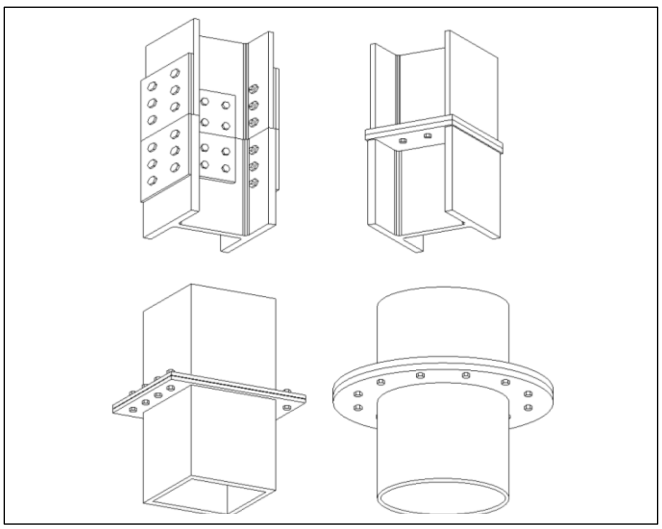
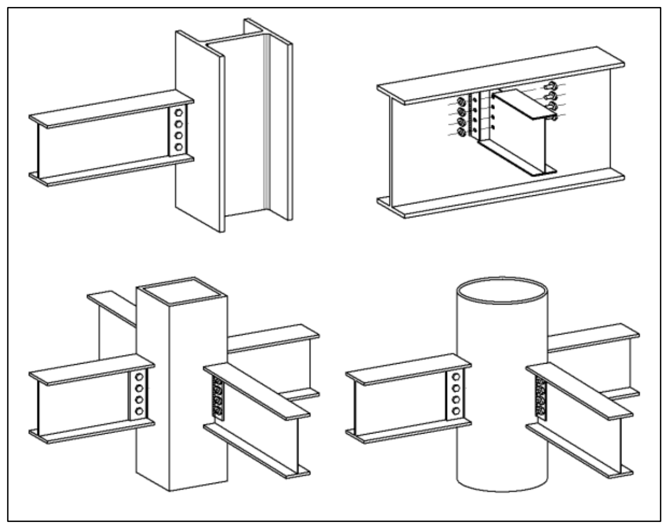
CHAPTER SIX: CONNECTION

6.1 : Introduction

Connections of structural steel members are of critical importance. An inadequate connection, which can be the "weak link" in a structure, has been the cause of numerous failures. Failure of structural members is rare; most structural failures are the result of **poorly designed or detailed connections.**

Modern steel structures are connected by welding or bolting (either high-strength or "common" bolts) or by a combination of both.



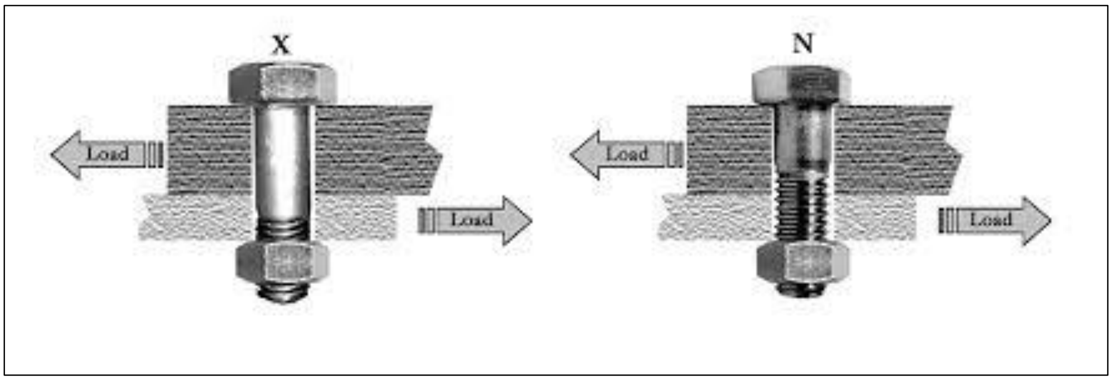


<u>High strength bolts</u>

Group A A325 bolt

Group B A490 bolt

A325-X	Threaded are excluded from shear plane
A325-N	Threaded are not excluded from shear plane
A490-X	Threaded are excluded from shear plane
A490-N	Threaded are not excluded from shear plane



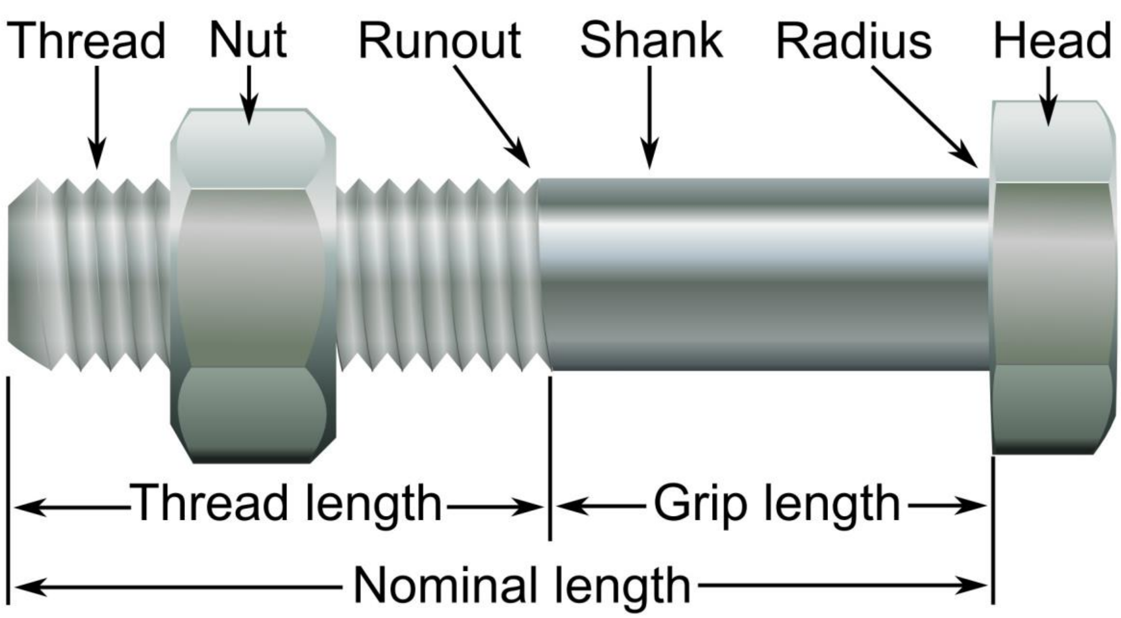


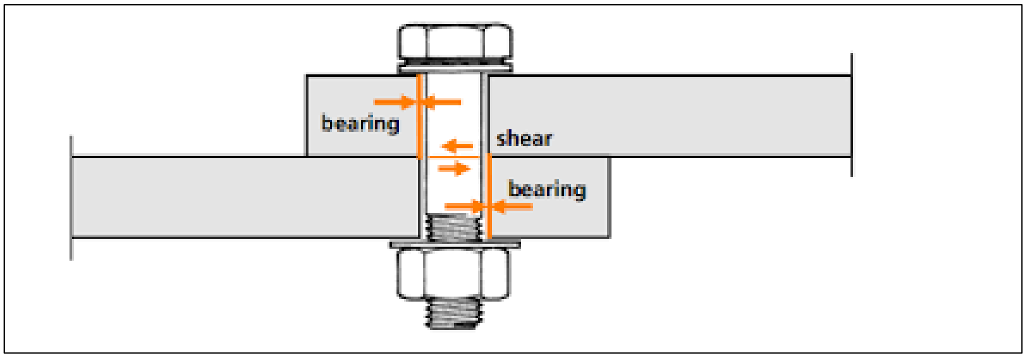
Table 7–2
Available Tensile Strength of Bolts, kips

	Nominal Bolt Diameter d_b, in.			5/8		3/4		7/8		1	
	Nominal Bolt Area, in.^{2}			0.307		0.442		0.601		0.785	
	ASTM Desig.	F_{nt}/Ω (ksi)	ϕF_{nt} (ksi)	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Group A	A325 & F1852	45.0	67.5	13.8	20.7	19.9	29.8	27.1	40.6	35.3	53.0
Group B	A490	56.5	84.8	17.3	26.0	25.0	37.4	34.0	51.0	44.4	66.6
	A307	22.5	33.8	6.90	10.4	9.94	14.9	13.5	20.3	17.7	26.5
	Nominal Bolt Diameter d_b, in.			1 1/8		1 1/4		1 3/8		1 1/2	
	Nominal Bolt Area, in.^{2}			0.994		1.23		1.48		1.77	
	ASTM Desig.	F_{nt}/Ω (ksi)	ϕF_{nt} (ksi)	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Group A	A325 & F1852	45.0	67.5	44.7	67.1	55.2	82.8	66.8	100	79.5	119
Group B	A490	56.5	84.8	56.2	84.2	69.3	104	83.9	126	99.8	150
	A307	22.5	33.8	22.4	33.5	27.6	41.4	33.4	50.1	39.8	59.6

ASD	LRFD
$\Omega_v = 2.00$	$\phi_v = 0.75$

Type of connections

Bearing type connections – slip is permitted under service loads.



Slip- critical connections (Formally known as friction type connections) slip is not permitted under service loads

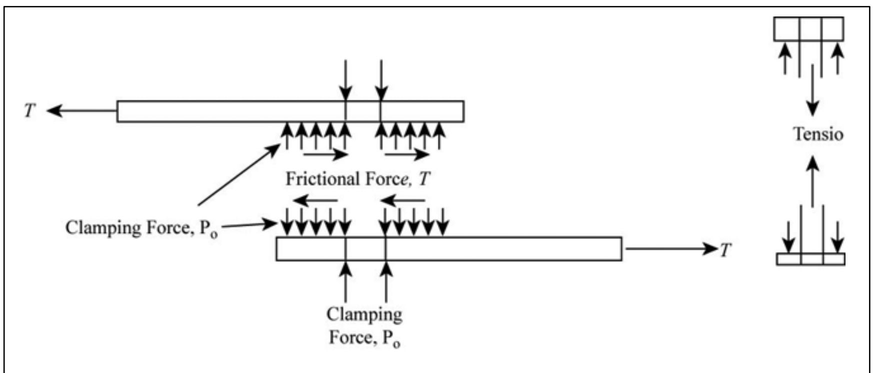
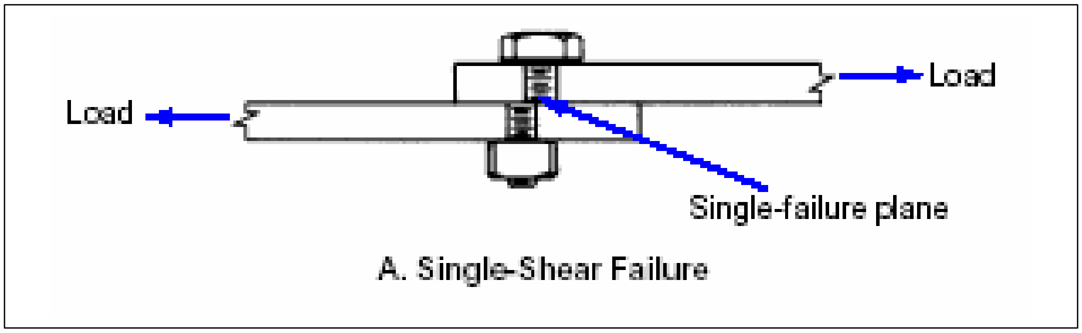


Figure (1)

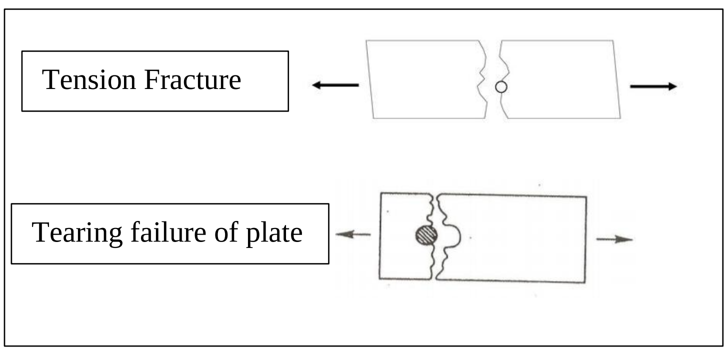
Failure modes

We need to examine the various modes of failure that are possible in connections with fasteners:

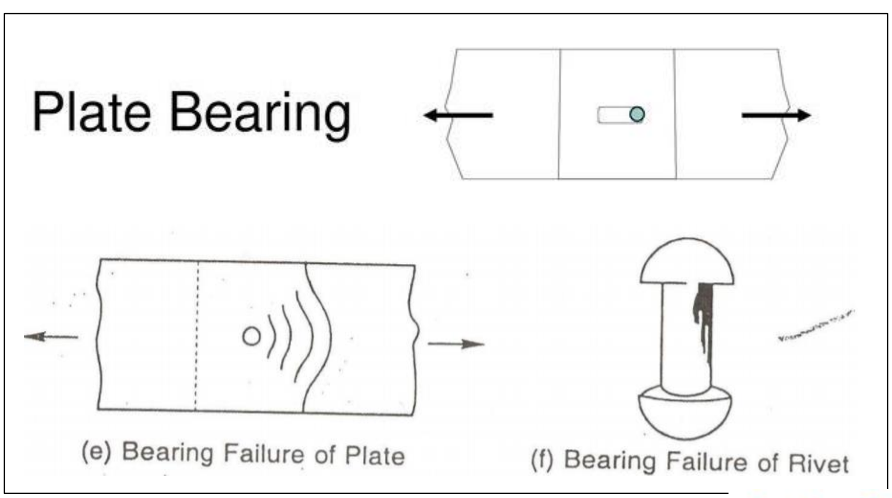
1- Bolt shear failure



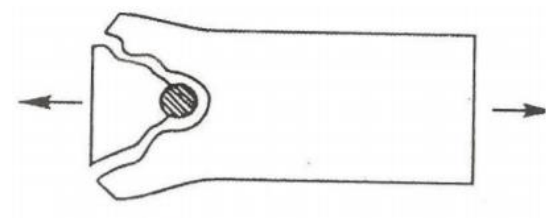
2- Tension fracture of plate



3- Bearing failure of plate (crushing failure)



4- Shear failure of plate

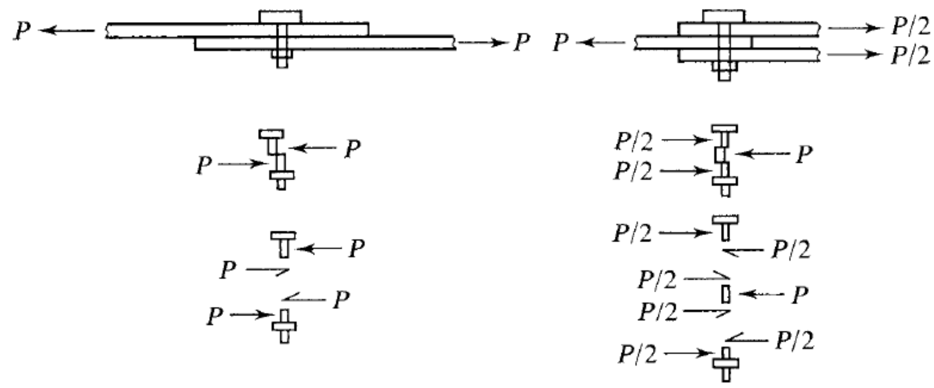


(b) Shear Failure of Plate

7.2 BOLTED SHEAR CONNECTIONS: FAILURE MODES

Consider the lap joint shown in Figure 7.4a. Failure of the fastener can be assumed to occur as shown.

FIGURE 7.4



(a) Single Shear (b) Double Shear

Tables 7–1. Available Shear Strength of Bolts

The available bolt shear strengths of various grades and sizes of bolts are summarized in Table 7–1.

Table 7–1
Available Shear Strength of Bolts, kips

Nominal Bolt Diameter d_b, in.					5/8		3/4		7/8		1	
Nominal Bolt Area, in.^{2}					0.307		0.442		0.601		0.785	
ASTM Desig.	Thread Cond.	F_{nv}/Ω (ksi)	ϕF_{nv} (ksi)	Load-ing	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$
		ASD	LRFD		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
A325 F1852	N	24.0	36.0	S	7.36	11.0	10.6	15.9	14.4	21.6	18.8	28.3
				D	14.7	22.1	21.2	31.8	28.9	43.3	37.7	56.5
	X	30.0	45.0	S	9.20	13.8	13.3	19.9	18.0	27.1	23.6	35.3
				D	18.4	27.6	26.5	39.8	36.1	54.1	47.1	70.7
A490	N	30.0	45.0	S	9.20	13.8	13.3	19.9	18.0	27.1	23.6	35.3
				D	18.4	27.6	26.5	39.8	36.1	54.1	47.1	70.7
	X	37.5	56.3	S	11.5	17.3	16.6	24.9	22.5	33.8	29.5	44.2
				D	23.0	34.5	33.1	49.7	45.1	67.6	58.9	88.4
A307	–	12.0	18.0	S	3.68	5.52	5.30	7.95	7.22	10.8	9.42	14.1
				D	7.36	11.0	10.6	15.9	14.4	21.6	18.8	28.3

Example

shear strength /bolt = $F_{nv} \times A_b$

$\frac{3}{4}'' \phi\ bolt\ A325-N$

From table J3-2 and table 7-1 shear strength /bolt = $F_{nv}xA_b$= 48x0.442=21.261, $\phi r = 0.75 \times 21.216 = 15.9\ kips$

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]
Group A	A325 or A325M bolts, when threads are not excluded from shear planes	90 (620) [e]	48 (330) [f]
Group A	A325 or A325M bolts, when threads are excluded from shear planes	90 (620) [e]	60 (414) [f]
Group B	A490 or A490M bolts, when threads are not excluded from shear planes	113 (780) [e]	60 (414) [f]
Group B	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]	$0.50 F_u$

Nominal Bolt Diameter d_b, in.					5/8		3/4		7/8		1	
Nominal Bolt Area, in.[2]					0.307		0.442		0.601		0.785	
ASTM Desig.	Thread Cond.	F_{nv}/Ω (ksi)	ϕF_{nv} (ksi)	Load-ing	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$	r_n/Ω_v	$\phi_v r_n$
		ASD	LRFD		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
A325 F1852	N	24.0	36.0	S	7.36	11.0	10.6	15.9	14.4	21.6	18.8	28.3
				D	14.7	22.1	21.2	31.8	28.9	43.3	37.7	56.5
	X	30.0	45.0	S	9.20	13.8	13.3	19.9	18.0	27.1	23.6	35.3
				D	18.4	27.6	26.5	39.8	36.1	54.1	47.1	70.7

Table 7-2 Tensile Strength

Design tensile strength /bolt = $\phi R_n = \phi F_{nt} \times A_b$

$\frac{3}{4}'' \phi\ bolt\ A325 - N$

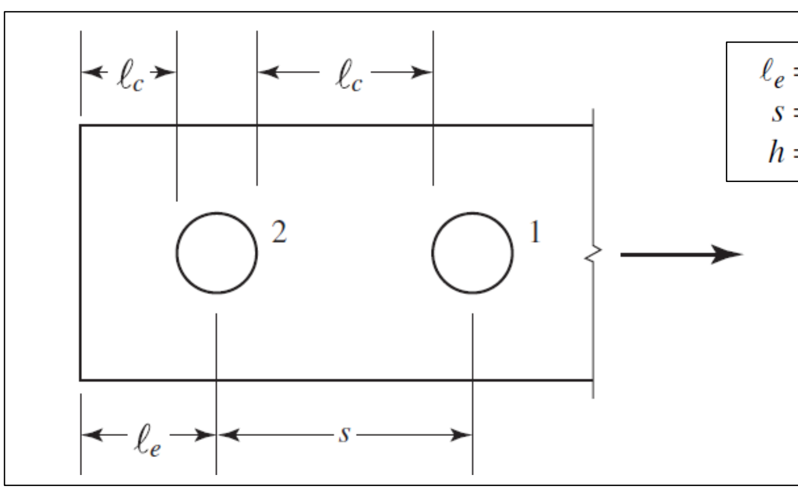
From table J3-2 and table 7-2 shear strength /bolt = $F_{nt} x A_b$= 90x0.442=39.78, $\phi r = 0.75 \times 39.78 = 29.8\ \ kips$

Nominal Bolt Diameter d_b, in.			5/8		3/4		7/8		1	
Nominal Bolt Area, in.^{2}			0.307		0.442		0.601		0.785	
ASTM Desig.	F_{nt}/Ω (ksi)	ϕF_{nt} (ksi)	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n	r_n/Ω	ϕr_n
	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
A325 & F1852	45.0	67.5	13.8	20.7	19.9	29.8	27.1	40.6	35.3	53.0
A490	56.5	84.8	17.3	26.0	25.0	37.4	34.0	51.0	44.4	66.6
A307	22.5	33.8	6.90	10.4	9.94	14.9	13.5	20.3	17.7	26.5

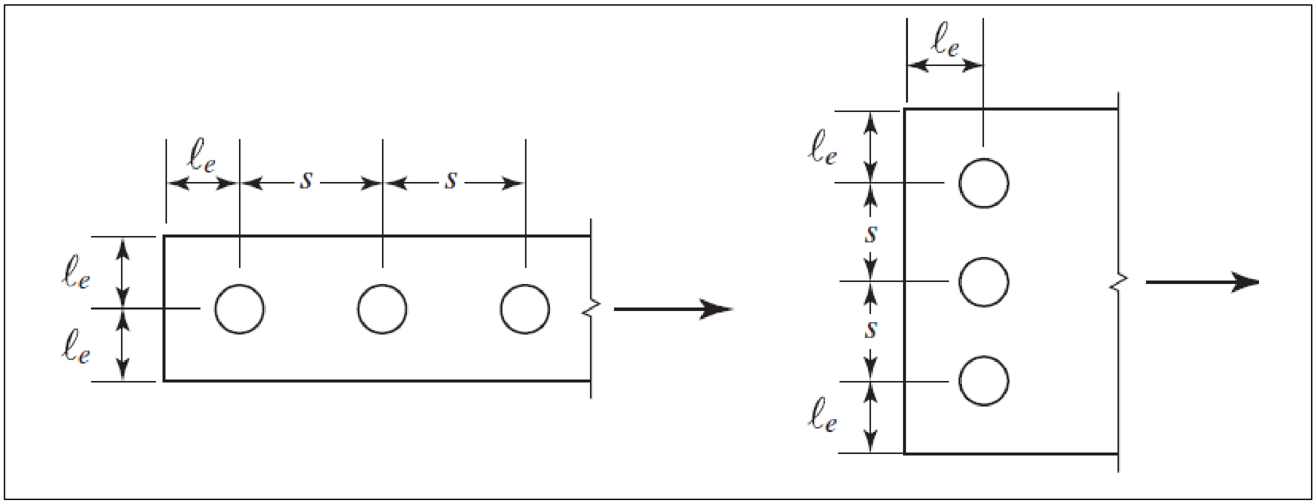
7.3 BEARING STRENGTH, SPACING, AND EDGE-DISTANCE REQUIREMENTS

Bearing strength is independent of the type of fastener because the stress under consideration is on the part being connected rather than on the fastener.

For this reason, bearing strength, as well as spacing and edge-distance requirements, which also are independent of the type of fastener, will be considered before bolt shear and tensile strength.



ℓ_e = edge-distance to center of the hole
s = center-to-center spacing of holes
h = hole diameter



Bolts located closest to the edges

$L_c = L_e - {}^1/_2\, d_{hole}$

$d_{hole} = d_{bolt} + \frac{1}{16}$

$R_n = nominal\ strenght\ for\ bearing = 1.2\, L_c t\, F_u \leq 2.4\, F_u d_t$

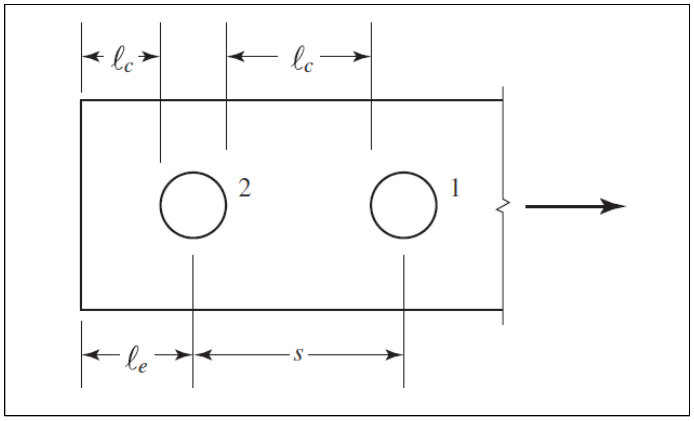
t= thickness of the connected part

F_u= min tensile strength of the connected part

d=bolt diameter

$\phi R_n = design\ strenght$

$\phi = 0.75$



Other Bolts

$L_c = S - d_{hole}$

$d_{hole} = d_{bolt} + \frac{1}{16}$

$R_n = nominal\ strenght\ for\ bearing = 1.2\, L_c t\, F_u \leq 2.4\, F_u d_t$

Summary of Bearing Strength, Spacing, and Edge-Distance Requirements (Standard Holes)

a. Bearing strength:

$$R_n = 1.2\ell_c t F_u \leq 2.4 d t F_u \qquad \text{(AISC Equation J3-6a)}$$

b. Minimum spacing and edge distance: In any direction, both in the line of force and transverse to the line of force,

$s \geq 2\tfrac{2}{3}d$ (preferably $3d$)

$\ell_e \geq$ value from AISC Table J3.4

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