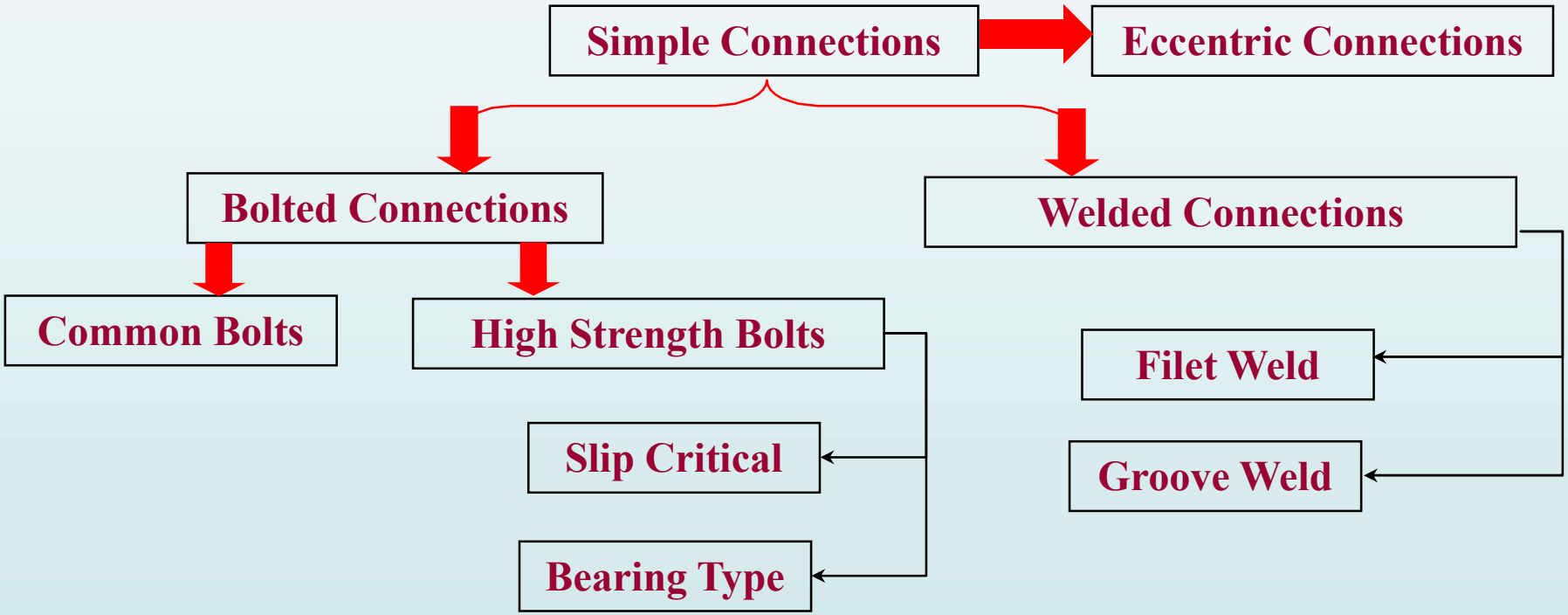
Design of Connections

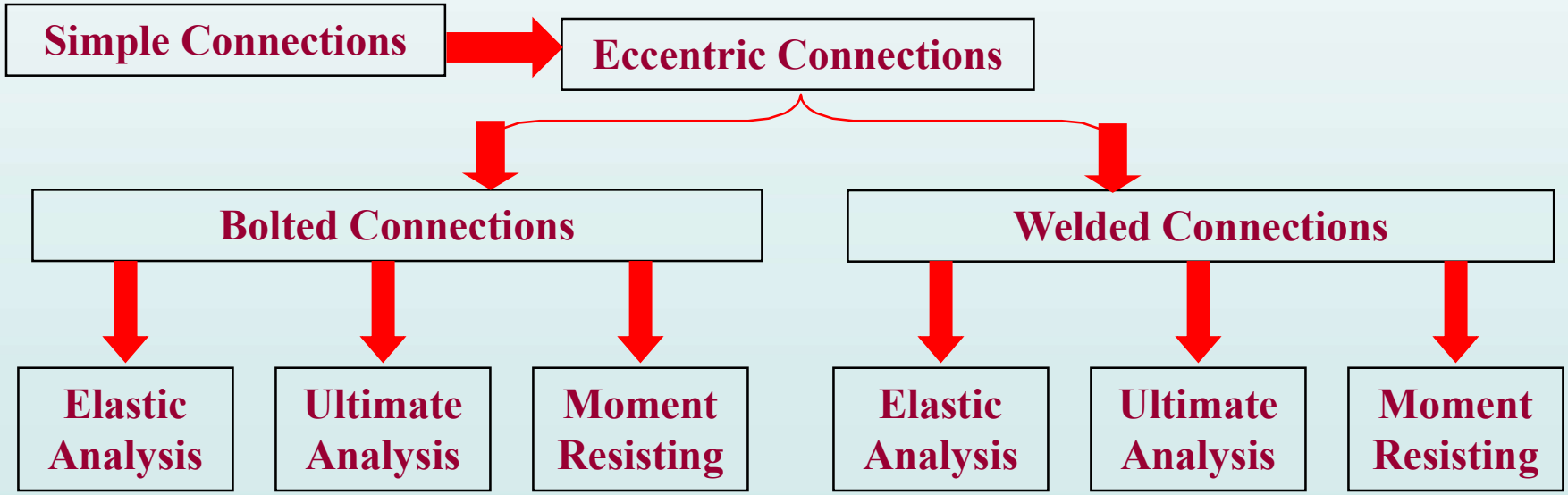
Bolted Connections

- Types of Connections
- Simple Bolted Shear Connections
- Bearing and Slip Critical Connections
- Eccentric Bolted Connections
- Moment Resisting Bolted Connections
- Simple Welded Connections
- Eccentric Welded Connections
- Moment Resisting Welded Connections

Types of Connections



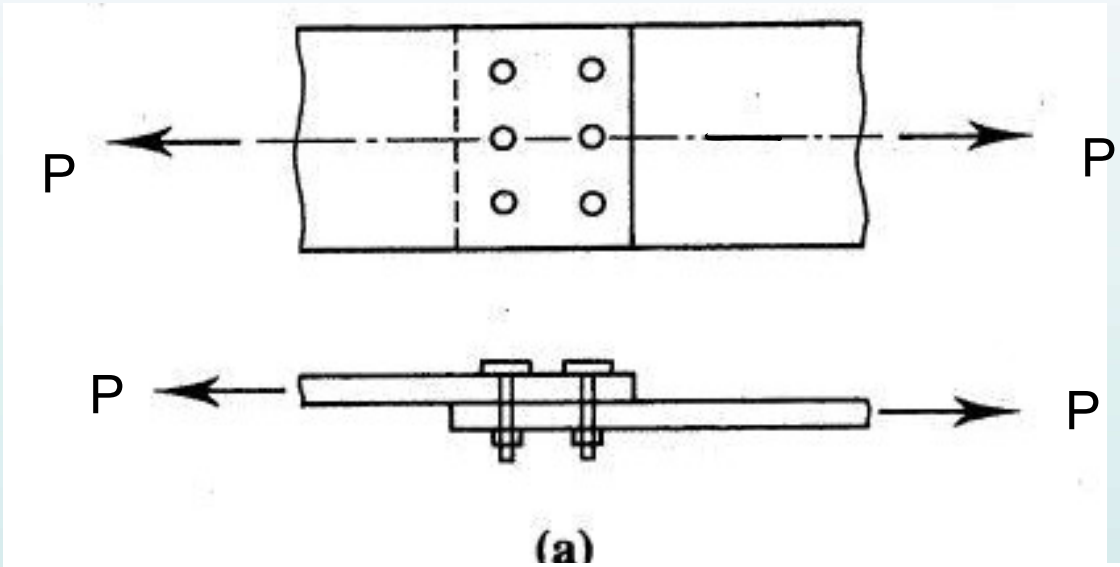
Types of Connections



Simple Bolted Connections

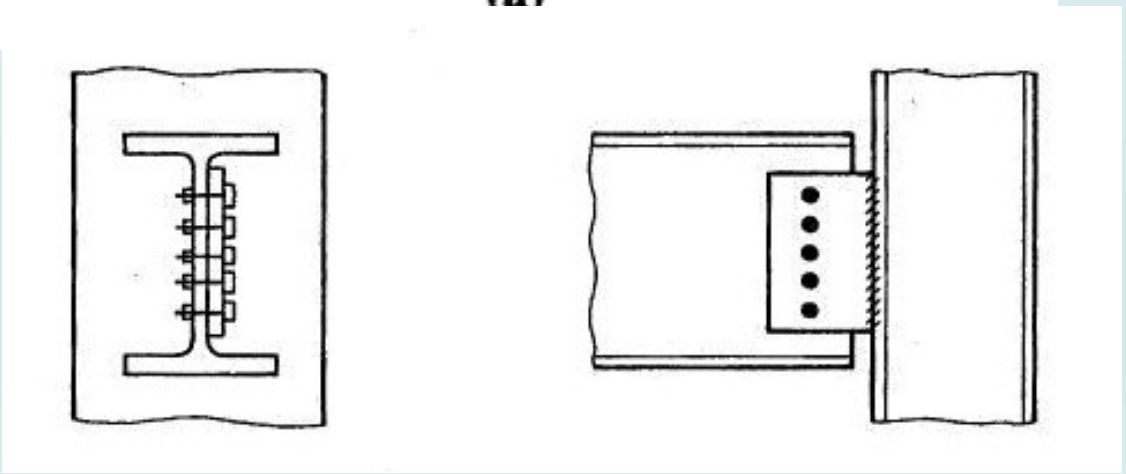
- There are different types of bolted connections. They can be categorized based on the type of loading.
  - Tension member connection and splice. It subjects the bolts to forces that tend to shear the shank.
  - Beam end simple connection. It subjects the bolts to forces that tend to shear the shank.
  - Hanger connection. The hanger connection puts the bolts in tension

Simple Bolted Connections



Tension member

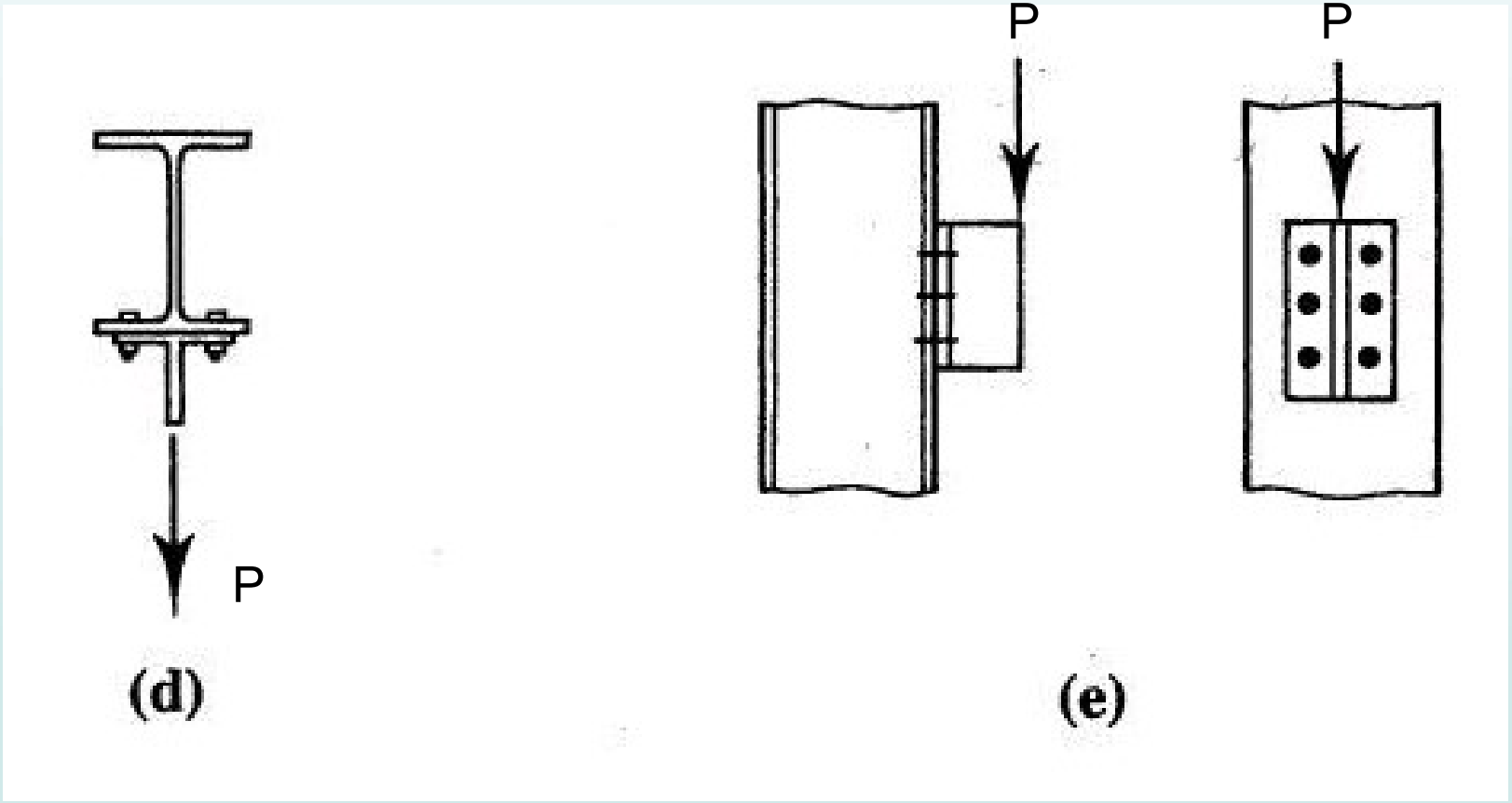
Connection/ splice



Beam end

Simple shear connection

Simple Bolted Connections



Hanger connection
(Tension)

Moment resisting
connection

Simple Bolted Connections

- The bolts are subjected to shear or tension loading.
  - In most bolted connection, the bolts are subjected to shear.
  - Bolts can fail in shear or in tension.
  - You can calculate the shear strength or the tensile strength of a bolt
- Simple connection: If the line of action of the force acting on the connection passes through the center of gravity of the connection, then each bolt can be assumed to resist an equal share of the load.
- The strength of the simple connection will be equal to the sum of the strengths of the individual bolts in the connection.

Bolt Types & Materials

A307 - *Unfinished* (*Ordinary* or *Common*) bolts
low carbon steel A36, F_u = 413 MPa,
for light structures under static load

A325 - *High strength* bolts, heat-treated medium carbon steel, F_u = 827 MPa,
for structural joints

A490 - *High strength* bolts, Quenched and Tempered Alloy steel, F_u = 1033 MPa
for structural joints

A449 - *High strength* bolts with diameter > 1 ½”, anchor bolts, lifting hooks, tie-downs

Common Bolts

- ASTM A307 bolts
- Common bolts are no longer common for current structural design but are still available

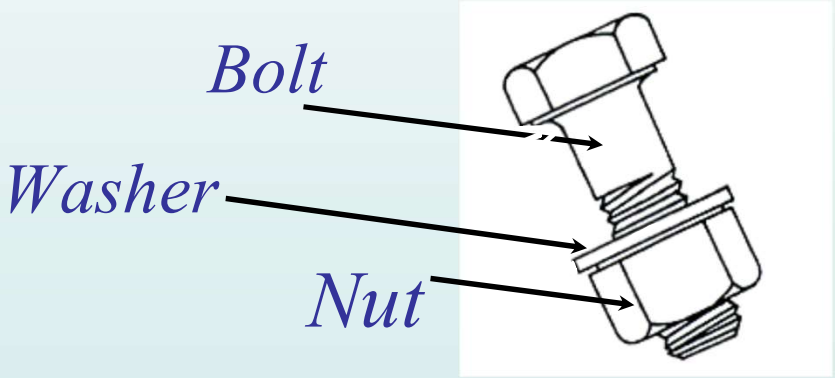
$$P_u \leq \phi R_n \qquad \phi = 0.75$$

$$R_n = f_v A_{bolt}$$

$$f_v = 165\ MPa$$

High Strength Bolts

- High strength bolts (HSB) are available as ASTM A 325 and ASTM A490



Courtesy of Kao Wang Screw Co., Ltd.

Slip Critical

Bearing Type

- **Advantages of HSB over A307 bolts**
  - **Fewer bolts will be used compared to 307 → cheaper connection!**
  - **Smaller workman force required compared to 307**
  - **Higher fatigue strength**
  - **Ease of bolt removal → changing connection**

HSB – Bearing Type Connections

- The shear strength of bolts shall be determined as follows

$$P_u \leq \phi R_n \qquad \phi = 0.75$$

$$R_n = f_v A_{bolt}$$

AISC Table J3.2

The table bellow shows the values of f_v (MPa) for different types of bolts

Type	Type N Thread	Type X Thread
A325	330	413
A490	413	517

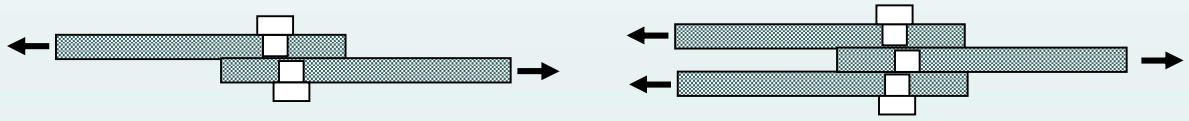
- If the level of threads is not known, it is conservative to assume that the threads are type N.

Bolted Shear Connections

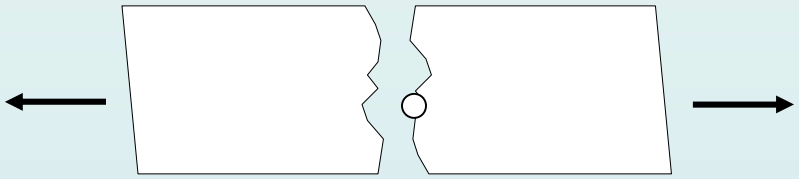
- We want to design the bolted shear connections so that the factored design strength (ϕR_n) is greater than or equal to the factored load. $\phi R_n \geq P_u$
- So, we need to examine the various possible failure modes and calculate the corresponding design strengths.
- Possible failure modes are:
  - Shear failure of the bolts
  - Failure of member being connected due to fracture or yielding or ….
  - Edge tearing or fracture of the connected plate
  - Tearing or fracture of the connected plate between two bolt holes
  - Excessive bearing deformation at the bolt hole

Failure Modes of Bolted Connections

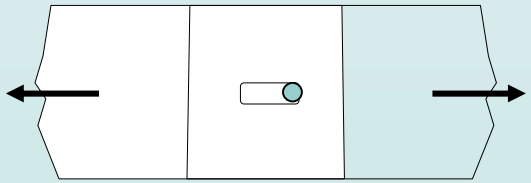
- Bolt Shearing



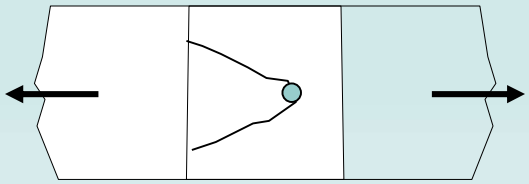
- Tension Fracture



- Plate Bearing

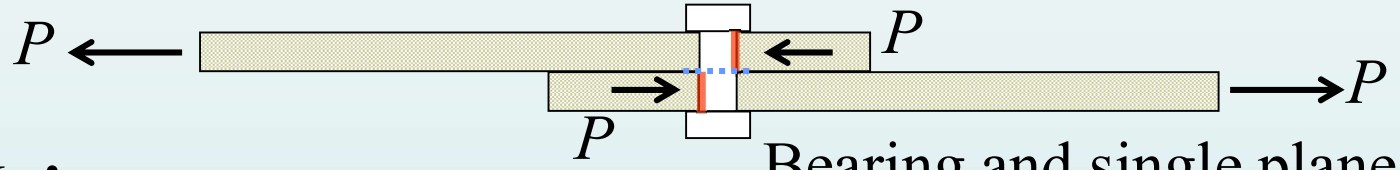


- Block Shear



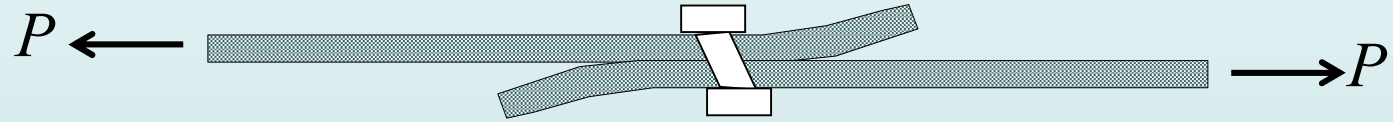
Actions on Bolt

Shear, bearing, bending



Lap Joint

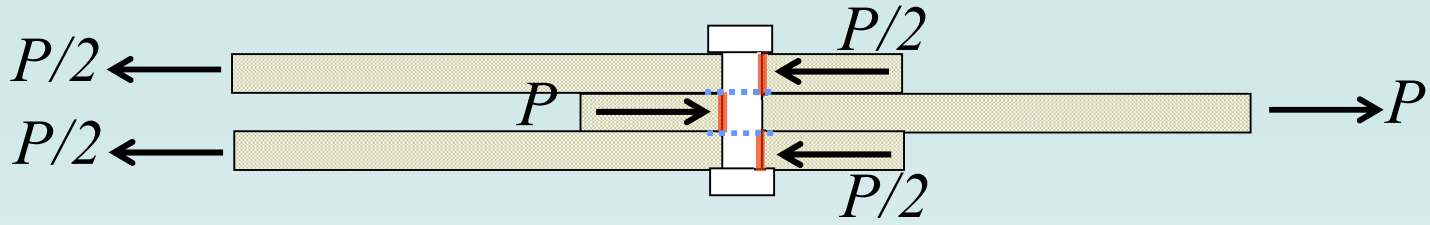
Bearing and single plane Shear



Bending

Butt Joint

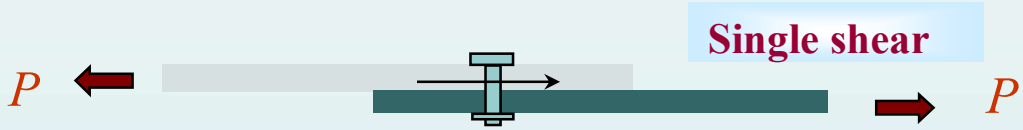
Bearing and double plane Shear



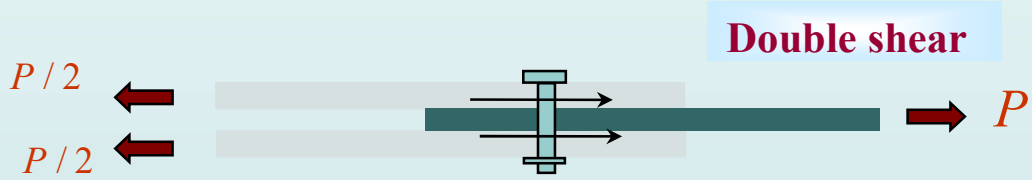
Bolted Shear Connections

- **Possible failure modes**
  - **Failure of bolts: single or double shear**

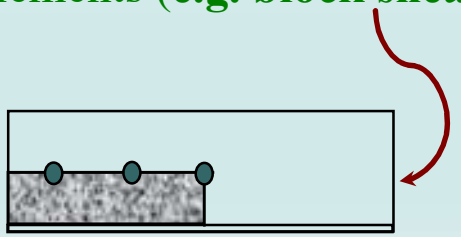
$$P_{Single\ Shear} = f_v\, A_{bolt}$$



$$P_{Double\ Shear} = 2\, f_v\, A_{bolt}$$



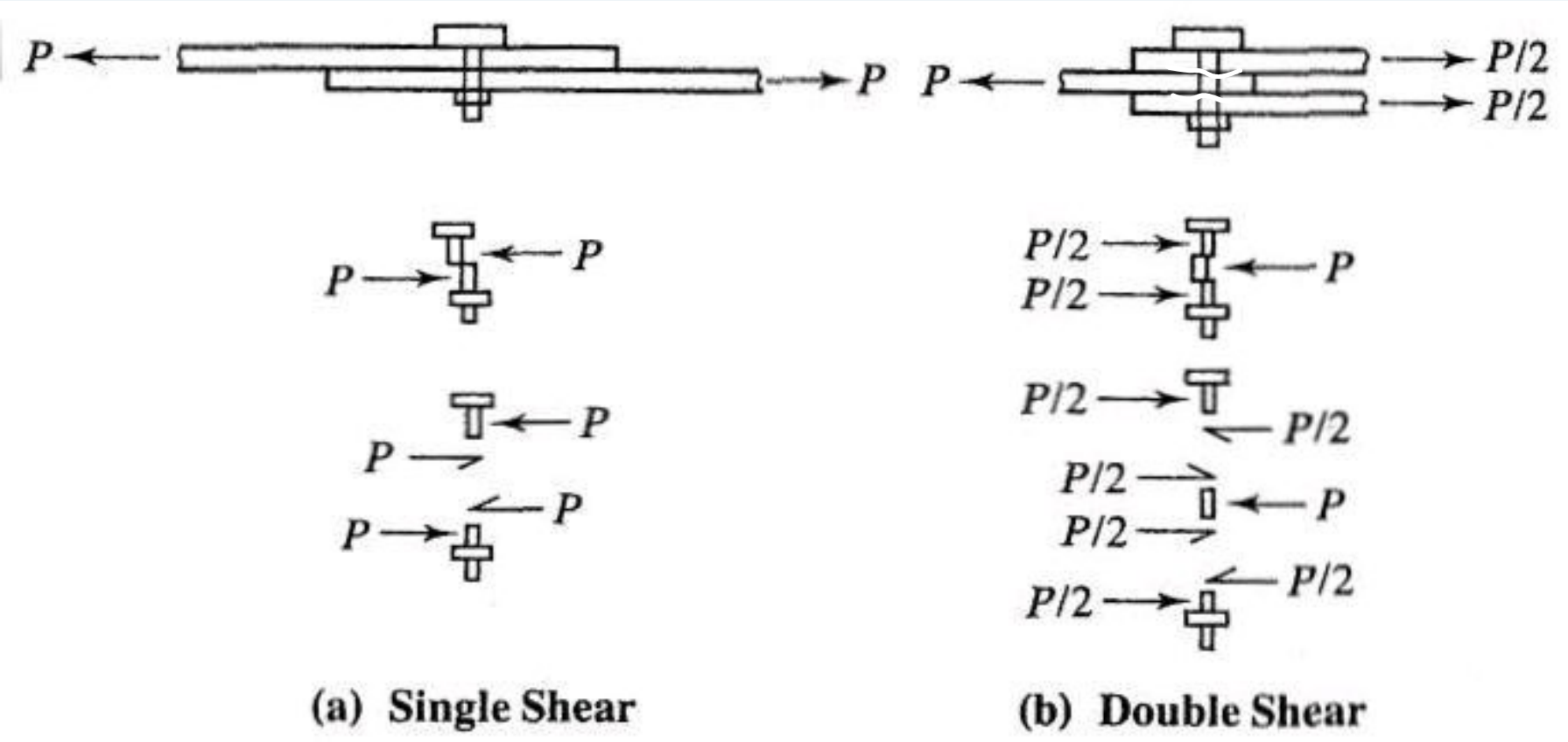
  - **Failure of connected elements:**
    - **Shear, tension or bending failure** of the connected elements (**e.g. block shear**)
    - **Bearing failure** at bolt location



Bolted Shear Connections

- Shear failure of bolts
  - Average shearing stress in the bolt = $f_v = P/A = P/(\pi d_b^2/4)$
  - P is the load acting on an individual bolt
  - A is the area of the bolt and db is its diameter
  - Strength of the bolt = $P = f_v \times (\pi d_b^2/4)$ where f_v = shear yield stress = $0.6F_y$
  - Bolts can be in *single* shear or *double* shear as shown above.
  - When the bolt is in double shear, two cross-sections are effective in resisting the load. The bolt in *double shear* will have the twice the shear strength of a bolt in single shear.

Bolted Shear Connections



Bolted Shear Connections

- Failure of connected member
  - covered this in detail in this course on tension members
  - Member can fail due to tension fracture or yielding.
- Bearing failure of connected/connecting part due to bearing from bolt holes
  - Hole is slightly larger than the fastener and the fastener is loosely placed in hole
  - Contact between the fastener and the connected part over approximately half the circumference of the fastener
  - As such the stress will be highest at the radial contact point (A). However, the average stress can be calculated as the applied force divided by the projected area of contact

Bolted Shear Connections

- Average bearing stress $f_p = P/(d_b\ t)$, where P is the force applied to the fastener.
- The bearing stress state can be complicated by the presence of nearby bolt or edge. The bolt spacing and edge distance will have an effect on the bearing strength.
- Bearing stress effects are independent of the bolt type because the bearing stress acts on the connected plate not the bolt.
- A possible failure mode resulting from excessive bearing close to the edge of the connected element is shear tear-out as shown below. This type of shear tear-out can also occur between two holes in the direction of the bearing load.

$$\mathbf{R_n = 2 \times 0.6\ F_u\ L_c\ t = 1.2\ F_u\ L_c\ t}$$