CE 415
DESIGN OF STEEL STRUCTURES

LECTURE 5
BLOCK SHEAR

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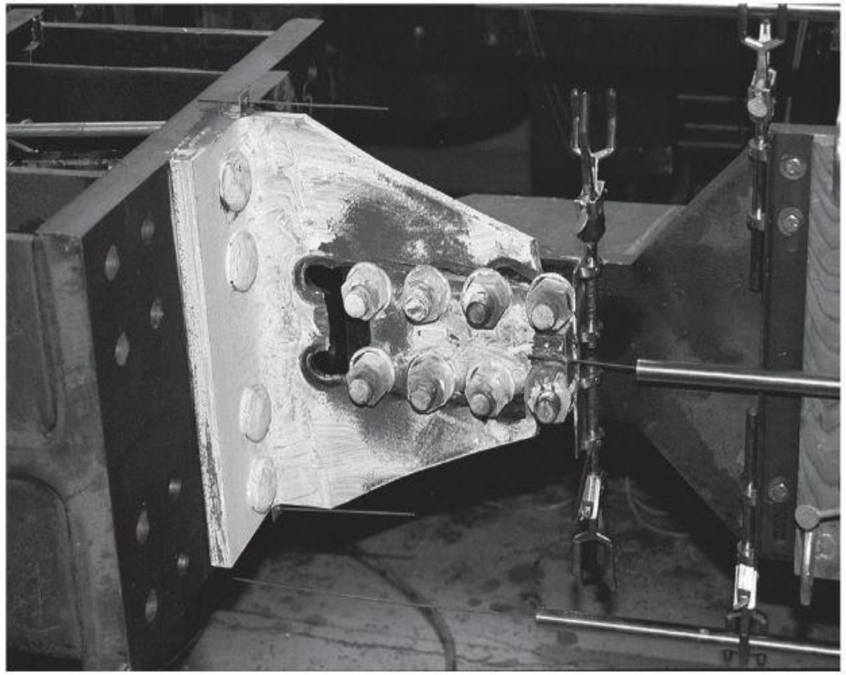
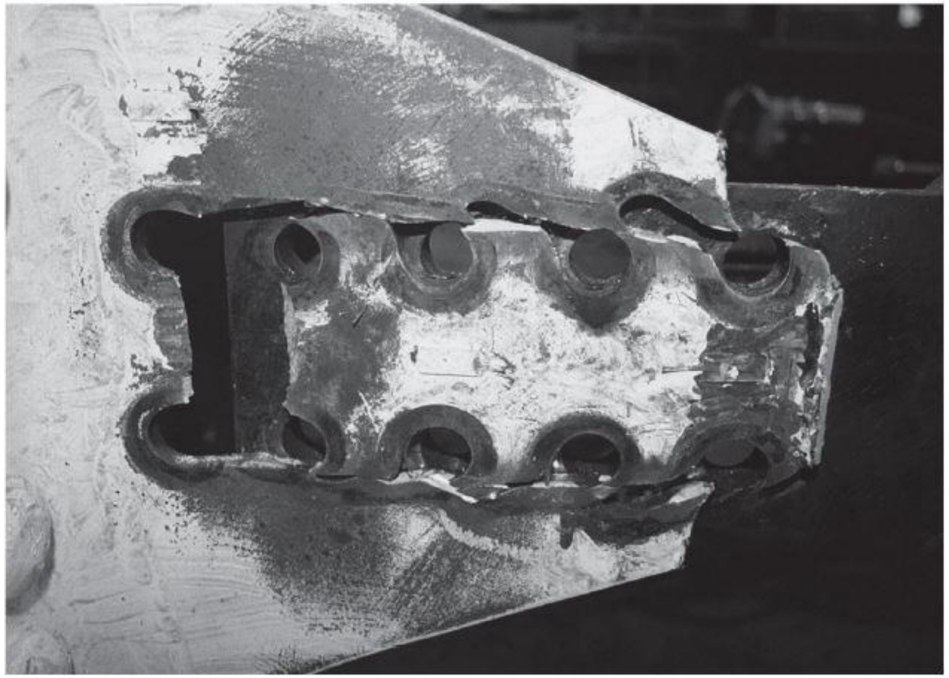
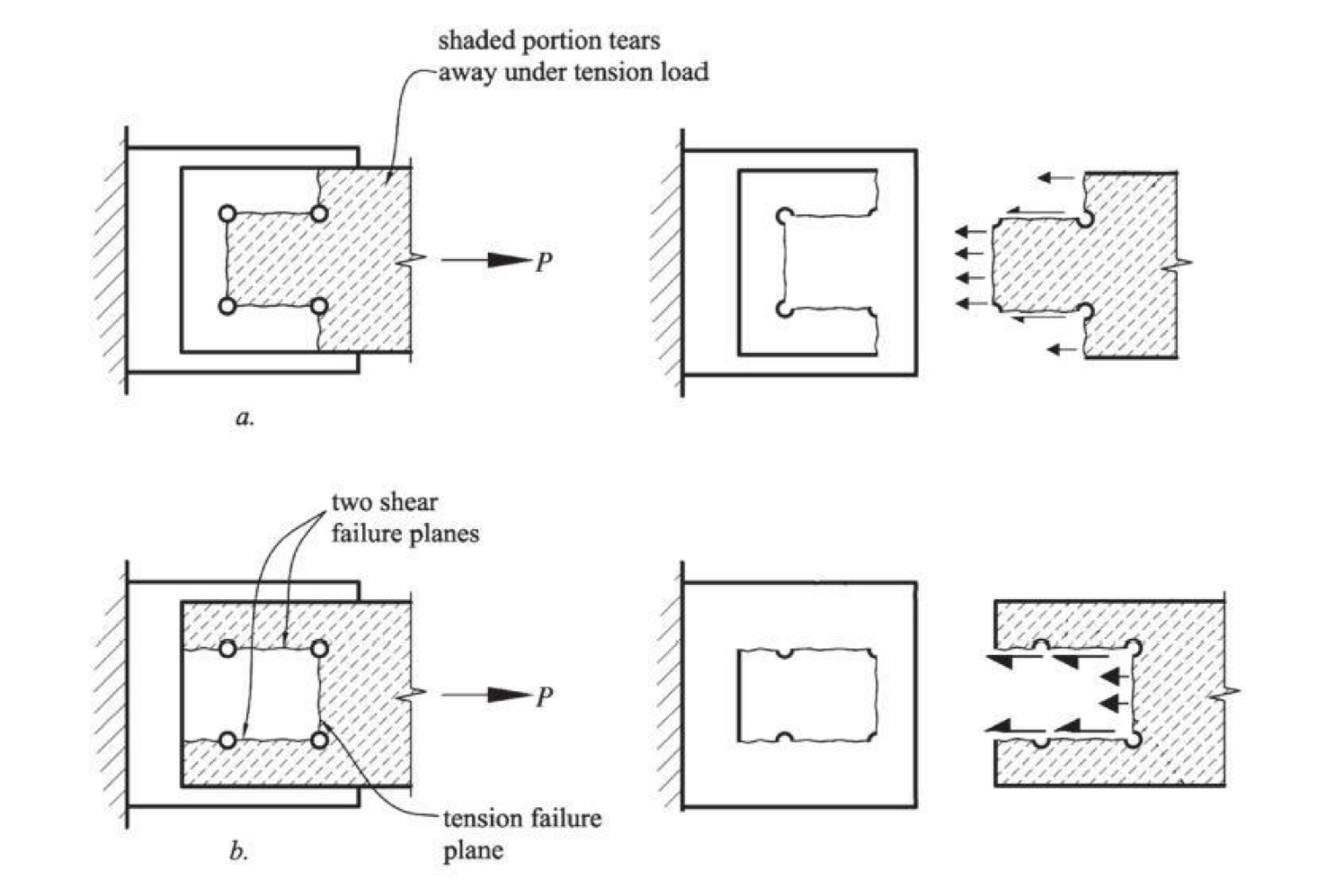
OUTLINE

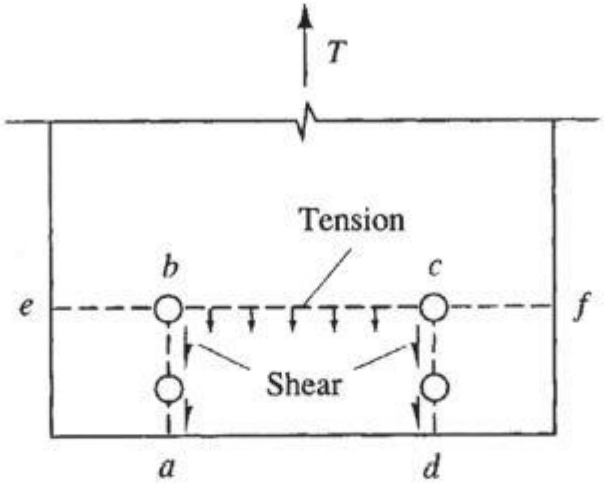
- Block Shear theory ASD and LRFD
- Shear yielding tension rupture
- Shear fracture tension rupture
- Calculation of block shear capacity



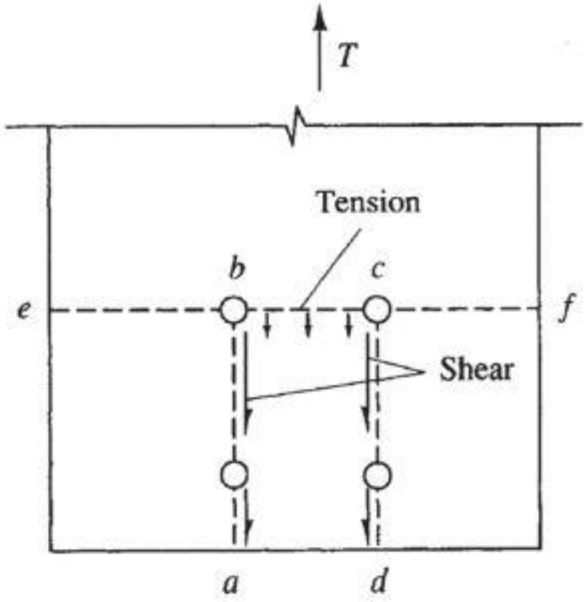



shaded portion tears
away under tension load
P
a.
two shear
failure planes
P
tension failure
plane
b.

Block Shear Failure



Large tension, small shear



Large shear, small tension

AISC-J4.3. defines two block shear failure modes:

1. **Rupture along the tensile plane (b-c in left fig.) accompanied by yielding along the shear planes (a-b and c-d in left fig.).**
2. **Rupture along the shear planes (a-b and c-d right fig.) accompanied by rupture along the tensile plane (b-c in right fig.).**

Block Shear Strength

The tensile failure is defined by *rupture along the net area* in both modes,

The failure along the shear planes can either be
***Rupture along the net shear area* or**
***Yield along the gross shear area*, whichever is smaller.**

Consistent with the limit states discussed earlier, the *gross area* is used for the yielding limit state and the *net area* is used for the fracture limit state.

Following the energy-of-distortion theory,

- **Shear yield stress τ_y is taken as $0.6F_y$**
- **Shear strength/rupture τ_u is taken as $0.6F_u$**

The nominal block shear strength T_n in tension

Shear yielding - tension rupture ($\tau_y A_{gv} < \tau_u A_{nv}$) or ($0.6F_y A_{gv} < 0.6F_u A_{nv}$)

$$T_n = 0.6F_y A_{gv} + F_u U_{bs} A_{nt}$$

Shear fracture - tension rupture ($\tau_y A_{gv} \geq \tau_u A_{nv}$) or ($0.6F_y A_{gv} \geq 0.6F_u A_{nv}$)

$$T_n = 0.6F_u A_{nv} + F_u U_{bs} A_{nt}$$

where

A_{gv} : gross area acted upon by shear

A_n : net area acted upon by tension

A_{nv} : net area acted upon by shear

F_u : specified (ASTM) minimum tensile strength

F_y : specified (ASTM) minimum yield stress

When the tension stress is uniform, use U_{bs} = 1, where the tension is non-uniform use U_{bs} = 0.5.

ASD Design

Block Shear Strength

Shear yielding - tension rupture ($0.6F_y A_{gv} < 0.6F_u A_{nv}$)

$$T_n/\Omega = (0.6F_y A_{gv} + F_u U_{bs} A_{nt})/\Omega = (0.6F_y A_{gv} + F_u U_{bs} A_{nt})/2.0$$

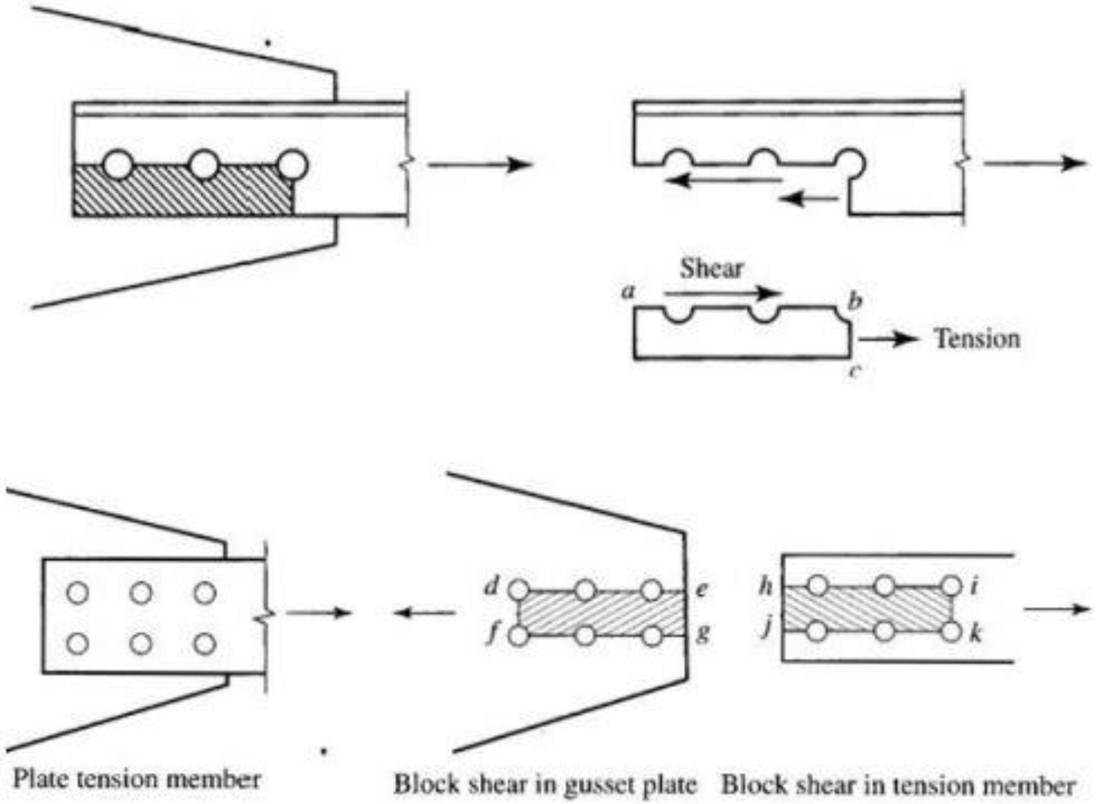
Shear fracture - tension rupture ($0.6F_y A_{gv} \geq 0.6F_u A_{nv}$)

$$T_n/\Omega = (0.6F_u A_{nv} + F_u U_{bs} A_{nt})/\Omega = (0.6F_u A_{nv} + F_u U_{bs} A_{nt})/2.0$$

Where,

A_{gv} : gross area acted upon by shear
A_n : net area acted upon by tension
A_{nv} : net area acted upon by shear
F_u : specified (ASTM) minimum tensile strength
F_y : specified (ASTM) minimum yield stress

Safety factor Ω = 2.00 for block shear which is essentially a fracture limit state



Two types of failure occurs during block shear.

Tensile Failure Occurs at cross sections that are transverse to applied load.

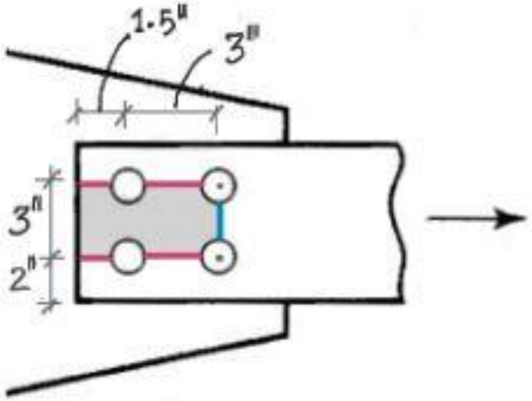
Shear Failure Occurs at cross sections that are along the direction of applied load.

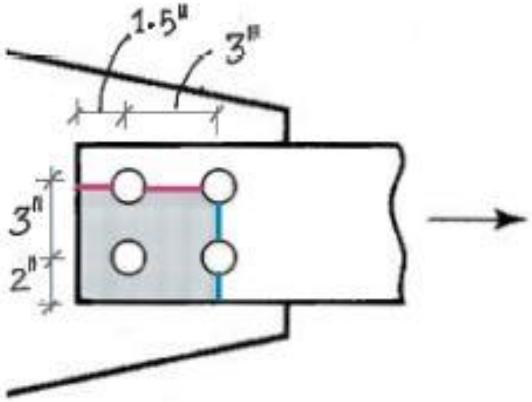
Nominal Capcaity The minimum of the following two expressions.

$$R_n = \begin{cases} 0.60F_y A_{gv} + F_u A_{nt} \\ 0.60F_u A_{nv} + F_u A_{nt} \end{cases}$$

A_{gv}	Gross area for shear
A_{nv}	Net area for shear
A_{nt}	Net area for tension
F_y	Yield Strength
F_u	Ultimate Strength

Ques. Determine block shear strength of the following plate which is 1/2 inch thickness. Bolts have 5/8 inch diameter. Assume A36 steel.





Block Shear - Mode 1

Areas

$$A_{gv} = \frac{1}{2} \times [4.5] \times 2 = 4.5 \text{ in}^2$$

$$A_{nv} = \frac{1}{2} \times \left[4.5 - 1.5 \times \left(\frac{5}{8} + \frac{1}{8}\right)\right] \times 2 = 3.375 \text{ in}^2$$

$$A_{nt} = \frac{1}{2} \times \left[3 - 1 \times \left(\frac{5}{8} + \frac{1}{8}\right)\right] = 1.125 \text{ in}^2$$

Capacity

$$R_n = 0.60 F_y A_{gv} + F_u A_{nt} = 0.60 \times 36 \times 4.5 + 58 \times 1.125 = 162.4 \ (\leftarrow)$$

$$R_n = 0.60 F_u A_{nv} + F_u A_{nt} = 0.60 \times 58 \times 3.375 + 58 \times 1.125 = 182.7 \text{ kip}$$

$$\phi_t R_n = 0.9 \times 162.4 = 146.1 \text{ kip}$$

Block Shear - Mode 2

Areas

$$A_{gv} = \frac{1}{2} \times [4.5] \times 1 = 2.25 \text{ in}^2$$

$$A_{nv} = \frac{1}{2} \times \left[4.5 - 1.5 \times \left(\frac{5}{8} + \frac{1}{8}\right)\right] = 1.687 \text{ in}^2$$

$$A_{nt} = \frac{1}{2} \times \left[5 - 1.5 \times \left(\frac{5}{8} + \frac{1}{8}\right)\right] = 1.936 \text{ in}^2$$

Capacity

$$R_n = 0.60 F_y A_{gv} + F_u A_{nt} = 0.60 \times 36 \times 2.25 + 58 \times 1.936 = 160.9 \ (\leftarrow)$$

$$R_n = 0.60 F_u A_{nv} + F_u A_{nt} = 0.60 \times 58 \times 1.687 + 58 \times 1.936 = 171 \text{ kip}$$

$$\phi_t R_n = 0.9 \times 160.9 = 144.8 \text{ kip}$$

Ans. Block shear strength is 144.8 kip