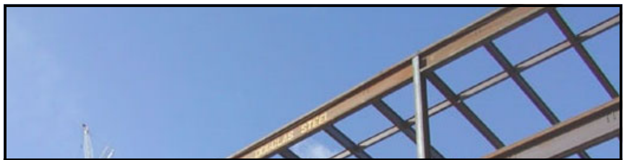
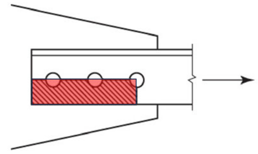


Chapter 3
Tension Members

1

Chapter 3.5 – Block Shear

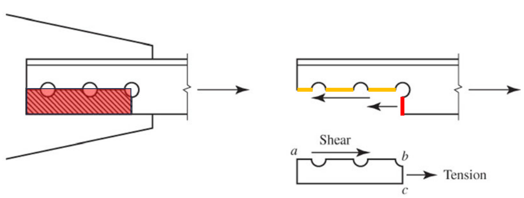
- For certain connection configurations, a segment or "***block***" of material at the end of the member can ***tear out***.
- For example, the connection of the single-angle tension member shown below is susceptible to this phenomenon, called ***block shear***.



2

Chapter 3.5 – Block Shear

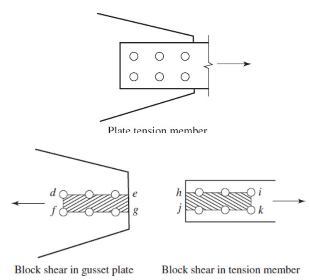
- For the case illustrated, the ***shaded block*** would tend to fail.
- By ***shear*** along the longitudinal section ***ab***.
- And by ***tension*** on the transverse section ***bc***.



3

Chapter 3.5 – Block Shear

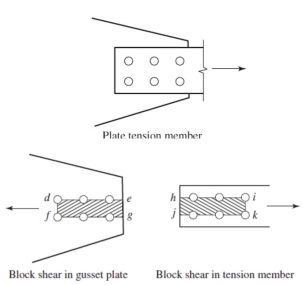
- For certain arrangements of bolts, ***block shear*** can also occur in gusset plates.



4

Chapter 3.5 – Block Shear

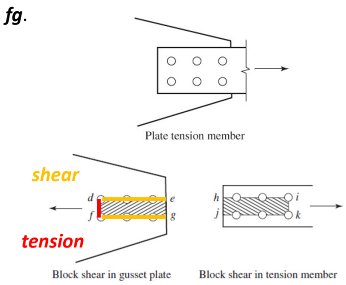
- In this connection, ***block shear*** could occur in both the gusset plate and the tension member.



5

Chapter 3.5 – Block Shear

- For the gusset plate, ***tension*** failure would be along ***df***.
- ***Shear*** failure would occur on two longitudinal surfaces, ***de*** and ***fg***.



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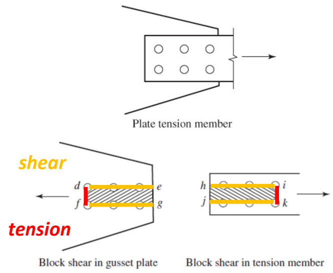
Chapter 3.5 – Block Shear

- ***Block shear*** failure in the plate tension member would be:
  Tension on ***ik***.
  Shear on both ***hi*** and ***jk***.



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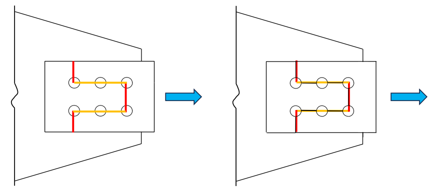
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

  Case 1: **U**-shaped section with two shear lines and three tension lines.



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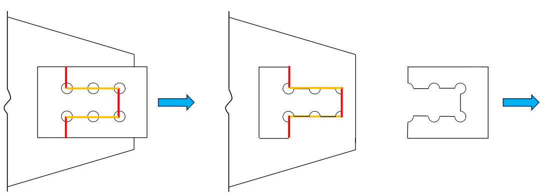
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

  Case 1: **U**-shaped section with two shear lines and three tension lines.



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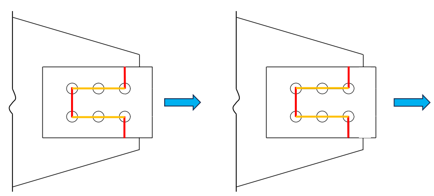
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

  Case 2: **T**-shaped section with two shear lines and three tension lines.



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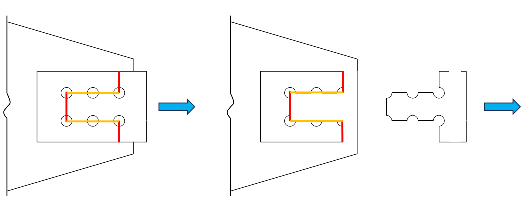
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

  Case 2: **T**-shaped section with two shear lines and three tension lines.



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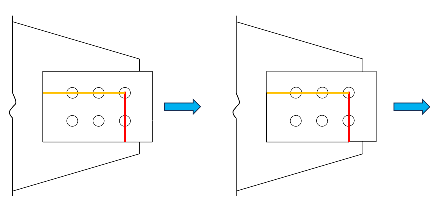
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

  Case 3: **L**-shaped section with one shear line and one tension line.



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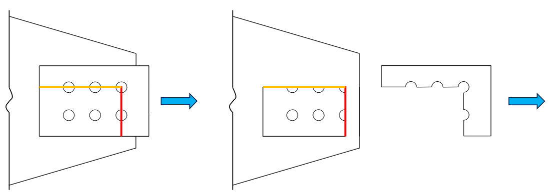
Chapter 3.5 – Block Shear

- Potential block shear failure modes of a tension member.

Case 3: **L**-shaped section with one shear line and one tension line.



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Chapter 3.5 – Block Shear

- This topic is not covered explicitly in ***AISC Chapter D*** ("Design of Members for Tension") but in ***Chapter J*** ("Design of Connections"), ***Section J4.3***, "Block Shear Strength."

16.1-146 AFFECTED ELEMENTS OF MEMBERS AND CONNECTING ELEMENTS [Sect. J4.

3. Block Shear Strength

The available strength for the limit state of block shear rupture along a shear failure path or paths and a perpendicular tension failure path shall be determined as follows:

$$R_n = 0.60F_uA_{nv} + U_{bs}F_uA_{nt} \le 0.60F_yA_{gv} + U_{bs}F_uA_{nt} \quad \text{(J4-5)}$$

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

where

A_{nt} = net area subjected to tension, in.^{2} (mm^2)

Where the tension stress is uniform, $U_{bs} = 1$; where the tension stress is nonuniform, $U_{bs} = 0.5$.

User Note: Typical cases where U_{bs} should be taken as equal to 0.5 are illustrated in the Commentary.

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Chapter 3.5 – Block Shear

- The model used in the ***AISC Specification*** assumes that failure occurs by ***rupture*** on the ***shear area*** and ***rupture*** on the ***tension area***.
- Both surfaces contribute to the total strength, and the resistance to ***block shear*** will be the sum of the strengths of the two surfaces.
- The shear rupture stress is taken as 60% of the tensile ultimate stress, so the ***nominal strength*** in ***shear*** is:

$$0.60F_uA_{nv}$$

where $\boldsymbol{A_{nv}}$ is the net area along the ***shear*** surface or surfaces

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Chapter 3.5 – Block Shear

- The model used in the ***AISC Specification*** assumes that failure occurs by ***rupture*** on the ***shear area*** and ***rupture*** on the ***tension area***.
- Both surfaces contribute to the total strength, and the resistance to ***block shear*** will be the sum of the strengths of the two surfaces.
- The ***nominal strength*** in ***tension*** is:

$$F_uA_{nt}$$

where $\boldsymbol{A_{nt}}$ is the net area along the ***tension*** surface

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Chapter 3.5 – Block Shear

- This gives a total nominal strength of:

$$R_n = 0.60F_uA_{nv} + F_uA_{nt}$$

- The ***AISC Specification*** uses the above equation for angles and gusset plates.
- For certain types of coped beam connections (to be covered in Chapter 5), the second term is reduced to account for nonuniform tensile stress.

$$R_n = 0.60F_uA_{nv} + 0.5F_uA_{nt}$$

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Chapter 3.5 – Block Shear

- The **AISC Specification** limits the $\boldsymbol{0.6F_uA_{nv}}$ term to $\boldsymbol{0.6F_yA_{gv}}$ where $\boldsymbol{A_{gv}}$ is the gross area along the shear surface, and $\boldsymbol{0.6F_y}$ is the shear yield stress.
- The ***AISC Equation J4-5*** is:

$$R_n = 0.60F_uA_{nv} + U_{bs}F_uA_{nt} \le 0.60F_yA_{gv} + U_{bs}F_uA_{nt}$$

where $\boldsymbol{U_{bs}}$ = 1 when the tension stress is uniform (angles, gusset plates, and most coped beams) and $\boldsymbol{U_{bs}}$ = 0.5 when the tension stress is nonuniform.

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Chapter 3.5 – Block Shear

- The **AISC Specification** limits the $\mathbf{0.6F_uA_{nv}}$ term to $\mathbf{0.6F_yA_{gv}}$ where $\mathbf{A_{gv}}$ is the gross area along the shear surface, and $\mathbf{0.6F_y}$ is the shear yield stress.
- The ***AISC Equation J4-5*** is:

$$R_n = 0.60F_uA_{nv} + U_{bs}F_uA_{nt} \leq 0.60F_yA_{gv} + U_{bs}F_uA_{nt}$$

- Although ***AISC Equation J4-5*** is expressed in terms of bolted connections, block shear can also occur in ***welded connections***, especially in gusset plates.

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Chapter 3.5 – Block Shear

- The **AISC Specification** limits the $\mathbf{0.6F_uA_{nv}}$ term to $\mathbf{0.6F_yA_{gv}}$ where $\mathbf{A_{gv}}$ is the gross area along the shear surface, and $\mathbf{0.6F_y}$ is the shear yield stress.
- The ***AISC Equation J4-5*** is:

$$R_n = 0.60F_uA_{nv} + U_{bs}F_uA_{nt} \leq 0.60F_yA_{gv} + U_{bs}F_uA_{nt}$$

- An alternative formulation is:

$$R_n = \min\left[0.60F_uA_{nv}\,;\, 0.60F_yA_{gv}\right] + U_{bs}F_uA_{nt}$$

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Chapter 3.5 – Block Shear

- Summary of ***LRFD*** tension ***strength limit states***:

$$P_u \leq \phi_t P_n \qquad \text{or} \qquad \phi_t P_n \geq P_u$$

1. ***Yielding*** of gross area:	$\phi_t P_n = \phi_t F_y A_g = 0.90 F_y A_g$
2. ***Rupture*** of effective area:	$\phi_t P_n = \phi_t F_u A_e = 0.75 F_u U A_n$
3. ***Block shear*** rupture: $\phi_t P_n = 0.75\left(\min\left[0.60F_uA_{nv}\,;\, 0.60F_yA_{gv}\right] + U_{bs}F_uA_{nt}\right)$	

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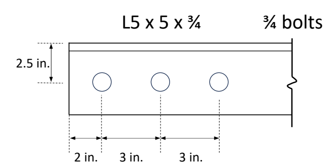
Chapter 3.5 – Block Shear

- **Example 3-10**: Compute the block shear strength of the tension member shown below. The holes are for ¾-inch bolts and ***A572, Grade 50,*** steel with F_y = 50 ksi and F_u = 65 ksi.



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Chapter 3.5 – Block Shear

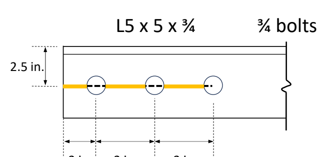
- **Example 3-10**: The shear areas are:

$$A_{gv} = \left(\tfrac{3}{4}\text{in.}\right)\left(2\text{in.} + 3\text{in.} + 3\text{in.}\right) = 6\text{ in}^2$$

$$A_{nv} = \left(\tfrac{3}{4}\text{in.}\right)\left(8\text{in.} - 2.5\left(\tfrac{3}{4}\text{in.} + \tfrac{1}{8}\text{in.}\right)\right) = 4.359\text{ in}^2$$

2.5 bolt holes

Hole diameter



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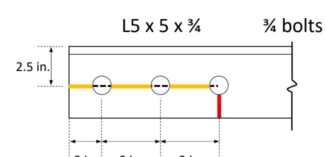
Chapter 3.5 – Block Shear

- **Example 3-10**: The shear areas are:

$$A_{nt} = \left(\tfrac{3}{4}\text{in.}\right)\left(2.5\text{in.} - 0.5\left(\tfrac{3}{4}\text{in.} + \tfrac{1}{8}\text{in.}\right)\right) = 1.547\text{ in}^2$$

½ bolt hole



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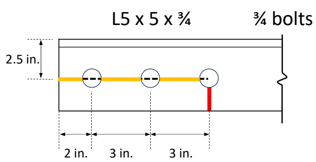
Chapter 3.5 – Block Shear

- **Example 3-10**: Since the block shear occurs in an angle, U_{bs} = 1.

$$R_n = 0.60 F_u A_{nv} + U_{bs} F_u A_{nt}$$
$$= 0.60(65ksi)(4.359 \text{ in}^2) + (1)(65ksi)(1.547 \text{ in}^2)$$
$$= \boxed{270.6k}$$



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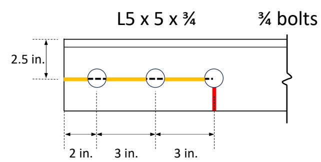
Chapter 3.5 – Block Shear

- **Example 3-10**: With an upper limit of:

$$R_n = 0.60 F_y A_{gv} + U_{bs} F_u A_{nt}$$
$$= 0.60(50ksi)(6 \text{ in}^2) + (1)(65ksi)(1.547 \text{ in}^2)$$
$$= \boxed{280.6k}$$

The nominal block shear strength is therefore $\boxed{270.6k}$



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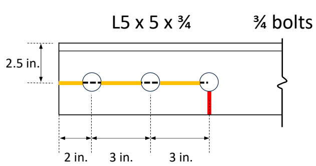
Chapter 3.5 – Block Shear

- **Example 3-10**: Alternative computation:

$$P_n = \min\left[0.60 F_u A_{nv};\ 0.60 F_y A_{gv}\right] + U_{bs} F_u A_{nt}$$
$$= \min\left[0.60(65ksi)(4.359 \text{ in}^2); 0.60(50ksi)(6 \text{ in}^2)\right] + (1)(65ksi)(1.547 \text{ in}^2)$$
$$= \min[170.0k; 180.0k] + 100.56k = \boxed{270.6k}$$

The nominal block shear strength is therefore $\boxed{270.6k}$



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Chapter 3.5 – Block Shear

Let's work on some problems

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Chapter 3.5 – Block Shear

Any questions?

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