CHAPTER 2 PROBLEM SOLUTIONS (SECOND EDITION)

1. Name and describe five basic types/sources of building loads. (See Section 2.2)

Dead Load – the sum of the weights of permanent building and construction materials including self weight of the structure, partitions, floor and ceiling materials, equipment, etc

Live Load – the load on the structure that comes from all non-permanent installations including the weight of the occupants, moveable equipment, furniture, etc

Snow Load – Load experienced by a structure due to the weight of snow; dependent on local climate, building exposure, and building geometry

Wind Load – Load experienced by a structure due to its exposure to wind

Seismic Load – Load experienced by a structure during an earthquake

2. Categorize the following loads as dead load, live load, snow load, wind load, seismic load, or special load. (See Section 2.2)

a. Load on an office floor due to filing cabinets, desks, and computers. *Live*
b. Load on a roof from a permanent air handling unit. *Dead*
c. Load on stadium bleachers from students jumping up and down during a college football game. *Live*
d. Load on a building caused by an explosion. *Special – Blast*
e. Weight on a steel beam from a concrete slab that it is supporting. *Dead*
f. Load experienced by an office building in California as it shakes during an earthquake. *Seismic*
g. Load on a skyscraper in Chicago on a day with blustery conditions causing the building to sway back and forth. *Wind*

3. What is one source you can consult to find the snow load data for a particular region as well as maps showing wind gust data to allow you to calculate wind loads? (See Section 2.2)

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4. Where in the AISC Manual can you find a table of selected unit weights of common building materials? (See Section 2.3)

Table 17-13

5. What analysis method allows the designer to visualize the load on a particular structural element without performing an actual equilibrium calculation? (See Section 2.3)

Tributary Area Method

6. In determining the snow load on a structure, what value that can be obtained from the applicable building code is multiplied by a series of factors to obtain the actual snow load? (See Section 2.3.3)

Ground Snow Load

7. Name four factors that must be taken into account in converting wind speed data referenced by the building code into wind pressure on a given building. (See Section 2.3.4)

Building importance, height above ground, topography, direction of dominate winds

8. If a response modification factor of 3 is chosen in the design of a steel building to resist seismic loads, what design specification should be consulted? (See Section 2.3.5)

AISC Specification for Structural Steel Buildings

9. Which design approach combines loads that are normally at their nominal or serviceability levels? (See Section 2.4)

ASD - allowable strength design

10. Strength load combinations that are incorporated by the LRFD method take into account what two factors? (See Section 2.4)

The likelihood of the loads occurring simultaneously at their highest level and the margin against which failure of the structure is measured

11. Using ASCE 7-10, determine the minimum uniformly distributed live load for a hospital operating room.

Table 4-1, 60 psf

12. Using ASCE 7-10, determine the minimum uniformly distributed live load for library stacks.

Table 4-1, 150 psf

13. Using ASCE 7-10, determine the minimum uniformly distributed live load for an apartment building.

Table 4-1, 40 psf for private rooms

14. Determine the nominal uniformly distributed self-weight of a 6 in. thick reinforced concrete slab.

Reinforced concrete weighs 150 pounds per cubic foot. Thus (6/12)(150)=75 psf

15. A building has a column layout as shown in Figure P2.15 with 30 ft bays in each direction. It must support a uniform dead load of 90 psf and a uniform live load of 80 psf. Determine the required strength of the members noted below for design by (a) LRFD and (b) ASD.

i. The beam on column line 3 between column lines A and B if the deck spans from line 2-2 to 3-3 to 4-4.

ii. The girder on column line C between column lines 3 and 4 if the deck spans from line B-B to C-C to D-D.
iii. The column at the corner on lines 4 and A.
iv. The column on the edge at the intersection of lines C and 4.
v. The interior column at the intersection of column lines D and 3.

Part a. uniform load for LRFD $w_u = 1.2(90) + 1.6(80) = 236$ psf

Part b. uniform load for ASD $w_a = 90 + 80 = 170$ psf

Without Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$M_u = \dfrac{30(0.236)30^2}{8} = 797$ ft-kips $V_u = 30.0(0.236)\left(\dfrac{30.0}{2}\right) = 106$ kips	$M_a = \dfrac{30(0.170)30^2}{8} = 574$ ft-kips $V_a = 30.0(0.170)\left(\dfrac{30.0}{2}\right) = 76.5$ kips
ii.	$M_u = \dfrac{30(0.236)30^2}{8} = 797$ ft-kips $V_u = 30.0(0.236)\left(\dfrac{30.0}{2}\right) = 106$ kips	$M_a = \dfrac{30(0.170)30^2}{8} = 574$ ft-kips $V_a = 30.0(0.170)\left(\dfrac{30.0}{2}\right) = 76.5$ kips
iii.	$P_u = 15(15)(0.236) = 53.1$ kips	$P_a = 15(15)(0.170) = 38.3$ kips
iv.	$P_u = 30(15)(0.236) = 106$ kips	$P_a = 30(15)(0.170) = 76.5$ kips
v.	$P_u = 30(30)(0.236) = 212$ kips	$P_a = 30(30)(0.170) = 153$ kips

With Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$A_I = 30(60) = 1800\text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_u = 1.2(90) + 0.60(1.6)(80) = 185$ psf $M_u = \dfrac{30(0.185)30^2}{8} = 624$ ft-kips $V_u = 30.0(0.185)\left(\dfrac{30.0}{2}\right) = 83.3$ kips	$A_I = 30(60) = 1800\text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_a = 90 + 0.60(80) = 138$ psf $M_a = \dfrac{30(0.138)30^2}{8} = 466$ ft-kips $V_a = 30.0(0.138)\left(\dfrac{30.0}{2}\right) = 62.1$ kips

ii.	$A_I = 30(60) = 1800 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_u = 1.2(90) + 0.60(1.6)(80) = 185 \text{ psf}$ $M_u = \dfrac{30(0.185)30^2}{8} = 624 \text{ ft-kips}$ $V_u = 30.0(0.185)\left(\dfrac{30.0}{2}\right) = 83.3 \text{ kips}$	$A_I = 30(60) = 1800 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_a = 90 + 0.60(80) = 138 \text{ psf}$ $M_a = \dfrac{30(0.138)30^2}{8} = 466 \text{ ft-kips}$ $V_a = 30.0(0.138)\left(\dfrac{30.0}{2}\right) = 62.1 \text{ kips}$
iii.	$A_I = 30(30) = 900 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{900}}\right) = 0.75L_o > 0.50L_0$ $w_u = 1.2(90) + 0.75(1.6)(80) = 204 \text{ psf}$ $P_u = 15(15)(0.204) = 45.9 \text{ kips}$	$A_I = 30(30) = 900 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{900}}\right) = 0.75L_o > 0.50L_0$ $w_a = 90 + 0.75(80) = 150 \text{ psf}$ $P_a = 15(15)(0.150) = 33.8 \text{ kips}$
iv.	$A_I = 30(60) = 1800 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_u = 1.2(90) + 0.75(1.6)(80) = 185 \text{ psf}$ $P_u = 30(15)(0.185) = 83.3 \text{ kips}$	$A_I = 30(30) = 1800 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{1800}}\right) = 0.60L_o > 0.50L_0$ $w_a = 90 + 0.60(80) = 138 \text{ psf}$ $P_a = 30(15)(0.138) = 62.1 \text{ kips}$
v.	$A_I = 60(60) = 3600 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{3600}}\right) = 0.50L_o > 0.50L_0$ $w_u = 1.2(90) + 0.50(1.6)(80) = 172 \text{ psf}$ $P_u = 30(30)(0.204) = 184 \text{ kips}$	$A_I = 60(60) = 3600 \text{ ft}^2$ $L = L_o\left(0.25 + \dfrac{15}{\sqrt{3600}}\right) = 0.50L_o > 0.50L_0$ $w_a = 90 + 0.50(80) = 130 \text{ psf}$ $P_a = 30(30)(0.130) = 117 \text{ kips}$

16. If the framing plan shown in Figure P2.16 were for the roof of a structure that carried a dead load of 55 psf and a roof live load of 30 psf, determine the required moment and shear strength for beams and axial strength for columns, as required below for (a) design by LRFD and (b) design by ASD.

i. The girder on column line A between column lines 1 and 2 if the deck spans from line A-A to B-B.
ii. The beam on column line 3 between column lines B and C if the deck spans from line 2-2 to 3-3 to 4-4.
iii. The column at the corner on lines 1 and E.
iv. The column on the edge at the intersection of lines 1 and B.

v. The interior column at the intersection of column lines C and 2.

Part a. uniform load for LRFD $w_u = 1.2(55) + 1.6(30) = 114 \text{ psf}$

Part b. uniform load for ASD $w_a = 55 + 30 = 85 \text{ psf}$

Without Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$M_u = \frac{12.5(0.114)25^2}{8} = 111 \text{ ft-kips}$ $V_u = 12.5(0.114)\left(\frac{25}{2}\right) = 17.8 \text{ kips}$	$M_a = \frac{12.5(0.085)25^2}{8} = 83.0 \text{ ft-kips}$ $V_a = 12.5(0.085)\left(\frac{25}{2}\right) = 13.3 \text{ kips}$
ii.	$M_u = \frac{25(0.114)25^2}{8} = 223 \text{ ft-kips}$ $V_u = 25(0.114)\left(\frac{25}{2}\right) = 35.6 \text{ kips}$	$M_a = \frac{25(0.085)25^2}{8} = 166 \text{ ft-kips}$ $V_a = 25(0.0.085)\left(\frac{25}{2}\right) = 26.6 \text{ kips}$
iii.	$P_u = 12.5(12.5)(0.114) = 17.8 \text{ kips}$	$P_a = 12.5(12.5)(0.085) = 13.3 \text{ kips}$
iv.	$P_u = 12.5(25)(0.114) = 35.6 \text{ kips}$	$P_a = 12.5(25)(0.085) = 26.6 \text{ kips}$
v.	$P_u = 25(25)(0.114) = 71.3 \text{ kips}$	$P_a = 25(25)(0.085) = 53.1 \text{ kips}$

Since the roof live load, given as 30 psf, is greater than the normal roof live load of 20 psf, the usual floor live load reductions will be used. It might be a better practice to not reduce roof live loads when they are greater than 20 psf.

With Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$A_I = 25(25) = 625 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{625}}\right) = 0.85L_o > 0.50L_0$ $w_u = 1.2(55) + 0.85(1.6)(30) = 107 \text{ psf}$ $M_u = \frac{12.5(0.107)25^2}{8} = 104 \text{ ft-kips}$ $V_u = 12.5(0.107)\left(\frac{25}{2}\right) = 16.7 \text{ kips}$	$A_I = 25(25) = 625 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{625}}\right) = 0.85L_o > 0.50L_0$ $w_a = 55 + 0.85(30) = 80.5 \text{ psf}$ $M_a = \frac{12.5(0.0805)25^2}{8} = 78.6 \text{ ft-kips}$ $V_a = 12.5(0.0805)\left(\frac{25}{2}\right) = 12.6 \text{ kips}$

ii.	$A_I = 25(50) = 1250\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1250}}\right) = 0.67L_o > 0.50L_0$ $w_u = 1.2(55) + 0.67(1.6)(30) = 98.2\text{ psf}$ $M_u = \frac{25(0.0982)25^2}{8} = 192\text{ ft-kips}$ $V_u = 25(0.0982)\left(\frac{25}{2}\right) = 30.7\text{ kips}$	$A_I = 25(50) = 1250\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1250}}\right) = 0.67L_o > 0.50L_0$ $w_a = 55 + 0.67(30) = 75.1\text{ psf}$ $M_a = \frac{25(0.0751)25^2}{8} = 147\text{ ft-kips}$ $V_a = 25(0.0751)\left(\frac{25}{2}\right) = 23.5\text{ kips}$
iii.	$A_I = 25(25) = 625\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{625}}\right) = 0.85L_o > 0.50L_0$ $w_u = 1.2(55) + 0.85(1.6)(30) = 107\text{ psf}$ $P_u = 12.5(12.5)(0.107) = 16.7\text{ kips}$	$A_I = 25(25) = 625\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{625}}\right) = 0.85L_o > 0.50L_0$ $w_a = 55 + 0.85(30) = 80.5\text{ psf}$ $P_a = 12.5(12.5)(0.0805) = 12.6\text{ kips}$
iv.	$A_I = 25(50) = 1250\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1250}}\right) = 0.67L_o > 0.50L_0$ $w_u = 1.2(55) + 0.67(1.6)(30) = 98.2\text{ psf}$ $P_u = 12.5(25.0)(0.0982) = 30.7\text{ kips}$	$A_I = 25(50) = 1250\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1250}}\right) = 0.67L_o > 0.50L_0$ $w_a = 55 + 0.67(30) = 75.1\text{ psf}$ $P_a = 12.5(25.0)(0.0751) = 23.5\text{ kips}$
v.	$A_I = 50(50) = 2500\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{2500}}\right) = 0.55L_o > 0.50L_0$ $w_u = 1.2(55) + 0.55(1.6)(30) = 92.4\text{ psf}$ $P_u = 25(25)(0.0924) = 57.8\text{ kips}$	$A_I = 50(50) = 2500\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{2500}}\right) = 0.55L_o > 0.50L_0$ $w_a = 55 + 0.55(30) = 71.5\text{ psf}$ $P_a = 25(25)(0.0715) = 44.7\text{ kips}$

17. **T**he framing plan shown in Figure P2.17 is for an 18-story office building. It must support a dead load of 80 psf and a live load of 50 psf. In all cases, the decking spans in a direction from line A toward line E. Determine the required moment and shear strength for the beams and axial strength for the columns as required below for (a) design by LRFD and (b) design by ASD.

i. The beam between column lines 2 and 3 along line D.
ii. The girder on column line 3 between column line E and mid way between lines D and C.

iii. The beam on the line between lines C and D and column lines 3 and 4.
iv. The column at the corner on lines 1 and E that supports eight levels.
v. The column on the edge at the intersection of lines 4 and A that supports eight levels.
vi. The interior column at the intersection of column line 4 and the point midway between lines C and D that supports three levels.

Part a. uniform load for LRFD $w_u = 1.2(80) + 1.6(50) = 176 \text{ psf}$

Part b. uniform load for ASD $w_a = 80 + 50 = 130 \text{ psf}$

Without Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$M_u = \frac{12(0.176)(24)^2}{8} = 152 \text{ ft-kips}$ $V_u = 12(0.176)\frac{(24)}{2} = 25.3 \text{ kips}$	$M_a = \frac{12(0.130)(24)^2}{8} = 112 \text{ ft-kips}$ $V_a = 12(0.130)\frac{(24)}{2} = 18.7 \text{ kips}$
ii.	$P_u = 2(25.3) = 50.6 \text{ kips}$ $M_u = \frac{50.6(36)}{3} = 607 \text{ ft-kips}$ $V_u = 50.6 \text{ kips}$	$P_a = 2(18.7) = 37.4 \text{ kips}$ $M_a = \frac{37.4(36)}{3} = 489 \text{ ft-kips}$ $V_a = 37.4 \text{ kips}$
iii.	$M_u = \frac{12(0.176)(24)^2}{8} = 152 \text{ ft-kips}$ $V_u = 12(0.176)\frac{(24)}{2} = 25.3 \text{ kips}$	$M_a = \frac{12(0.130)(24)^2}{8} = 112 \text{ ft-kips}$ $V_a = 12(0.130)\frac{(24)}{2} = 18.7 \text{ kips}$
iv.	$P_u = \frac{8(24)(24)}{4}(0.176) = 203 \text{ kips}$	$P_a = \frac{8(24)(24)}{4}(0.130) = 150 \text{ kips}$
v.	$P_u = \frac{8(48)(36)}{4}(0.176) = 608 \text{ kips}$	$P_a = \frac{8(48)(36)}{4}(0.130) = 449 \text{ kips}$
vi.	$P_u = \frac{3(48)(60)}{4}(0.176) = 380 \text{ kips}$	$P_a = \frac{3(48)(60)}{4}(0.130) = 281 \text{ kips}$

With Live Load Reductions

	Part a. LRFD	**Part b. ASD**
i.	$A_I = 24(24) = 576\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{576}}\right) = 0.88L_o > 0.50L_0$ $w_u = 1.2(80) + 0.88(1.6)(50) = 166\text{ psf}$ $M_u = \frac{12(0.166)(24)^2}{8} = 143\text{ ft-kips}$ $V_u = 12(0.166)\frac{(24.0)}{2} = 23.9\text{ kips}$	$A_I = 24(24) = 576\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{576}}\right) = 0.88L_o > 0.50L_0$ $w_a = 80 + 0.88(50) = 124\text{ psf}$ $M_a = \frac{12(0.124)(24)^2}{8} = 107\text{ ft-kips}$ $V_a = 12(0.124)\frac{(24)}{2} = 17.9\text{ kips}$
ii.	$A_I = 48(36) = 1728\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1728}}\right) = 0.61L_o > 0.50L_0$ $w_u = 1.2(80) + 0.61(1.6)(50) = 145\text{ psf}$ $P_u = 2\left[12(0.145)\frac{(24)}{2}\right] = 41.8\text{ kips}$ $M_u = \frac{41.8(36)}{3} = 502\text{ ft-kips}$ $V_u = 41.8\text{ kips}$	$A_I = 48(36) = 1728\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{1728}}\right) = 0.61L_o > 0.50L_0$ $w_a = 80 + 0.61(50) = 111\text{ psf}$ $P_a = 2\left[12(0.111)\frac{(24)}{2}\right] = 32.0\text{ kips}$ $M_a = \frac{32.0(36)}{3} = 384\text{ ft-kips}$ $V_a = 32.0\text{ kips}$
iii.	$A_I = 24(24) = 576\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{576}}\right) = 0.88L_o > 0.50L_0$ $w_u = 1.2(80) + 0.88(1.6)(50) = 166\text{ psf}$ $M_u = \frac{12(0.166)(24)^2}{8} = 143\text{ ft-kips}$ $V_u = 12(0.166)\frac{(24)}{2} = 23.9\text{ kips}$	$A_I = 24(24) = 576\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{576}}\right) = 0.88L_o > 0.50L_0$ $w_a = 55 + 0.88(30) = 124\text{ psf}$ $M_a = \frac{12(0.124)(24)^2}{8} = 107\text{ ft-kips}$ $V_a = 12(0.124)\frac{(24)}{2} = 89.3\text{ kips}$
iv.	$A_I = 8(24)(24) = 4608\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{4608}}\right) = 0.47L_o > 0.40L_0$ $w_u = 1.2(80) + 0.47(1.6)(50) = 134\text{ psf}$ $P_u = \frac{8(24)(24)}{4}(0.134) = 154\text{ kips}$	$A_I = 8(24)(24) = 4608\text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{4608}}\right) = 0.47L_o > 0.40L_0$ $w_a = 80 + 0.47(50) = 104\text{ psf}$ $P_a = \frac{8(24)(24)}{4}(0.104) = 120\text{ kips}$

v.	$A_I = 8(48)(36) = 13824 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{13824}}\right) = 0.38L_o < 0.40L_0$ $w_u = 1.2(80) + 0.40(1.6)(50) = 128 \text{ psf}$ $P_u = \frac{8(48)(36)}{4}(0.128) = 442 \text{ kips}$	$A_I = 8(48)(36) = 13824 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{13824}}\right) = 0.38L_o < 0.40L_0$ $w_a = 80 + 0.40(50) = 100 \text{ psf}$ $P_a = \frac{8(48)(36)}{4}(0.100) = 346 \text{ kips}$
vi.	$A_I = 3(48)(60) = 8640 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{8640}}\right) = 0.41L_o > 0.40L_0$ $w_u = 1.2(80) + 0.41(1.6)(50) = 129 \text{ psf}$ $P_u = \frac{3(48)(60)}{4}(0.129) = 279 \text{ kips}$	$A_I = 3(48)(60) = 8640 \text{ ft}^2$ $L = L_o\left(0.25 + \frac{15}{\sqrt{8640}}\right) = 0.41L_o > 0.40L_0$ $w_a = 80 + 0.41(50) = 101 \text{ psf}$ $P_a = \frac{3(48)(60)}{4}(0.101) = 218 \text{ kips}$