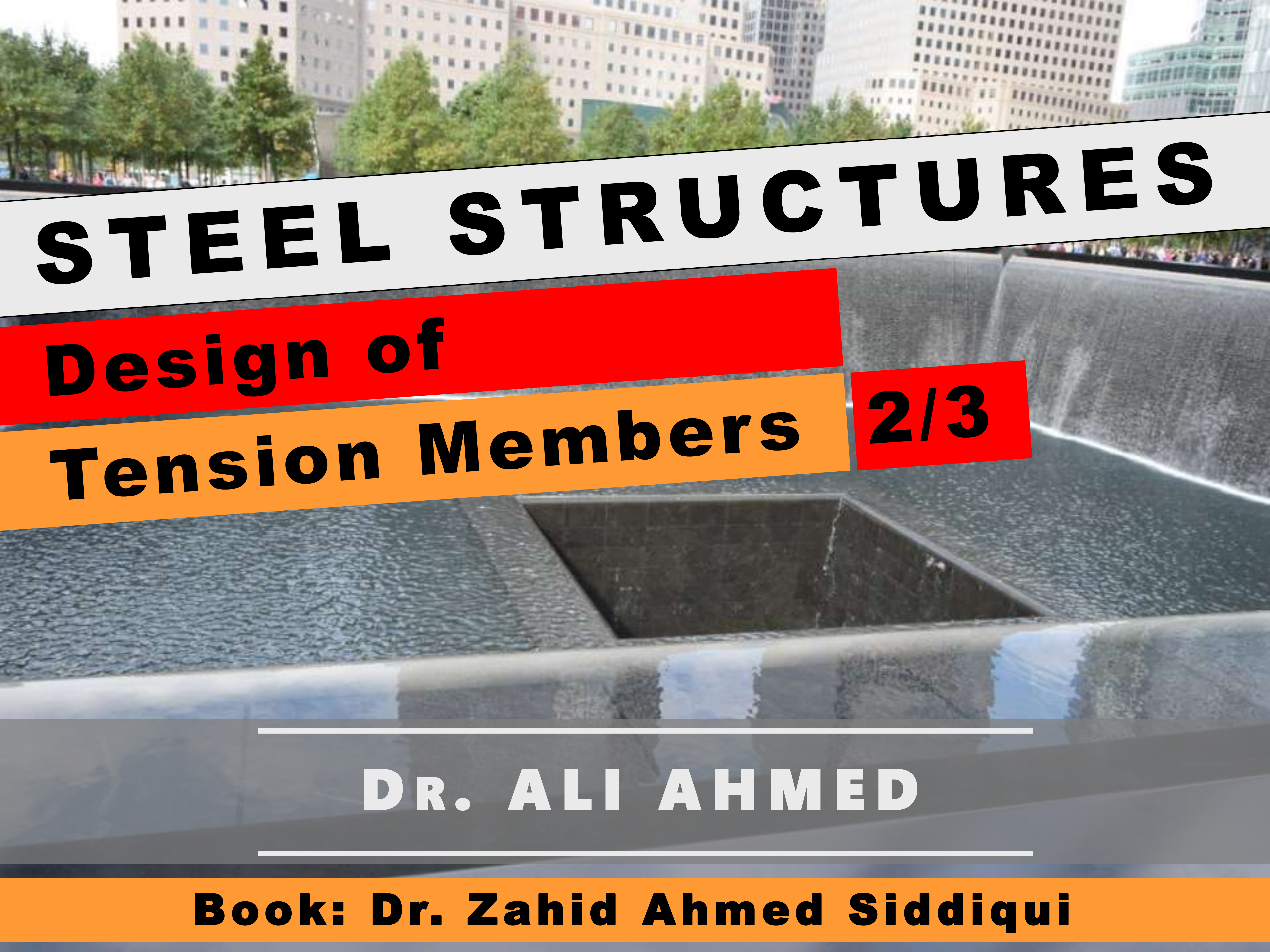

STEEL STRUCTURES

Design of Tension Members 2/3

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DESIGN FOR REPEATED LOADING/FATIGUE STRENGTH

Repeated loading and unloading may result in failure at a stress level lesser than the yield stress.

Fatigue = reduction in material strength & failure under cyclic loading.

The effect is more pronounced when repeating loads have tensile extreme value.

The fatigue strength is mainly governed by three variables:

a. **The number of cycles of loading.**

b. **The range of variation of service load stress.**

Range = Maximum Stress – Minimum Stress

OR

Range = Magnitude of Max Tension – Magnitude of Max Compression

c. **The presence and initial size of any microscopic discontinuities or flaws within the metal structure.**

In Appendix-3, AISC Specifications prescribe no fatigue effect for fewer than 20,000 cycles, which is approximately two applications a day for 25 years.

Since, most loadings in buildings are in this category, fatigue is generally not considered.

DESIGN OF TENSION MEMBERS

T_u = factored or ultimate tensile load

T_a = actual or service tensile load

ϕ_t = resistance factor related with tensile strength,

0.9 when failure occurs by yielding

0.75 when failure occurs by fracture

T_n = nominal strength of a tension member

$\phi_t T_n$ = expected strength to be used in LRFD design, and

T_n/Ω_t = allowable tensile strength to be used in design (ASD)

Design equation: $T_u \le \phi_t T_n$ **(LRFD)**

$T_a \le T_n / \Omega_t$ **(ASD)**

The design strength $\phi_t T_n$ or T_n/Ω_t according to AISC-D2 is the smaller of that based on:

Yielding in the gross section (Yielding Limit State)

$T_n = F_y A_g$ **;** ϕ_t **= 0.90 (LRFD) and** Ω_t **= 1.67 (ASD)**

For LRFD design, $T_u = \phi_t T_n = \phi_t F_y A_g / 1000$

$$\left(A_g\right)_{req} = \frac{T_u\,(in\ kN) \times 1000}{0.9\, F_y}$$

For ASD design, $T_a = T_n / \Omega_t = \dfrac{F_y A_g}{\Omega_t \times 1000}$

$$\left(A_g\right)_{req} = \frac{T_a (in\ kN) \times 1670}{F_y}$$

Fracture in the net section (Fracture Limit State)

$$T_n = F_u A_e$$
$$= F_u U A_n$$

$\phi_t = 0.75$ (LRFD) and $\Omega_t = 2.00$ (ASD)

For LRFD design,

$$T_u = \phi_t T_n = \phi_t F_u U R A_g / 1000$$

$$\left(A_g\right)_{req} = \frac{T_u (in\ kN) \times 1000}{0.75\ F_u \times U \times R}$$

R = assumed ratio of A_n and A_g

For ASD design, $T_a = T_n / \Omega_t = \dfrac{F_u U R A_g}{\Omega_t \times 1000}$

$$\left(A_g\right)_{req} = \frac{T_a\,(in\ kN) \times 2000}{F_u \times U \times R}$$

Yielding in the net section is not a failure but yielding on the gross section is a failure.

The reason is that the net section is limited in length and hence elongation due to yielding may not be excessive.

Fracture in Net Area

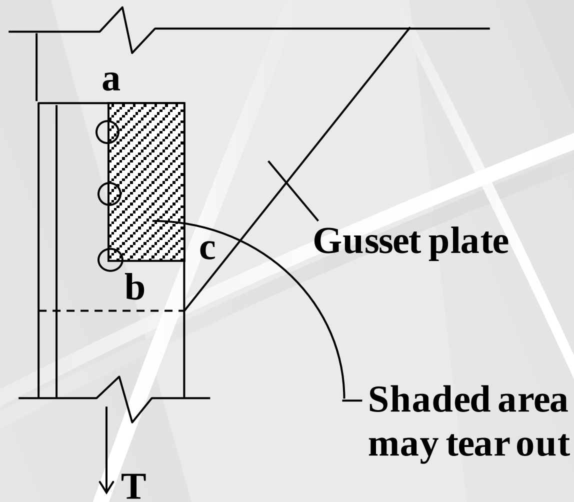
However, gross area is present nearly all along the length and the elongation limit state may be exceeded.

TEARING FAILURE AT BOLT HOLES/ BLOCK SHEAR FAILURE MODE

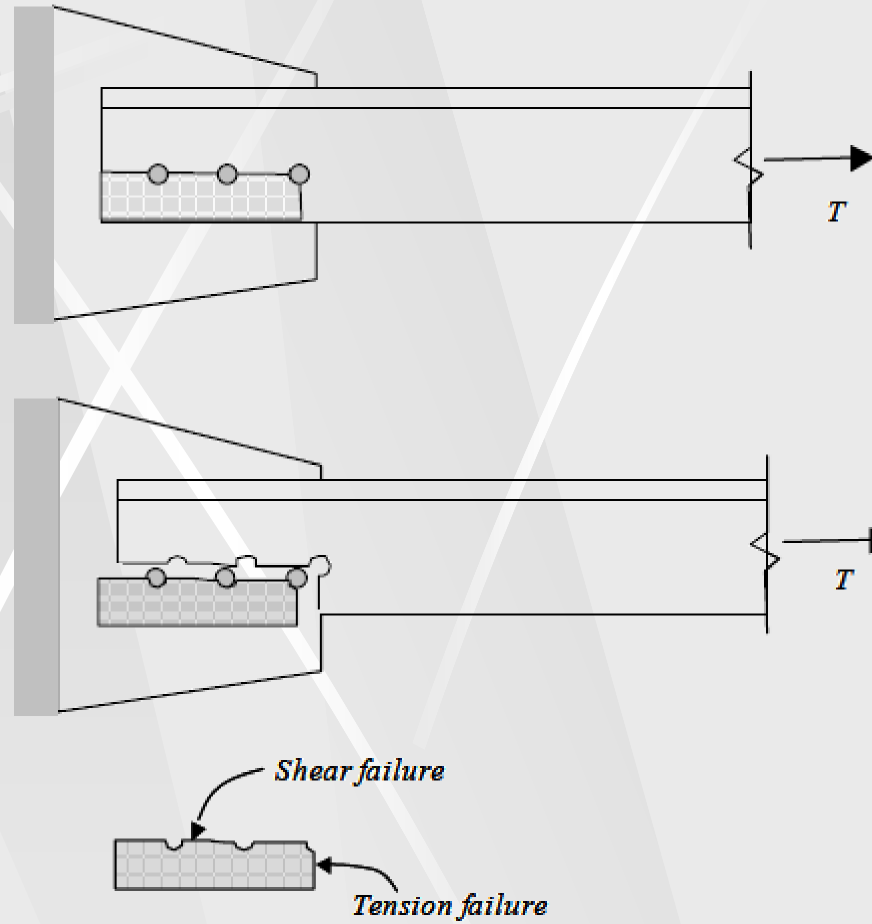
In block shear failure, a part of the failure plane is transverse subjected to tension while the other part is longitudinal subjected to shear.

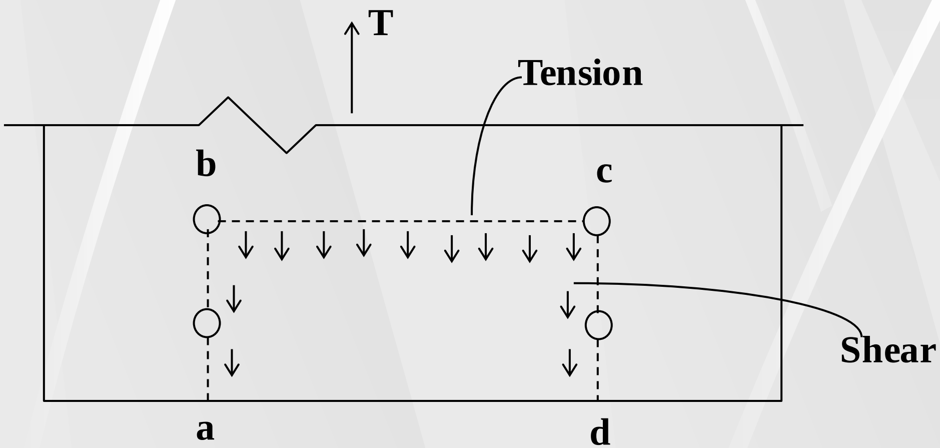
In Figure 2.13 (a), *ab* part is subjected to shear and *bc* part is having tension.

Block Shear Tear-out

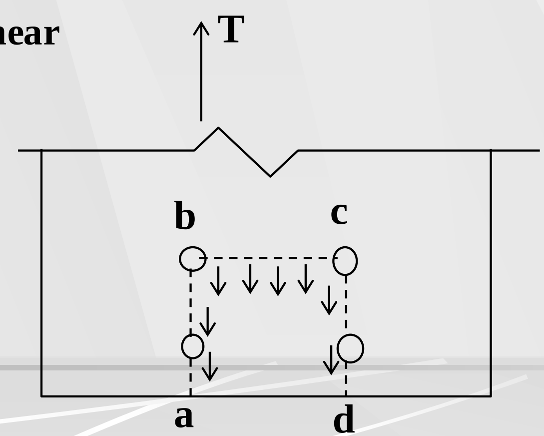


a)Failure by tearing out





b)Large tension, small shear



c)Large shear, small tension

The failure plane *abcd*, as shown in Figures 2.13 (b) and (c), consists of a plane subjected to tension denoted by *bc* and two planes subjected to shear shown as *ab* and *dc*.
The tearing out failure is either

1. **Fracture failure on both the tension resisting and shear resisting sections together**
2. **Shear yielding combined with tension fracture failure.**

The nominal strength for block shear is the lesser of the following two cases because only that will cause the final separation of the block from the member:

R_n = lesser of

1) $0.6\, F_u\, A_{nv} + U_{bs}\, F_u\, A_{nt}$

2) $0.6\, F_y\, A_{gv} + U_{bs}\, F_u\, A_{nt}$

Nominal tension rupture strength = $U_{bs}\, F_u\, A_{nt}$

Nominal shear rupture strength = $0.6\, F_u\, A_{nv}$

Shear yielding strength = $0.6\, F_y\, A_{gv}$

$0.6F_y \cong$ yield shear strength $= \tau_y$

$0.6F_u \cong$ ultimate shear strength $= \tau_u$

ϕ = *0.75 (LRFD) and* Ω *= 2.00 (ASD)*

A_{gv} = **gross area subjected to shear**

A_{nv} = **net area in shear**

A_{nt} = **net area in tension**

U_{bs} = **tensile rupture strength reduction factor (subscript 'bs' stands for block shear)**

= **1.0 when tensile stress is uniform, such as in all tensile members and gusset plates and single row beam end connections**

= **0.5 when tensile stress is not uniform such as for multiple row beam end connections**

For welded connection, welded length provided longitudinally multiplied with the thickness of the connected leg becomes the area in shear.

Area in tension is considered as the transverse area of connected leg alone.