nv}, ksi (MPa)
A307 bolts	45 (310) [a][b]	24 (165) [b][c][f]
A325 or A325M bolts, when threads are not excluded from shear planes	90 (620) [e]	48 (330) [f]
A325 or A325M bolts, when threads are excluded from shear planes	90 (620) [e]	60 (414) [f]
A490 or A490M bolts, when threads are not excluded from shear planes	113 (780) [e]	60 (414) [f]
A490 or A490M bolts, when threads are excluded from shear planes	113 (780) [e]	75 (520) [f]
Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes	0.75 F_u [a][d]	0.40 F_u
Threaded parts meeting the requirements of Section A3.4, when threads are excluded from shear planes	0.75 F_u [a][d]	0.50 F_u

[a] Subject to the requirements of Appendix 3.

[b] For A307 bolts the tabulated values shall be reduced by 1 percent for each $^{1}/_{16}$ in. (2 mm) over 5 diameters of length in the grip.

[c] Threads permitted in shear planes.

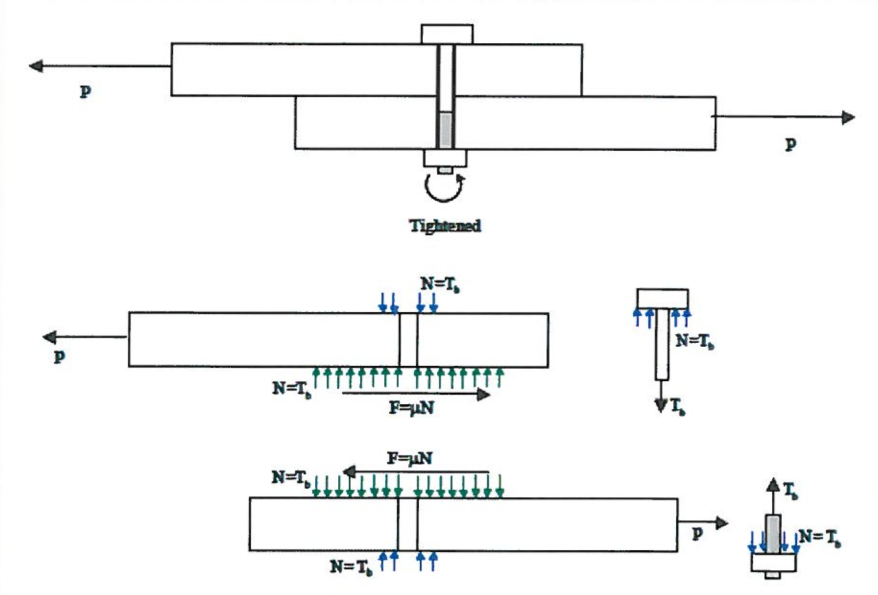
[d] The nominal tensile strength of the threaded portion of an upset rod, based upon the cross-sectional area at its major thread diameter, A_D, which shall be larger than the nominal body area of the rod before upsetting times F_y.

[e] For A325 or A325M and A490 or A490M bolts subject to tensile fatigue loading, see Appendix 3.

[f] 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. (1270 mm), tabulated values shall be reduced by 20 percent.

SLIP-CRITICAL BOLTED CONNECTIONS:

- ✓ High strength (A325 and A490) bolts only can be installed with such a degree of tightness that they are subject to large tensile forces.
- ✓ These large tensile forces in the bolt clamp the connected plates together. The shear force applied to such a tightened connection will be resisted by friction as shown in the Figure below.



- ✓ Thus, slip-critical bolted connections can be designed to resist the applied shear forces using friction. If the applied shear force is less than the friction that develops between the two surfaces, then no slip will occur between them.

- ✓ However, slip will occur when the friction force is less than the applied shear force. After slip occurs, the connection will behave similar to the bearing-type bolted connections designed earlier.

Table J3.1 summarizes the minimum bolt tension that must be applied to develop a slip critical connection.

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections. When slip-critical bolts pass through fillers, all surfaces subject to slip shall be prepared to achieve design slip resistance.

The shear resistance of fully tensioned bolts to slip at factored loads is given by AISC Specification (J3-8).
The available slip resistance for the limit state of slip shall be determined as follows:

$\boxed{Rn = 1.13\ \mu\ Tb\ Ns}$ or

$\boxed{Rn = \mu\ Du\ hf\ Tb\ Ns}$ .... (J3-4)

(a) For connections with standard size (STDH) and short-slotted holes (SSLH) perpendicular to the direction of the load in which prevention of slip is a serviceability limit state:

LRFD	ASD
$Ø = 1.0$	$\Omega = 1.5$

(b) For oversized (OVSH) and (SSLH) short-slotted holes parallel to the direction of the load:

LRFD	ASD
$Ø=0.85$	$\Omega = 1.76$

(c) For long-slotted holes:

LRFD	ASD
$Ø= 0.7$	$\Omega = 2.4$

Where,

(μ) = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

(i) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

$$\boxed{\mu = 0.30}$$

(ii) For Class B surfaces (unpainted blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)

$$\boxed{\mu = 0.50}$$

Du = 1.13, a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension. The use of other values may be approved by the engineer of record.

Tb = minimum fastener tension given in Table J3.1, kips.

hf = factor for fillers, determined as follows:

(i) Where there are no fillers or where bolts have been added to distribute loads in the filler

$$\boxed{hf = 1.0}$$

(ii) Where bolts have not been added to distribute the load in the filler:

(a) For one filler between connected parts

$$\boxed{hf = 1.0}$$

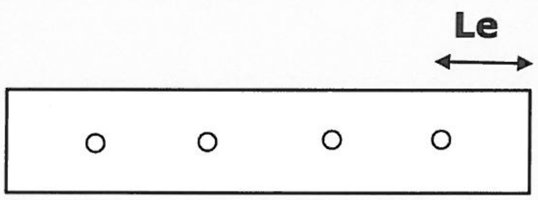
(c) For two or more fillers between connected parts

$$\boxed{hf = 0.85}$$

Ns = number of slip planes required to permit the connection to slip

Minimum edge distance:

The distance from the center of a standard hole to an edge of a connected part in any direction shall not be less than either the applicable value from Table J3.4, or as required in Section J3.10. The distance from the center of an oversized or slotted hole to an edge of a connected part shall be not less than that required for a standard hole to an edge of a connected part plus the applicable increment C2 from Table J3.5.



Maximum edge distance (Le):

Maximum edge distance from edge of element to nearest bolt hole equal to 12 t but not more 6", where (t) is the thickness of the connected part.

TABLE J3.4
Minimum Edge Distance,[a] in., from Center of Standard Hole[b] to Edge of Connected Part

Bolt Diameter (in.)	At Sheared Edges	At Rolled Edges of Plates, Shapes or Bars, or Thermally Cut Edges [c]
$1/2$	$7/8$	$3/4$
$5/8$	$1\,1/8$	$7/8$
$3/4$	$1\,1/4$	1
$7/8$	$1\,1/2$ [d]	$1\,1/8$
1	$1\,3/4$ [d]	$1\,1/4$
$1\,1/8$	2	$1\,1/2$
$1\,1/4$	$2\,1/4$	$1\,5/8$
Over $1\,1/4$	$1\,3/4 \times d$	$1\,1/4 \times d$

[a] Lesser edge distances are permitted to be used provided provisions of Section J3.10, as appropriate, are satisfied.

[b] For oversized or slotted holes, see Table J3.5.

[c] All edge distances in this *column* are permitted to be reduced $1/8$ in. when the hole is at a point where *required strength* does not exceed 25 percent of the maximum strength in the element.

[d] These are permitted to be $1\,1/4$ in. at the ends of *beam connection* angles and shear end plates.

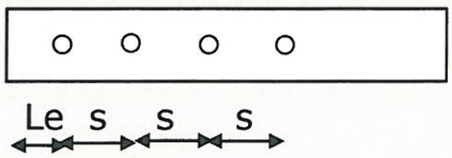
Minimum spacing of connectors:

The distance between centers of standard, oversized or slotted holes shall not be less than 2/3 (d), a distance of 3d is preferred.

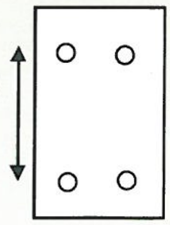
Maximum spacing of connectors:

(a) For painted members or unpainted members not subject to corrosion, s is the minimum of (24t or 12")

(b) For unpainted members of weathering steel subject to atmospheric corrosion, s is the minimum of (14t or 7").



S for contact elements



Type of bolt holes:

STDH: Standard size holes. Used in bearing type connections.
OVSH: Over size holes.
SSLH: Short slotted holes.
LSLH: Long slotted holes.

$\left.\begin{array}{l}\text{OVSH}\\ \text{SSLH}\\ \text{LSLH}\end{array}\right\}$ Used in slip critical connections

TABLE J3.3
Nominal Hole Dimensions, in.

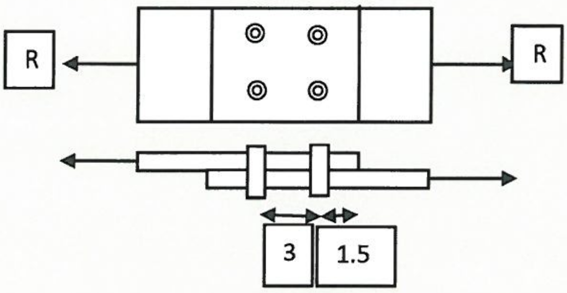
Bolt Diameter	Hole Dimensions			
	Standard (Dia.)	Oversize (Dia.)	Short-Slot (Width × Length)	Long-slot (Width × Length)
1/2	9/16	5/8	9/16 × 11/16	9/16 × 1 1/4
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
3/4	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1 1/8	15/16 × 2 3/16
1	1 1/16	1 1/4	1 1/16 × 1 5/16	1 1/16 × 2 1/2
≥1 1/8	$d + 1/16$	$d + 5/16$	$(d + 1/16) \times (d + 3/8)$	$(d + 1/16) \times (2.5 \times d)$

TABLE J3.5
Values of Edge Distance Increment C_2, in.

Nominal Diameter of Fastener (in.)	Oversized Holes	Slotted Holes		
		Long Axis Perpendicular to Edge		Long Axis Parallel to Edge
		Short Slots	Long Slots[a]	
≤7/8	1/16	1/8	$3/4d$	0
1	1/8	1/8		
≥1 1/8	1/8	3/16		

[a]When length of slot is less than maximum allowable (see Table J3.3), C_2 is permitted to be reduced by one-half the difference between the maximum and actual slot lengths.

EX/ Find design strength (ØRn & Rn/Ω) of the bearing type connection shown below, using A36 steel & A502,1 rivets of Ø3/4" in STD, Le=1.5', s=3" & Fv=25ksi. (t=1/2" & width of plate=10").



1- Sp, Dim & Properties:

Steel	fy	fu	Rivet	Ør	n	Fv	PL size
A36	36	58	A502,1	3/4	4	25	1/2x10

2- Strength of plate:

For tensile Yielding:

LRFD Øt=0.9	ASD Ωt=1.67
Øt Rn =Ø Fy Ag = 162kips	Rn / Ω = Fy Ag / Ω = 180kips

For tensile Rupture:

LRFD Øt= 0.75	ASD Ωt=2.0
An = Ag – n t (Ø+1/8) = 4.125 in^2 Ae = U An = 1.0 x 4.125 = 4.125 in^2 Øt Rn = Øt Fu Ae =0.75x58x4.125= 179.4kips	An = Ag – n t (Ø+1/8) = 4.125 in^2 Ae = U An = 1.0 x 4.125 = 4.125 in^2 Rn/Ωt = Fu Ae / Ωt =58x4.125/2 = 119kips

3- For single shear plane in Rivets:

LRFD $\emptyset=0.75$	ASD $\Omega=2.0$
$\emptyset$ Rn = $\emptyset$ n Fv Ar = 0.75 x 4 x 25 x 0.44 = 33kips	Rn/Ω = n Fv Ar / Ω = 4 x 0.44 x 25 / 2 = 22kips

4- For bearing with Lc = $1.5 - \frac{\frac{3}{4}-\frac{1}{8}}{2} = 1.06$ in distance from edge of plate to closest hole edge.

Rn = 1.2 Lc n t Fu = 1.2x1.06x4x0.5"x58 = 147.55kips

This should be < 2.4 Ør n t Fu = 2.4x4x0.75x58 = 208.8kips O.K

If not use smallest value as Rn

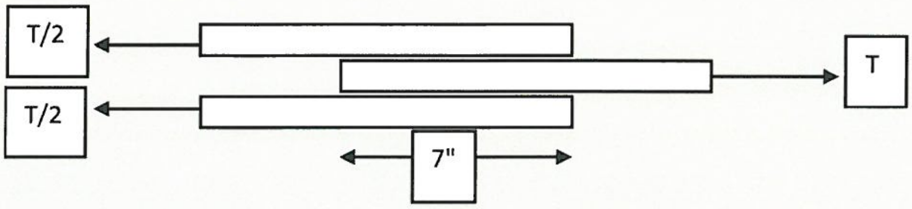
So:

LRFD $\emptyset=0.75$	ASD $\Omega=2.0$
$\emptyset$ Rn =0.75 x 147.55 = 110.7kips	Rn/Ω = 147.55 / 2 = 73.8kips

Therefore the design strength controlled by single shear plane of rivets

$\emptyset$ Rn or $\emptyset$ Vn=33kips & Rn/Ω or Vn/Ω =22kips

EX/ Given A36 steel for a butt joint with 1/2" plate thickness & connection length of 7", assuming edge distance is 2" from both ends, the loads are Tu= 300kips & Ta=200kips. Find number of required bolts using Ø3/4" A325 X bolts in STD (bearing type connection).



1- Spec, Dim. & Properties:

Steel	Fy	Fu	Sec	Bolt	Fv	Tu	Ta	p	Le
A36	36	58	1/2"PL	3/4A325X	60	300	200	5	2

2- Bearing strength of one bolt:

Lc = smaller of [$2-(\frac{\frac{3}{4}+\frac{1}{8}}{2}) = 1.56\ or\ 3-2\ (\frac{\frac{3}{4}+\frac{1}{8}}{2}) = 2.125"$]

So Lc = 1.56" control

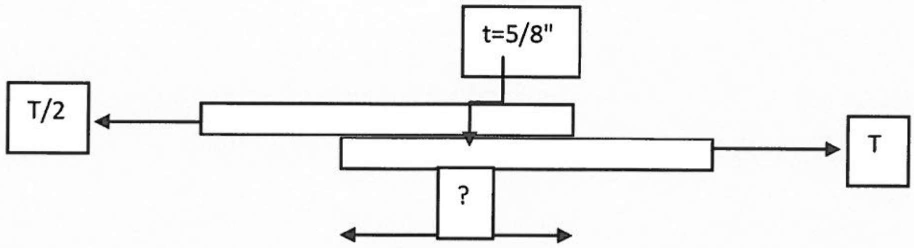
Pn = 1.2 Lc Ø Fu = 81.4kips ≤ 2.4 Ø t Fu =78.3kips but smaller value control.

3- Shearing strength of one bolt:

Vn = 2 shear plane x Ø x Fv = 2 x 3/4 x 60 = 52.8kips which it is the smallest value of bolt strength to be used in finding the bolt number.

LRFD Ø=0.75	ASD Ω=2
ØVn = 0.75 x 52.8 = 39.8kips No. of bolts = Tu / ØVn = 7.58 Say 8 Ø3/4 A325XBolts in STD	Vn/ Ω = 52.8 / 2 = 26.4kips No. of bolts = Ta / (Vn/Ω) = 7.58 Say 8 Ø3/4 A325XBolts in STD

EX/ Given a Lap joint shown below of t=5/8", TL =30kips & TD=50kips, Le =1.75" p=3". Use A572G50 steel. Find number of Ø1"A325SC-BOLTS in STD.



1- Sp. Dim. & Properties:

Steel	Fy	Fu	Sec	Bolt	Fv	Le	μ	Du	hsc
A572G50	50	65	5/8"PL	1"ØA325 SC		1.75"	0.35	1.13	1

2- Loadings:

LRFD	ASD
Tu = 1.2TL + 1.6 TD = 116kips	Ta = TD + TL = 80kips

3- Nominal Strength of one bolt:

Rn = μ Du hsc Tb Ns = 0.35x1.13x1x51x1=20.17kips where Nc=1.0

(a) Slip critical for serviceability state:

LRFD Ø=1.0	ASD Ω=1.5
ØRn = 1 x 20.17 = 20.17kips No. of bolts = Tu / ØRn = 116/20.17= 5.15 Say 6 bolts	Rn/ Ω = 20.17 / 1.5 =13.45kips No. of bolts = Ta / Rn/Ω = 80/13.45=5.95 Say 6 bolts

Check bearing of 6 bolts:

Lc = smaller value of $3-\left(1+\frac{1}{8}\right)=1.875\ or\ 1.75-\left(\frac{1+\frac{1}{8}}{2}\right)$ =1.187", so the control value of Lc is 1.187"

Total Pn = n (Lc t Fu) = 434kips ≤ n (2.4 Ø t Fu) = 585kips O.K

LRFD Ø=0.75	ASD Ω=2.0
ØPn = 0.75 x 434 = 326 >	Pn/Ω = 434/2=217 > 80kips

116kips O.K	O.K

Check shearing on 6 bolts (single shear plan):
Total Vn = n (Fv Ab) = 6 (60 x 0.785)=282.6kips

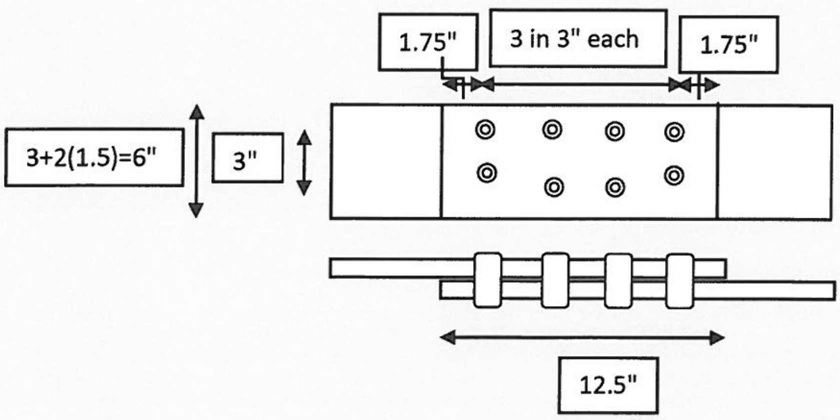
LRFD Ø=0.75	ASD Ω=2.0
ØVn = 0.75 x 282.6 = 212 > 116kips O.K	Vn/Ω = 282.6/2=141.3 > 80kips O.K

Therefore the required controlled strength is Rn=20.17kips (smaller value).

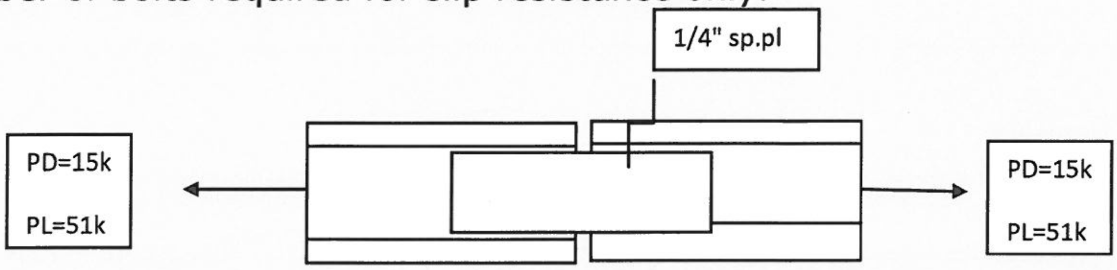
(b) Slip critical design for the required controlled strength:

LRFD Ø=0.85	ASD Ω=1.76
ØRn = 0.85 x 20.17 = 17.14kips No. of bolts = Tu/ ØRn = 6.77 Say 8	Rn/Ω = 20.17/1.76=11.46kips No. of bolts = Ta/ Rn/Ω = 6.98 Say 8

Now sketch the lap joint?



EX/ Given the tensile member shown W12x30 of A36 steel, jointed by a splice plate from both sides of web element. Select the number of ¾-in.-diameter ASTM A325SC (slip-critical) bolts with a Class A faying surface that are required to support the loads shown when the connection plates have short slots transverse to the load and no fillers are provided. Select the number of bolts required for slip resistance only.



1- Specification, Dimensions & Properties:

Steel	Fy	Fu	sec	T	Bolt	μ	Du	hf	Tb	n	
A36	36	58	W12x30	10⅛	Ø3/4"A325 SC	0.3	1.13	1	28	2	

2- Loadings:

LRFD	ASD
Tu = 1.2(17.0 kips) + 1.6(51.0 kips) = 102 kips	Ta = 17.0 kips + 51.0 kips = 68.0 kips

3- Strength:

μ = 0.30 for Class A surface

Du = 1.13

hf = 1.0, factor for fillers, assuming no more than one filler

Tb = 28 kips, from AISC Specification Table J3.1

Ns = 2, number of slip planes

Rn = μ Du hf Tb Ns (AISC. Eq. J3-4)

= 0.30(1.13)(1.0)(28 kips)(2) = 91.0 kips/bolt

LRFD Ø=1.0	ASD Ω=1.5
ØRn = 1.00(19.0 kips/bolt) = 19.0 kips/bolt	$\frac{Rn}{\Omega} = \frac{19}{1.5} = 12.7k/bolt$

4- Number of Bolts:

LRFD	ASD
$n = \frac{Tu}{\emptyset Rn} = \frac{102}{19} = 5.37$ Say 6ØA325 SC Bolts	$\frac{Ta}{Rn/\Omega} = \frac{68}{12.7} = 5.37$ Say 6ØA325 SC Bolts

Now sketch the connection: