AL-MUSTAQBAL UNIVERSITY

College of Engineering & Technology

Building and Construction Techniques Engineering Department

Design of Steel Structures

Fourth Class

Lecture No. 02 – Concepts in Structural Steel Design

Lecturer

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- The design of a structural member entails the selection of a cross section that will safely and economically resist the applied loads.

Required strength ≤ available strength

Allowable Stress Design (ASD) a member is selected that has cross-sectional properties such as area and moment of inertia that are large enough to prevent the maximum applied axial force, shear, or bending moment from exceeding an allowable, or permissible, value.

- This allowable value is obtained by dividing the nominal, or theoretical, strength by a factor of safety.

Allowable strength = (nominal (Theoretical) strength / safety factor)

Maximum applied stress ≤ allowable stress (If stresses are used instead of forces or moments). This approach to design is also called elastic design or working stress design. Working stresses are those resulting from the working loads, which are the applied loads. Working loads are also known as service loads.

Plastic design is based on a consideration of failure conditions rather than working load conditions. Members designed by plastic theory would reach the point of failure under the factored loads but are safe under actual working loads.

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

where

R_a = required strength
R_n = nominal strength (same as for LRFD)
Ω = safety factor
R_n/Ω = allowable strength

The required strength Ra is the sum of the service loads or load effects. Specific combinations of loads must be considered. Load combinations for ASD are given in ASCE 7. These combinations:

Combination 1: D

Combination 2: D + L

Combination 3: D + (Lr or S or R)

Combination 4: D + 0.75L + 0.75(Lr or S or R)

Combination 5: D ± (0.6W or 0.7E)

Combination 6a: D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)

Combination 6b: D + 0.75L ± 0.75(0.7E) + 0.75S

Combinations 7 and 8: 0.6D ± (0.6W or 0.7E)

where

D = dead load
L = live load due to occupancy
L_r = roof live load
S = snow load
R = rain or ice load*
W = wind load
E = earthquake (seismic load)

Load and resistance factor design (LRFD) is similar to plastic design in that strength, or the failure condition, is considered. Load factors are applied to the service loads, and a member is selected that will have enough strength to resist the factored loads.

- In addition, the theoretical strength of the member is reduced by the application of a resistance factor. The criterion that must be satisfied in the selection of a member is

Factored load ≤ factored strength

Loads x load factors ≤ resistance x resistance factor

- In terms of safety, this limit state can be fracture, yielding, or buckling.

$$\gamma_i Q_i \leq \phi R_n \tag{2.5}$$

where

Q_i = a load effect (a force or a moment)

γ_i = a load factor

R_n = the nominal resistance, or strength, of the component under consideration

ϕ = resistance factor

- ASCE 7 presents the basic load combinations in the following form:

Combination 1: 1.4D

Combination 2: 1.2D + 1.6L + 0.5(Lr or S or R)

Combination 3: 1.2D + 1.6(Lr or S or R) + (L or 0.5W)

Combination 4: 1.2D + 1.0W + L + 0.5(Lr or S or R)

Combination 5: 1.2D + 1.0E + L + 0.2S

Combination 6: 0.9D + 1.0W

Combination 7: 0.9D + 1.0E

where

D = dead load

L = live load due to occupancy

L_r = roof live load

S = snow load

R = rain or ice load*

W = wind load

E = earthquake (seismic load)

To conclude:

Allowable Stress Design ASD

- the total service load is compared to the allowable strength

The Tension Force $P = P_L + P_D$

Actual stress $f = \frac{P}{Ag}$ Ag = gross sectional area (in^2) f = Tensile Stress (ksi)

Allowable tension stress:

1- Yielding in Gross area (in solid section) $F_t \le \frac{Fy}{\Omega}$ Here $\Omega = 1.67$ $F_t = 0.6F_y$	2 – Fracture in Net area (in not solid section) $F_t \le \frac{Fu}{\Omega}$ Here $\Omega = 2$ $F_t = 0.5Fu$

Ω = strength factor

Load and resistance factor design (LRFD)

- The factored tensile load is compared to the design strength

HERE The ULTIMATE Tension Force $P_U = 1.6P_L + 1.2P_D$ (or other loads comb)

Actual stress $f = \frac{P}{Ag}$ Ag = gross sectional area (in^2) f = Tensile Stress (ksi)

Design strength:

2- Yielding in gross area (in solid section) $P_u \le ØF_yA_g$ Here Ø = 0.9	2 – Fracture in net area (in not solid section) $P_u \le ØF_uA_e$ Here Ø = 0.75

Ø = resistance Factor

STEEL CONSTRUCTION MANUAL

This publication contains the AISC Specification and numerous design aids in the form of tables and graphs, as well as a “catalog” of the most widely available structural shapes.

The Manual is divided into 17 parts as follows:

Part 1. Dimensions and Properties. This part contains details on standard hot-rolled shapes, pipe, and hollow structural sections, including all necessary cross-sectional dimensions and properties such as area and moment of inertia.

Part 2. General Design Considerations. This part includes a brief overview of various specifications (including a detailed discussion of the AISC Specification), codes and standards, some fundamental design and fabrication principles, and a discussion of the proper selection of materials.

Part 3. Design of Flexural Members. This part contains a discussion of Specification requirements and design aids for beams, including composite beams (in which a steel shape acts in combination with a reinforced concrete floor or roof slab) and plate girders.

Part 4. Design of Compression Members. Part 4 includes a discussion of the Specification requirements for compression members and numerous design aids.

Part 5. Design of Tension Members. This part includes design aids for tension members and a summary of the Specification requirements for tension members.

Part 6. Design of Members Subject to Combined Loading. Part 6 covers members subject to combined axial tension and flexure, combined axial compression and flexure, and combined torsion, flexure, shear, and/or axial force.

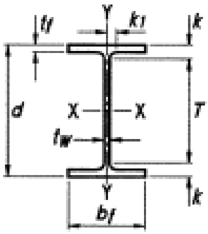

Table 1-1
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335[c]	98.5	44.0	44	1.03	1	1/2	15.9	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290[c]	85.4	43.6	43 5/8	0.865	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.36	2 7/16	1 1/4	↓	↓
×262[c]	77.2	43.3	43 1/4	0.785	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.20	2 1/4	1 3/16	↓	↓
×230[c,v]	67.8	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16	↓	↓
W40×593[h]	174	43.0	43	1.79	1 13/16	15/16	16.7	16 3/4	3.23	3 1/4	4.41	4 1/2	2 1/8	34	7 1/2
×503[h]	148	42.1	42	1.54	1 9/16	13/16	16.4	16 3/8	2.76	2 3/4	3.94	4	2	↓	↓
×431[h]	127	41.3	41 1/4	1.34	1 5/16	11/16	16.2	16 1/4	2.36	2 3/8	3.54	3 5/8	1 7/8	↓	↓
×397[h]	117	41.0	41	1.22	1 1/4	5/8	16.1	16 1/8	2.20	2 3/16	3.38	3 1/2	1 13/16	↓	↓
×372[h]	110	40.6	40 5/8	1.16	1 3/16	5/8	16.1	16 1/8	2.05	2 1/16	3.23	3 5/16	1 13/16	↓	↓
×362[h]	106	40.6	40 1/2	1.12	1 1/8	9/16	16.0	16	2.01	2	3.19	3 1/4	1 3/4	↓	↓
×324	95.3	40.2	40 1/8	1.00	1	1/2	15.9	15 7/8	1.81	1 13/16	2.99	3 1/16	1 11/16	↓	↓
×297[c]	87.3	39.8	39 7/8	0.930	15/16	1/2	15.8	15 7/8	1.65	1 5/8	2.83	2 15/16	1 11/16	↓	↓
×277[c]	81.5	39.7	39 3/4	0.830	13/16	7/16	15.8	15 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8	↓	↓
×249[c]	73.5	39.4	39 3/8	0.750	3/4	3/8	15.8	15 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16	↓	↓
×215[c]	63.5	39.0	39	0.650	5/8	5/16	15.8	15 3/4	1.22	1 1/4	2.40	2 1/2	1 9/16	↓	↓
×199[c]	58.8	38.7	38 5/8	0.650	5/8	5/16	15.8	15 3/4	1.07	1 1/16	2.25	2 5/16	1 9/16	↓	↓
W40×392[h]	116	41.6	41 5/8	1.42	1 7/16	3/4	12.4	12 3/8	2.52	2 1/2	3.70	3 13/16	1 15/16	34	7 1/2
×331[h]	97.7	40.8	40 3/4	1.22	1 1/4	5/8	12.2	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16	↓	↓
×327[h]	95.9	40.8	40 3/4	1.18	1 3/16	5/8	12.1	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16	↓	↓
×294	86.2	40.4	40 3/8	1.06	1 1/16	9/16	12.0	12	1.93	1 15/16	3.11	3 3/16	1 3/4	↓	↓
×278	82.3	40.2	40 1/8	1.03	1	1/2	12.0	12	1.81	1 13/16	2.99	3 1/16	1 3/4	↓	↓
×264	77.4	40.0	40	0.960	15/16	1/2	11.9	11 7/8	1.73	1 3/4	2.91	3	1 11/16	↓	↓
×235[c]	69.1	39.7	39 3/4	0.830	13/16	7/16	11.9	11 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8	↓	↓
×211[c]	62.1	39.4	39 3/8	0.750	3/4	3/8	11.8	11 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16	↓	↓
×183[c]	53.3	39.0	39	0.650	5/8	5/16	11.8	11 3/4	1.20	1 3/16	2.38	2 1/2	1 9/16	↓	↓
×167[c]	49.3	38.6	38 5/8	0.650	5/8	5/16	11.8	11 3/4	1.03	1	2.21	2 5/16	1 9/16	↓	↓
×149[c,v]	43.8	38.2	38 1/4	0.630	5/8	5/16	11.8	11 3/4	0.830	13/16	2.01	2 1/8	1 1/2	↓	↓

[c] Shape is slender for compression with $F_y = 50$ ksi.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

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