University of Thi-Qar
College of Engineering
Civil Engineering Department

Method of designs

- Allowable Strength Design (ASD)

- Load and Resistance Factor Design (LRFD)

- Both procedures are based on limit states design principles.

- Limit states is used to describe a condition at which a structure or part of a structure would be stopped to perform its function.

- - Strength: define load carrying capacity, including (excessive yielding, fracture, buckling, fatigue, and gross rigid body motion).

- - Serviceability: define the performance including (deflection, cracking, slipping, vibration, and deterioration.

- All limit states must be prevented.

◆ Allowable Strength Design (ASD)

required strength ≤ allowable strength

$$R_a \le \frac{R_n}{\Omega}$$

- R_a — Required Strength (ASD): Largest computed force in member
- R_n — Nominal Strength
- Ω — Factor of Safety

◆ Load and Resistance Factor Design (LRFD)

required strength ≤ design strength

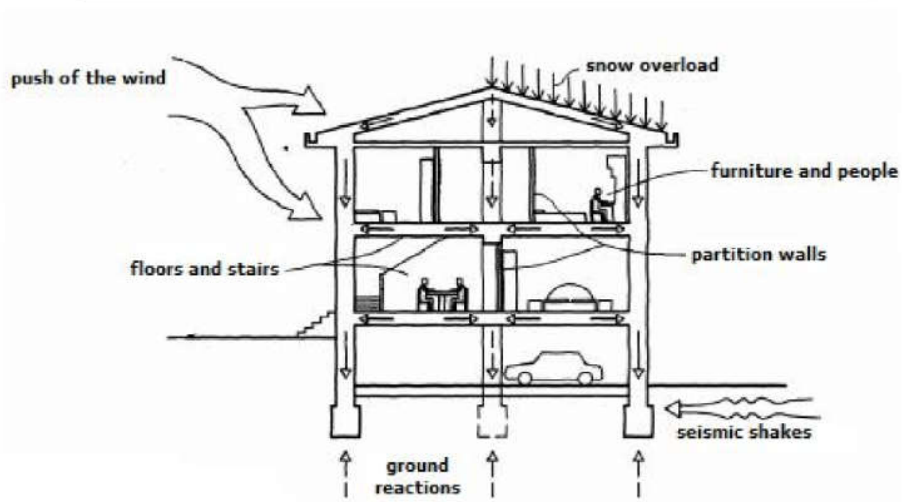
$$R_u = \sum \gamma_i Q_{ni} \le \phi R_n$$

- R_u — Required Strength (LRFD)
- γ_i — Load factor (> 1)
- Q_{ni} — Load
- ϕ — Resistance Factor (< 1)
- R_n — Nominal Strength/ Resistance

ASD Load Combinations

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W \text{ or } 0.7E)$
6. $D + 0.75L \pm 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$
7. $D + 0.75L \pm 0.75(0.7E) + 0.75S$
8. $0.6D \pm 0.6W$ UPLIFT
9. $0.6D \pm 0.7E$ UPLIFT

Possible Loads

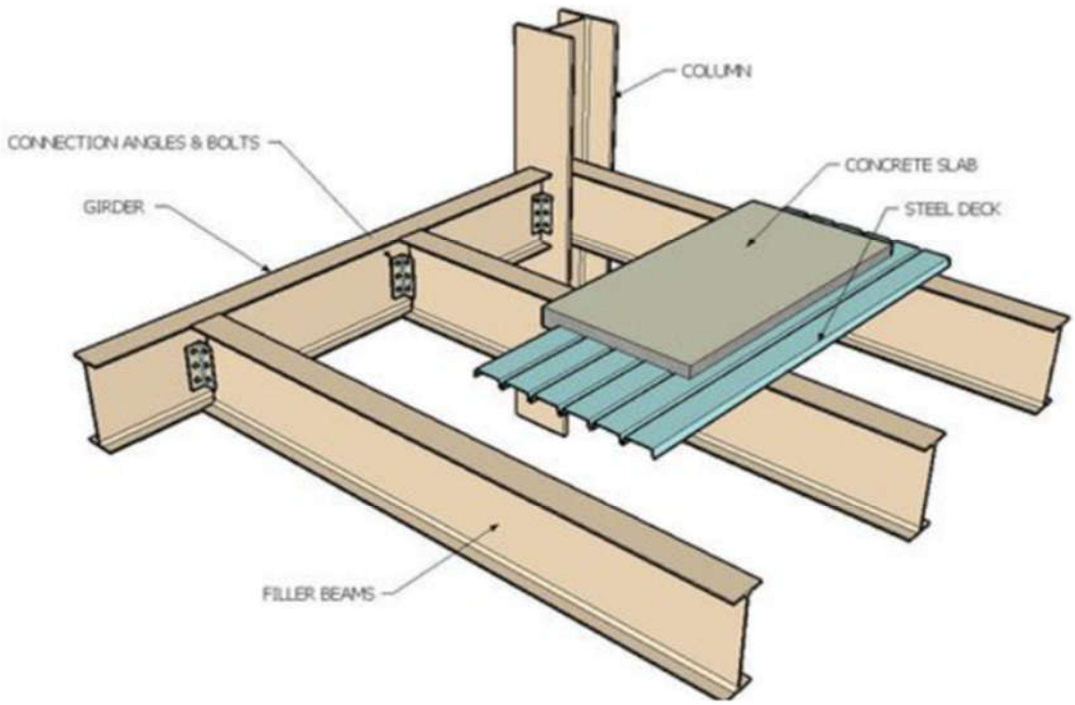


LRFD Load Combinations

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.5W)$
4. $1.2D \pm 1.0W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D \pm 1.0E + 0.5L + 0.2S$
6. $0.9D \pm 1.0W$ UPLIFT
7. $0.9D \pm 1.0E$ UPLIFT

Note: The load factor on *L* in load combinations 3, 4 and 5 is taken as 1.0 if the service live load is greater than 100 psf, and 0.5 for all other cases

Load path



Load path for gravity loads:

1. floor slab (metal deck + concrete) → beams
2. beams → girders
3. girders → columns

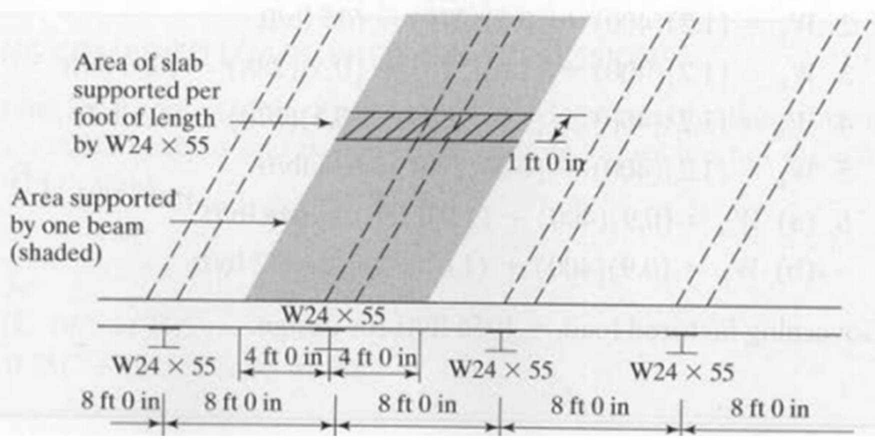
Example 2-1

The interior floor system shown in Figure 2.2 has W24 × 55 sections spaced 8 ft on center and is supporting a floor dead load of 50 psf and a live floor load of 80 psf. Determine the governing load in lb/ft that each beam must support.

Solution. Note that each foot of the beam must support itself (a dead load) plus $8 \times 1 = 8\ \text{ft}^2$ of the building floor.

$$D = 55\ \text{lb/ft} + (8\ \text{ft})(50\ \text{psf}) = 455\ \text{lb/ft}$$

$$L = (8\ \text{ft})(80\ \text{psf}) = 640\ \text{lb/ft}$$



Computing factored loads, using the LRFD load combinations. In this substitution, the terms having no values are omitted. Note that with a floor live load of 80 psf a load factor of 0.5 has been added to load combinations (3.), (4.), and (5.) per the exception stated in ASCE 7-10 and this text for floor live loads.

1. $W_u = (1.4)(455) = 637\ \text{lb/ft}$
2. $W_u = (1.2)(455) + (1.6)(640) = 1570\ \text{lb/ft}$
3. $W_u = (1.2)(455) + (0.5)(640) = 866\ \text{lb/ft}$
4. $W_u = (1.2)(455) + (0.5)(640) = 866\ \text{lb/ft}$
5. $W_u = (1.2)(455) + (0.5)(640) = 866\ \text{lb/ft}$
6. $W_u = (0.9)(455) = 409.5\ \text{lb/ft}$
7. $W_u = (0.9)(455) = 409.5\ \text{lb/ft}$

Governing factored load = 1570 lb/ft to be used for design.

Acceptable level of safety

$$R_a \leq \frac{R_n}{\Omega}$$

$$R_u = \sum \gamma_i Q_{ni} \leq \phi R_n$$

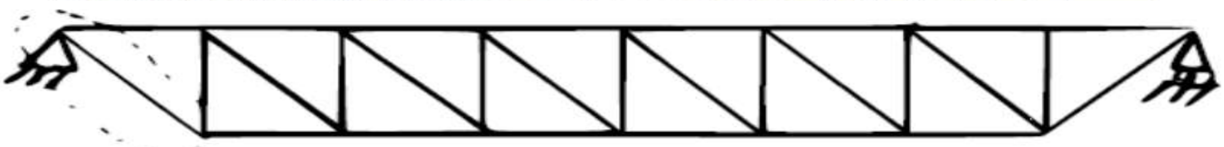
Ω= 1.5/Ø

IF Ø = 0.9 → Ω = 1.67

IF Ø = 0.75 → Ω = 2.00

Tension Members

- Found in bridge, roof trusses, towers, bracing systems, and used as a tie rods.



Bars (round and rectangular) | Cables | Single and double angles

A few examples of shapes typically used for tension members

Limit States in Tension

gross-section yield

net-section fracture

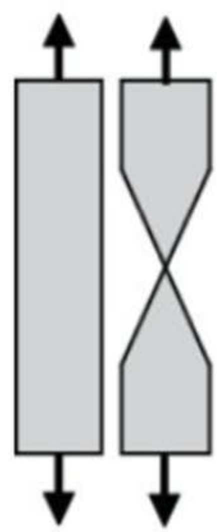
block shear fracture

Gross-section yield

$$P_n = F_y A_g \quad \text{Equation D2-1}$$

$$\phi_t = 0.90 \ (\Omega_t = 1.67)$$

A_g = Gross Area
Total cross-sectional area in the plane perpendicular to tensile stresses.

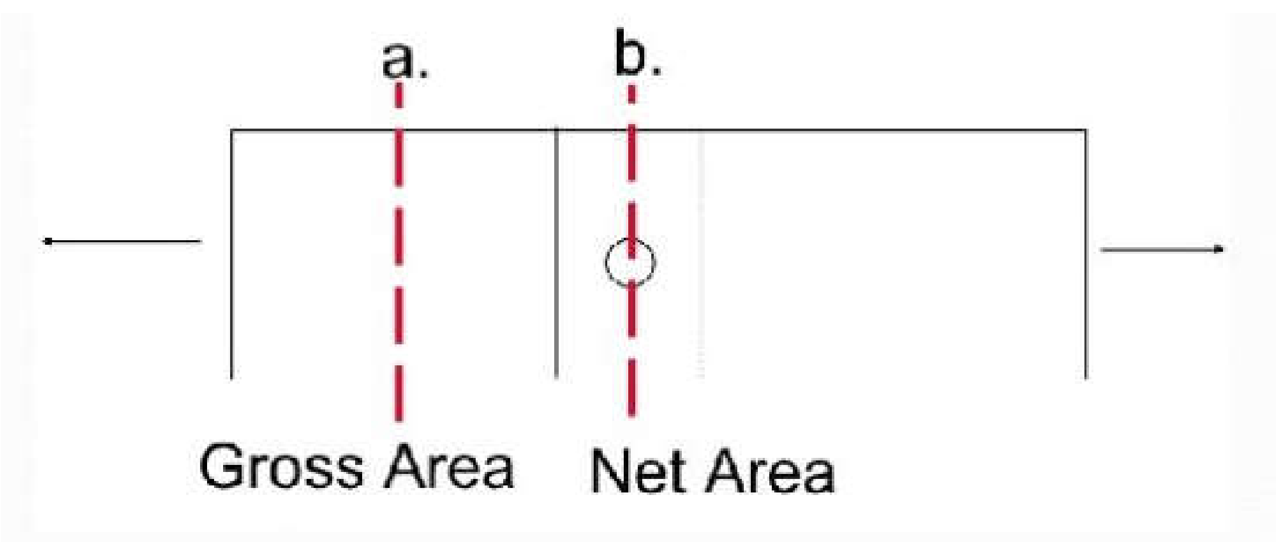


Net-section fracture

$$P_n = F_u A_e \qquad \text{Equation D2-2}$$

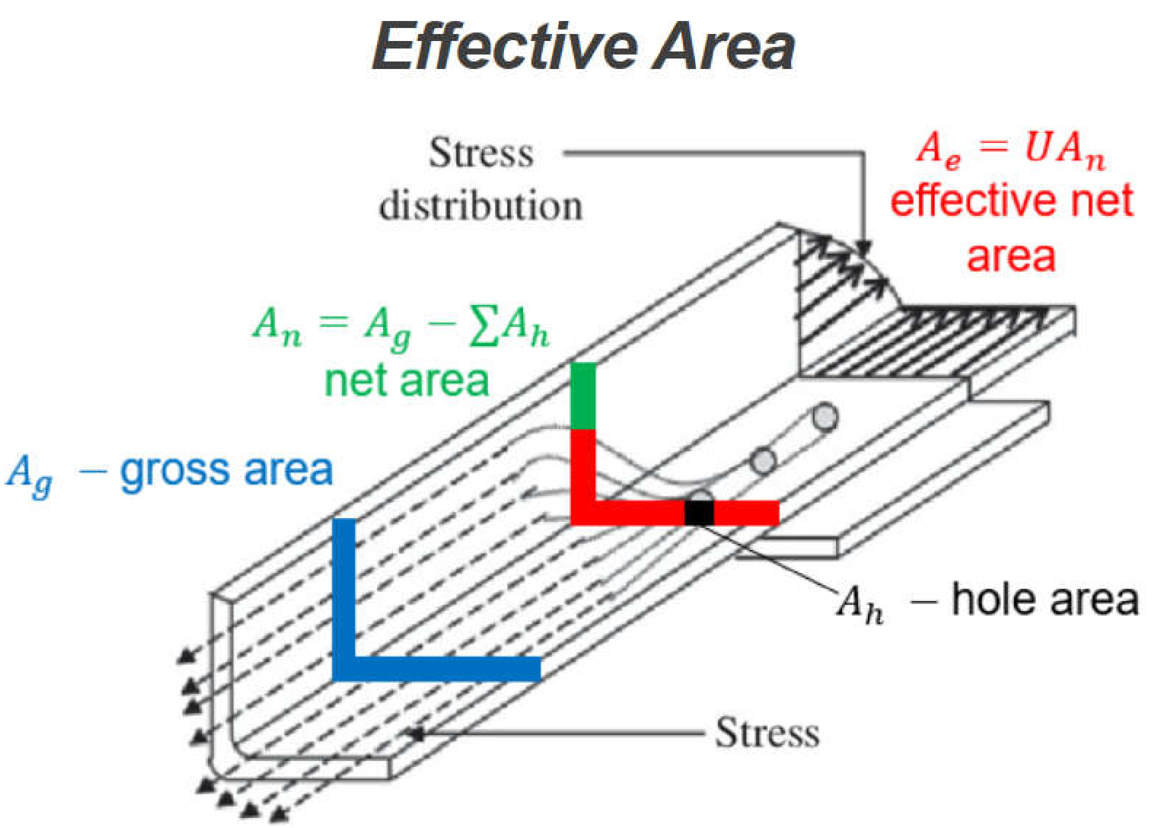
$$\phi_t = 0.75 \; (\Omega_t = 2.00)$$

A_e = Effective Net Area
Accounts for any holes or openings, potential failure planes not perpendicular to the tensile stresses, and effects of shear lag.



Shear lag factor (U)

- The factor, U, is used to account for the effects of shear lag, which is a reduction in the effective area of a cross section as the stress flows from a uniform distribution in the member to a more concentrated distribution in the vicinity of connections that do not engage the full cross section for force transfer.



Part 16 (Specifications)
Chapter D

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

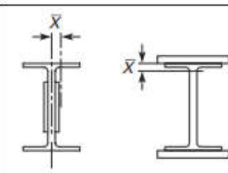
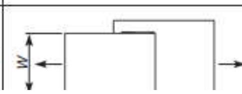
Case	Description of Element	Shear Lag Factor, *U*	Example
1	All tension members where the tension load is transmitted directly to each of cross-sectional elements by fasteners or welds. (except as in Cases 3, 4, 5 and 6)	$U = 1.0$	—
2	All tension members, except plates and HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or longitudinal welds (Alternatively, for W, M, S and HP, Case 7 may be used.)	$U = 1 - \bar{x}/l$	
3	All tension members where the tension load is transmitted by transverse welds to some but not all of the cross-sectional elements.	$U = 1.0$ and A_n = area of the directly connected elements	—
4	Plates where the tension load is transmitted by longitudinal welds only.	$l \geq 2w \ldots U = 1.0$ $2w > l \geq 1.5w \ldots U = 0.87$	

Table 5–2
Available Strength in Axial Tension
Angles

L8–L6

F_y = 36 ksi
F_u = 58 ksi

Shape	Gross Area, A_g	$A_e = 0.75A_g$	Yielding (kips)		Rupture (kips)	
			P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
	in.²	in.²	ASD	LRFD	ASD	LRFD
L8×8×1 1/8	16.7	12.5	360	541	363	544
×1	15.0	11.3	323	486	328	492
×7/8	13.2	9.90	285	428	287	431
×3/4	11.4	8.55	246	369	248	372
×5/8	9.61	7.21	207	311	209	314
×9/16	8.68	6.51	187	281	189	283
×1/2	7.75	5.81	167	251	168	253
L8×6×1	13.0	9.75	280	421	283	424
×7/8	11.5	8.63	248	373	250	375
×3/4	9.94	7.46	214	322	216	325
×5/8	8.36	6.27	180	271	182	273
×9/16	7.56	5.67	163	245	164	247
×1/2	6.75	5.06	146	219	147	220
×7/16	5.93	4.45	128	192	129	194

Example

Determine the net area of the 3/8x8 in plate as shown below. The plate is connected at its end with two lines of ¾ in bolts.