Design of Connections

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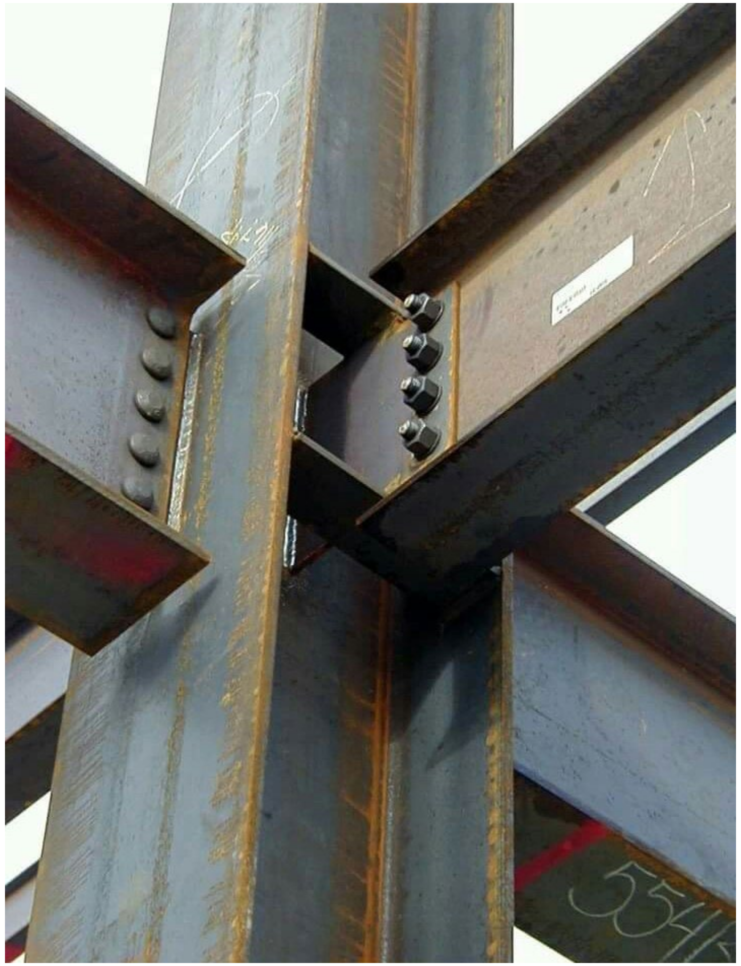
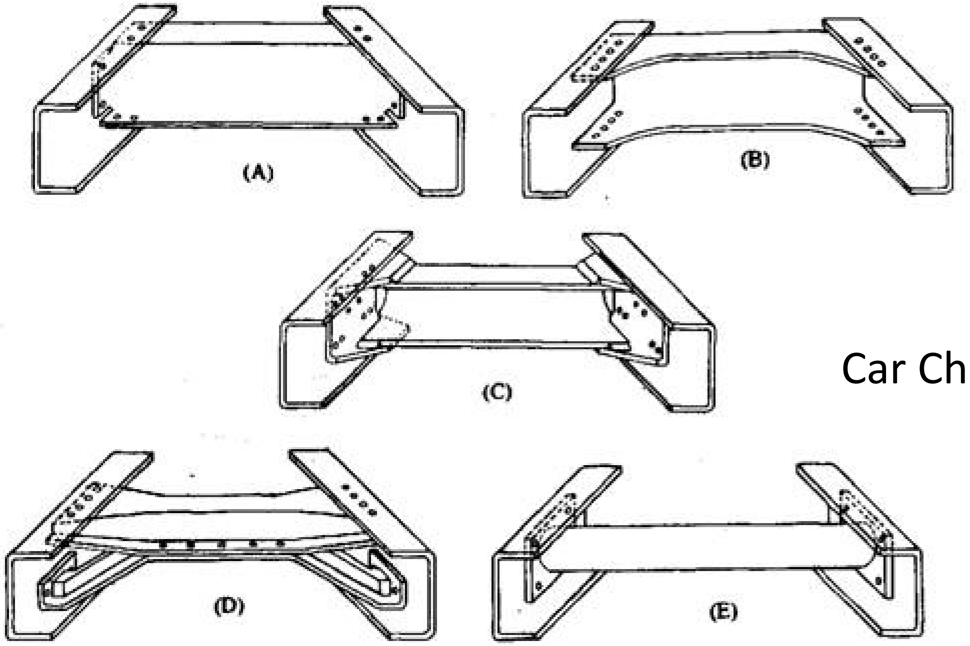
MECH 2333

Industrial Examples



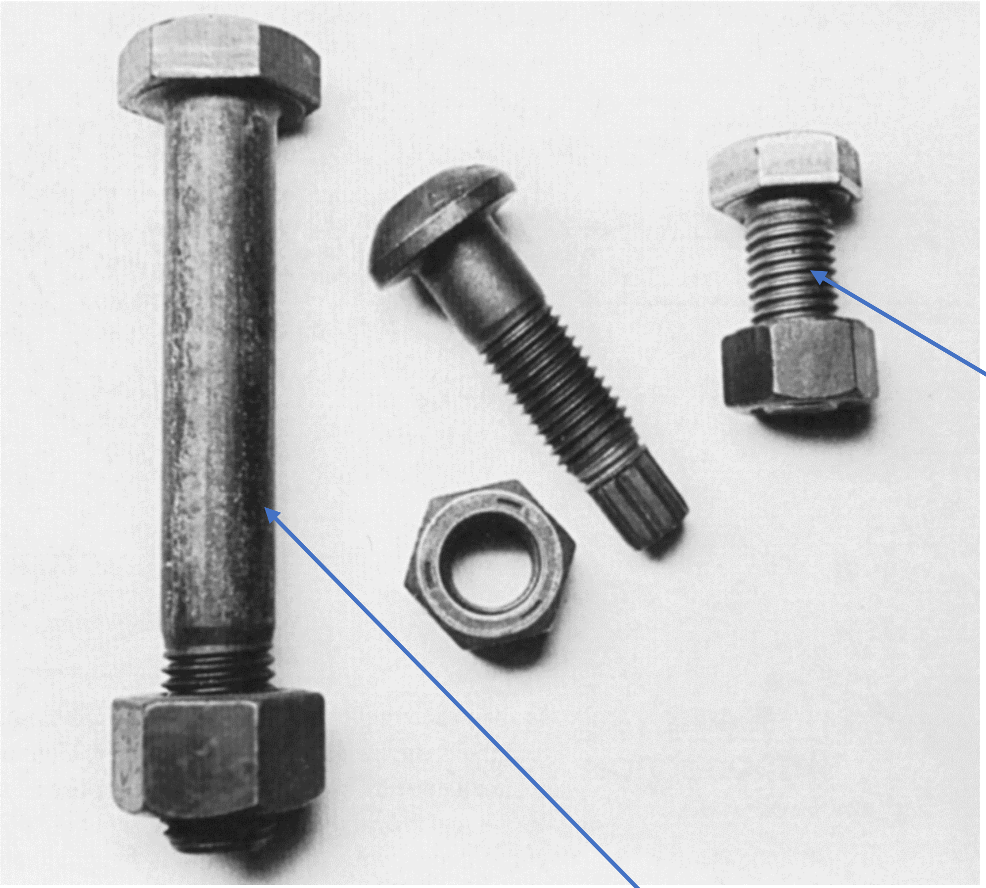
Single lap joint

Bolted Structural connection



Car Chassis Bolted Joint

Structural Bolts



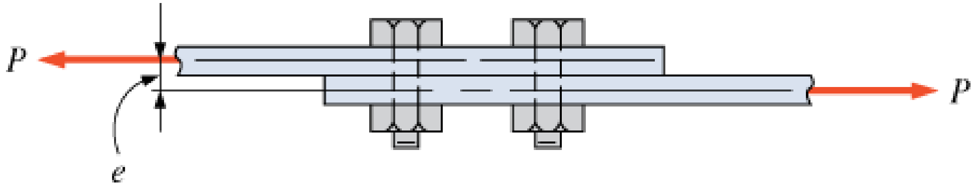
- Bolt and Nut

Threads in the Shear Plane

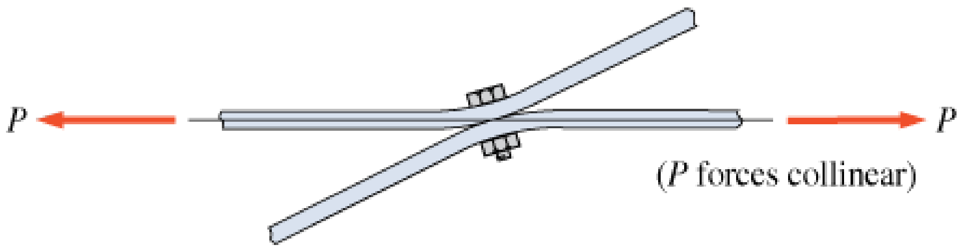
Threads Excluded in the Shear Plane

Types of Joints

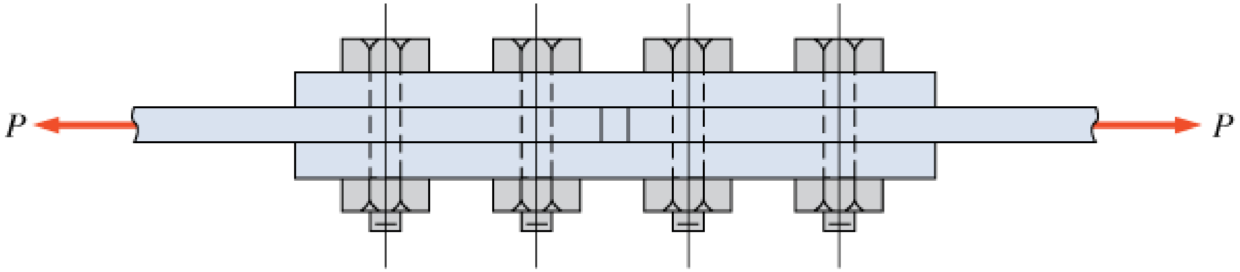
- Lap – Bolts in single shear
- Butt Joint- Bolts in double shear



(a) Lap joint

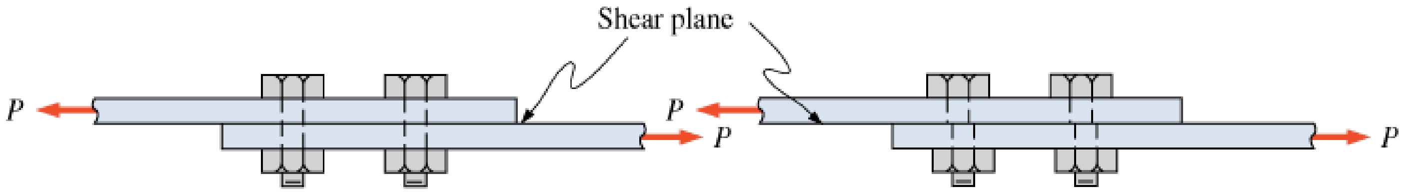


(b) Bending in lap joint

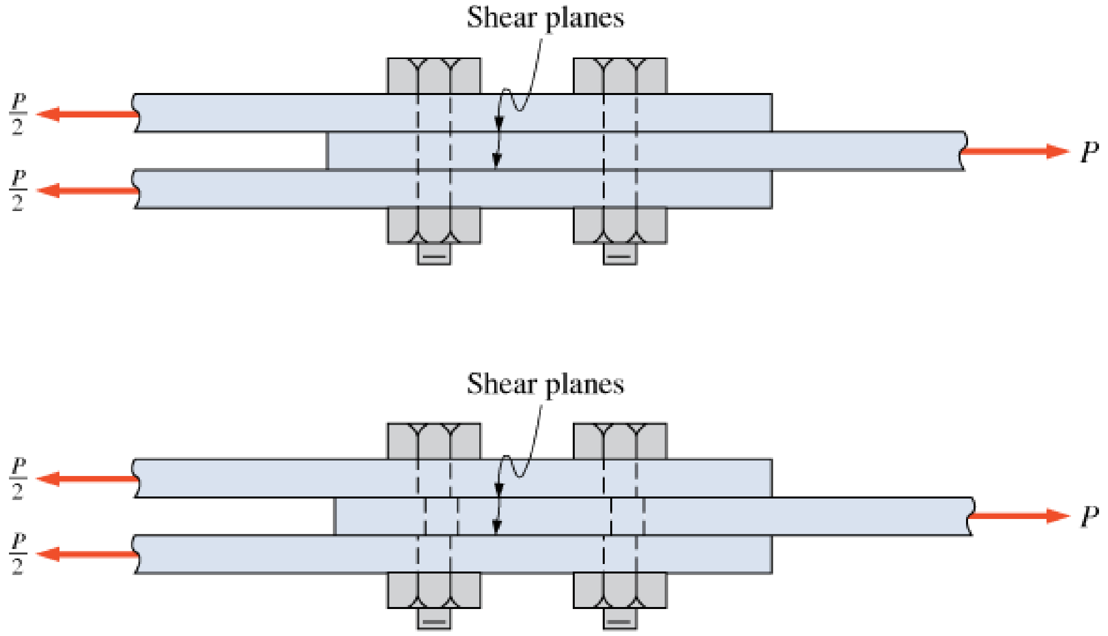


Butt Joint

Shear states

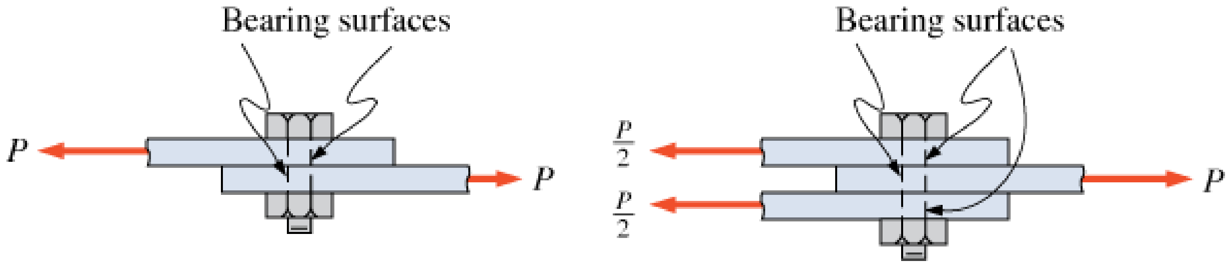


Lap Joint, bolts in single shear



Butt Joint, bolts are in double shear

Bearing Stress

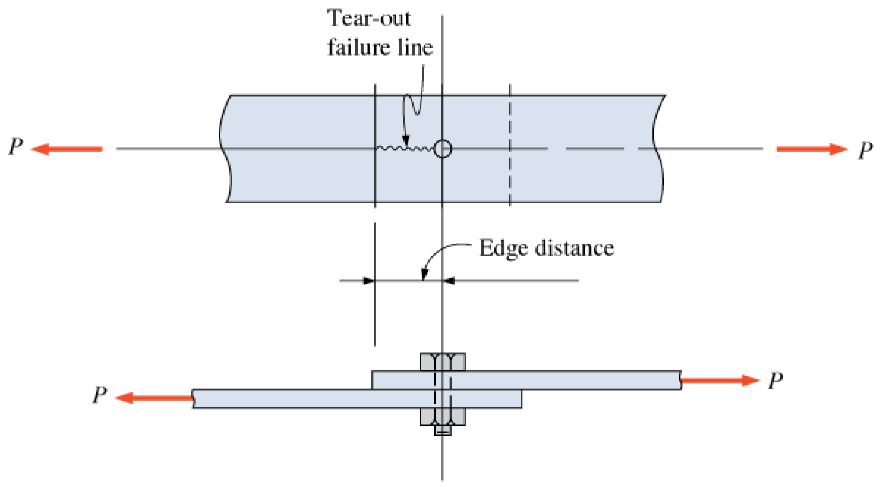


(a) Bearing on plates in single-shear connection

(b) Bearing on plates in double-shear connection

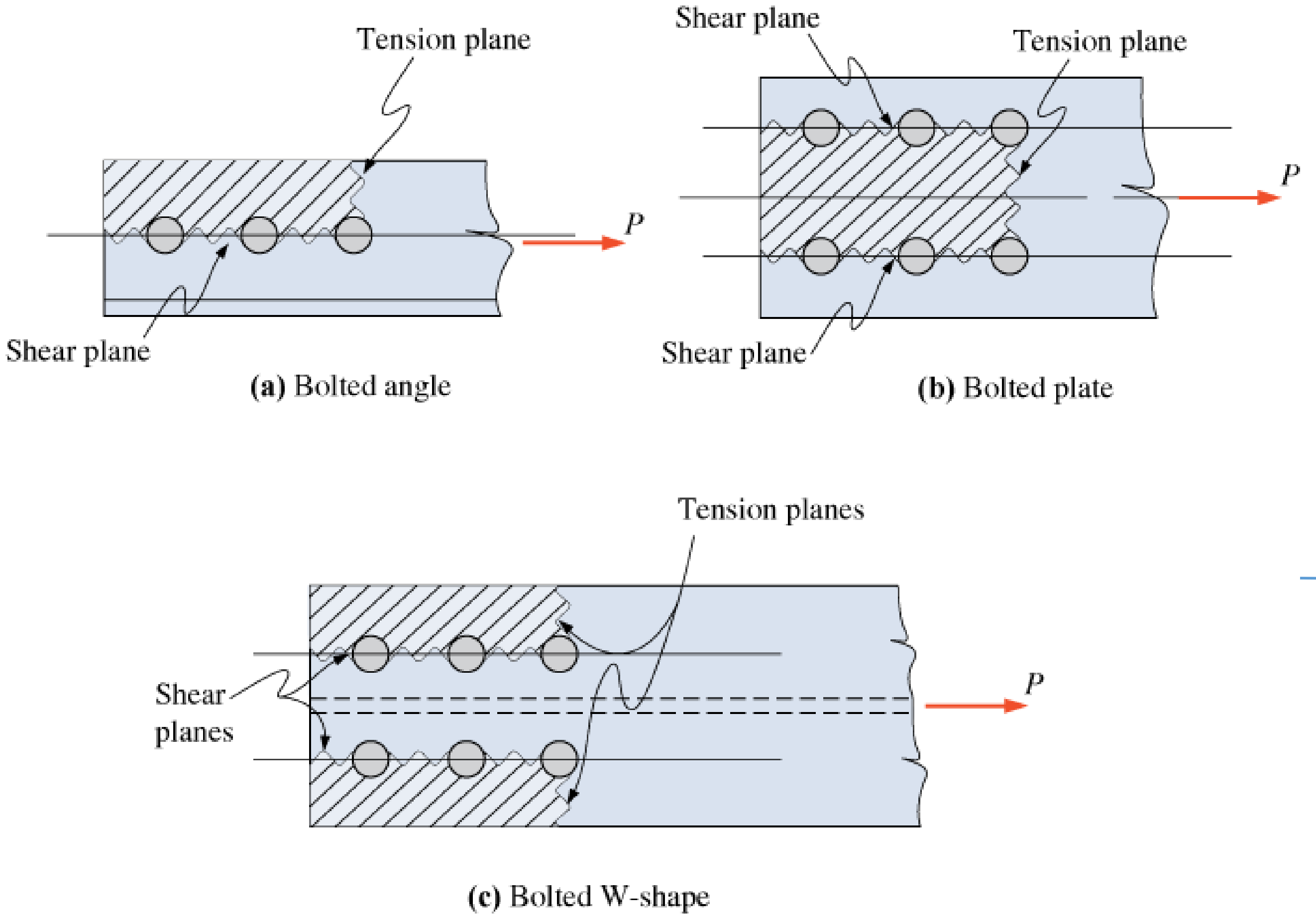
- Bearing Load-
- A measure of How much load a plate can carry
- Plate load capacity

Modes of Failure

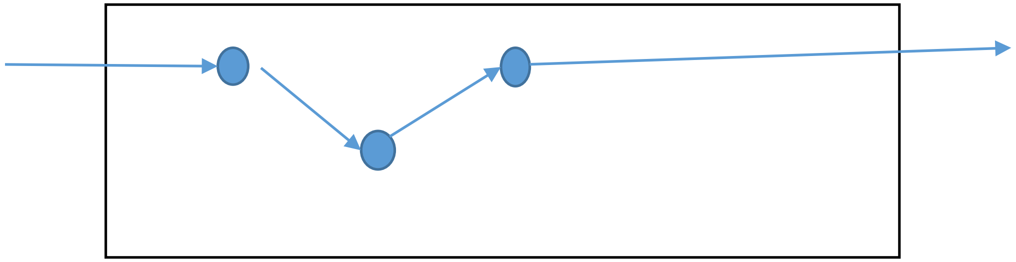


- Depends on the strength of Bolt and Plate
- 1. End Tear Out Failure

Modes of Failure

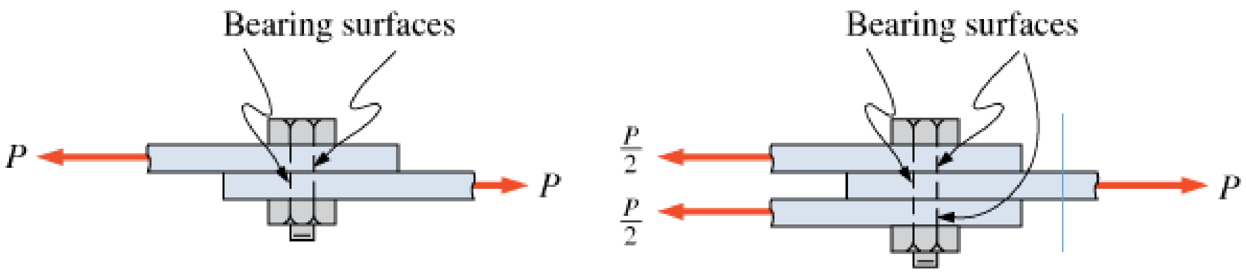


- 2. Block Shear, Combination of shear failure along the plane
  - Can be avoided by changing connection geometry



Zig-Zag Bolt geometry makes it hard to Fail

- 3. Bearing Failure



(a) Bearing on plates in single-shear connection

(b) Bearing on plates in double-shear connection

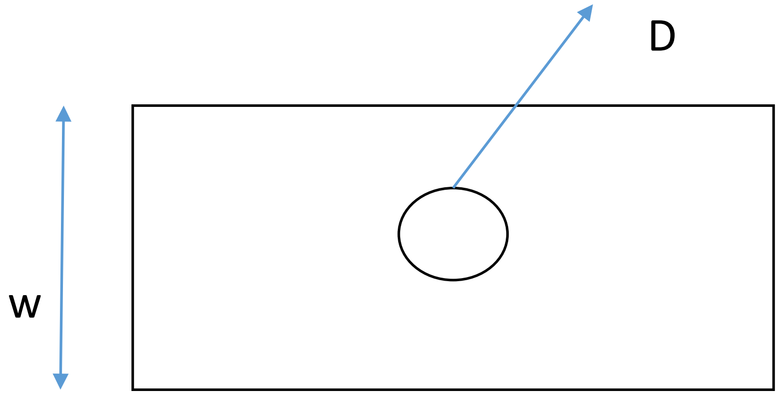


Plate thickness, t, so bearing surface area is D*t

Net area of the plate= Gross area-bolt area

=w*t-D*t

4. Tensile failure on the plate

Tensile load= Tensile strength*Net Area

Strength of Connections

19.4.1 Shear Strength

The shear strength for the connection, based on bolt shear, is the product of the cross-sectional area of the shank, its allowable shear stress, and the number of bolts in the connection. The allowable load is determined from

$$P_s = A_B F_v N \quad (19.1)$$

where P_s = the allowable load for the connection, based on bolt shear (lb, kips) (N)
A_B = the circular cross-sectional area of one bolt (in.^{2}) (mm^2)
F_v = the allowable shear stress in the bolt material (psi, ksi) (MPa)
N = the number of bolts contained in the connection being considered

Shear will be applied to bolt or plate? bolt
Where will bearing failure occur, bolt or plate? plate
Where will tensile failure occur, plate or bolt? plate

Bearing Strength

The bearing strength of a connection is a function of the bearing (crushing) strength of the connected material and the resisting contact area. The true distribution of the bearing stress on the material around the perimeter of a hole is unknown. Satisfactory results, however, have been obtained by assuming a uniform bearing stress acting on the projection of the contact area. This projected area, a rectangular area, is obtained as the product of the nominal diameter of the bolt and the thickness of the connected material. We obtain the strength of the connection, based on bearing on the connected material, as the product of the resisting contact area, an allowable bearing stress, and the number of bolts in the connection:

$$P_p = dtF_pN \quad (19.3)$$

where P_p = the allowable load for the connection, based on bearing on the connected material (lb, kips) (N)
d = the nominal bolt diameter (in.) (mm)
t = the thickness of the connected part (in.) (mm)
F_p = the allowable bearing stress on the connected material (psi, ksi) (MPa)
N = the number of bolts contained in the connection being considered

Allowable Stresses

TABLE 19.1 Allowable shear stress on steel fasteners (Bearing-type connection)

Description of Fastener	Allowable Shear Stress (F_v) [ksi (MPa)]
A307 low-carbon bolts	13.5 (94)
A325 bolts—threads in shear plane	27.0 (186)
A325 bolts—threads excluded from shear plane	34.0 (228.5)
A490 bolts—threads in shear plane	34.0 (228.5)
A490 bolts—threads excluded from shear plane	42.0 (289.5)

Note: U.S. Customary System values are based on the AISC Specification. SI values are converted from U.S. Customary System values.

Bolt is a type of fastener

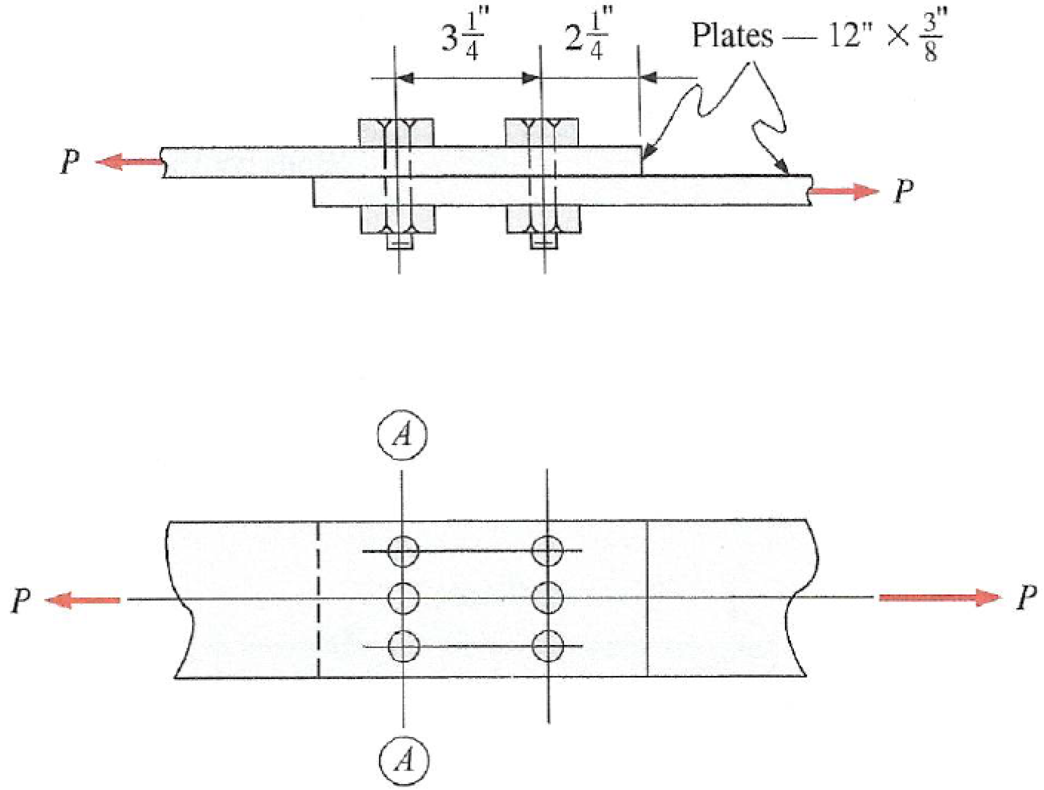
TABLE 19.2 Allowable stresses in ksi (MPa)

		Allowable Bearing Stress		Allowable Tensile Stress	
Structural Steels	F_u	$F_p = (1.5)F_u$	F_y	(Gross) $F_t = (0.60)F_y$	(Net) $F_t = (0.50)F_u$
A36 carbon	58[a] (400)	87[a] (600)	36 (250)	21.6 (150)	29[a] (200)
A992 high-strength low-alloy	65 (448)	97.5 (672)	50 (345)	30 (207)	32.5 (224)

Note: U.S. Customary System values are from the AISC Specification. SI values are converted from U.S. Customary System values.
[a]Minimum values.

Example Problem

Compute the allowable tensile load P for the single-shear lap joint shown in Figure 19.12. The plates are ASTM A36 steel and the high-strength bolts are $\frac{3}{4}$ -in.-diameter A325-X in standard holes.



Solution

- Allowable Shear Stress 34ksi

Allowable load for the connection based on the shear

$$P_s = nA_BF_vN$$

The cross-sectional area of the bolt is calculated from

$$A_B = \pi d^2/4 = 0.7854d^2 = 0.7854(0.75 \text{ in.})^2 = 0.442 \text{ in.}^2$$

Then

$$P_s = nA_BF_vN$$
$$= 1.0(0.442 \text{ in.}^2)(34 \text{ ksi})(6) = 90.1 \text{ k}$$

Use Bolt Sectional Area

Next, check bearing on the $\frac{3}{8}$-in.-thick plate. From Table 19.2, the allowable bearing stress F_p is 87 ksi. The allowable load for the connection, based on bearing on the connected material, is calculated from Equation (19.3):

Bearing Surface Area, d*t

$$P_p = dtF_pN$$
$$= (0.75 \text{ in.})(0.375 \text{ in.})(87 \text{ ksi})(6)$$
$$= 147 \text{ k}$$

Continue

Last, check the tensile capacity of the plates. Using the allowable tensile stresses from Table 19.2, the allowable tensile load, based on gross area, is calculated from Equation (19.4):

$$P_g = A_g F_t = (12\text{ in.})(0.375\text{ in.})(21.6\text{ ksi}) = 97.2\text{ k}$$

and, based on net area, from Eqs. (19.5) and (19.6),

$$A_n = bt - N_F d_H t = (12\text{ in.})(0.375\text{ in.}) - 3(0.875\text{ in.})(0.375\text{ in.}) = 3.52\text{ in.}^2$$

$$P_n = A_n F_t = (3.52\text{ in.}^2)(29\text{ ksi}) = 102\text{ k}$$

Ft= Tensile Strength

Take the lowest, of three, Ans is 90.1 kips.