CEE380
Engineering Structures II
Vertical Loads

Load path: simple frame

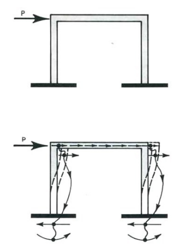
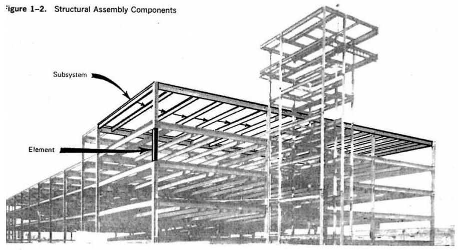


Figure 1–8. Load Path Diagram for Frame

Subdivide for a structural system

Figure 1–2. Structural Assembly Components



Beam design

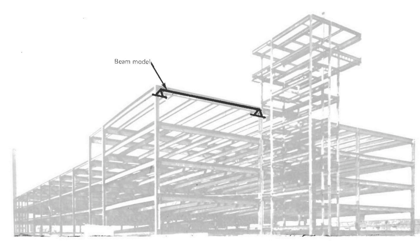
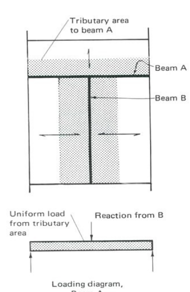


Figure 1–4. Mathematical Model of Beam

Tributary area for beams



Tributary area: Columns

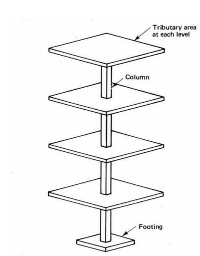
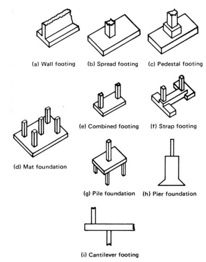


Figure 4–8. Tributary Area to Columns

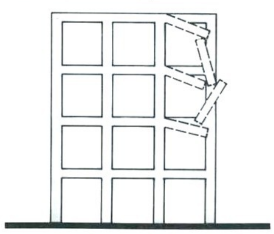
Hess (2004)

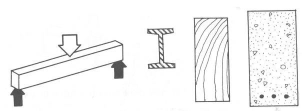
Foundation types



Progressive Collapse

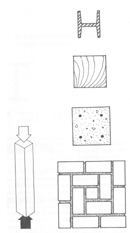
Figure 2–8. Progressive Collapse



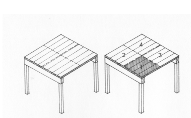


1.44 RELATIVE SIZE OF BEAMS

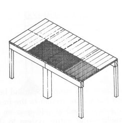
Use of Different Materials



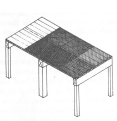
1.45 RELATIVE SIZE OF COLUMNS



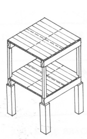
3.10 TWO SINGLE BAYS



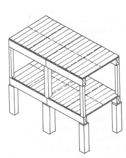
3.11 TWO BAYS COMBINED



3.12 ALTERNATE COMBINATION OF TWO BAYS



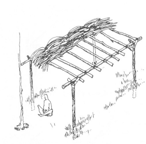
3.13 TWO STACKED BAYS



3.14 FOUR STACKED BAYS

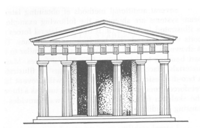
Post and beam structural evolution

[Corkill, Puderbaugh and Sawyers, (1965)]



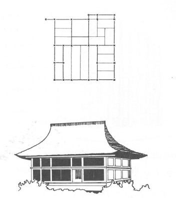
3.23 PRIMITIVE POST AND BEAM SHELTER

Greek temple: classic expression of post & beam



3.24 THE THESEION. ATHENS. 449-444 B.C.

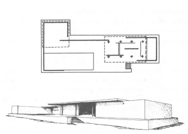
Post and beam in traditional Japanese architecture



3.25 JAPANESE HOUSE. 19th. CENTURY

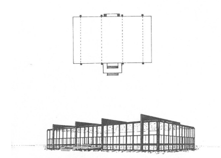
Severe plan limitations

Contemporary post & beam construction: flexible layout



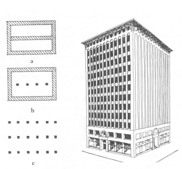
3.26 GERMAN PAVILION. BARCELONA.
MIES VAN DER ROHE. 1929

Glass facade with minimal column support



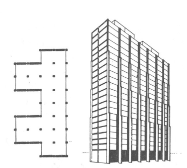
3.27 CROWN HALL. I.I.T.
MIES VAN DER ROHE. 1952

Early development of post & beam skyscraper



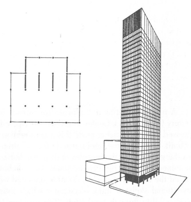
3.28 GUARANTY BUILDING. BUFFALO.
SULLIVAN. 1895

Skeleton frame

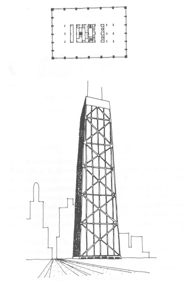


3.29 PROMONTORY APARTMENTS. CHICAGO.
MIES VAN DER ROHE. 1949

Evolution of skeleton frame



3.30 SEAGRAM BUILDING. NEW YORK.
MIES VAN DER ROHE. 1957



3.31 JOHN HANCOCK CENTER. CHICAGO.
SKIDMORE, OWINGS and MERRILL. 1968

Hess (2004)

And evolving…

Fordham Spire

Dead Loads

- Given: Dimensions and materials
- Find: Dead Load on Beam
- Solution:
  – Look up materials
  – Multiply by the tributary areas
  – Sum

Dead Loads

- Example [Coleman]: A floor spandrel (perimeter) beam supports a 4-ft width of 6-in thick concrete slab, the same tributary width of acoustical fiber board ceiling system and a 6 ft height of exterior masonry wall composed of 4-in thick and 8 in concrete block (heavy weight) of 55 psf. Calculate the dead load on the beam.

Solution

- Concrete Slab = 6 in x 12 psf/in x 4 ft =288 lb/ft
- Ceiling = 1 psf x 4 ft = 4 lb/ft
- Brick wall = 39 psf x 6 ft = 234 lb/ft
- Block wall = 55 psf x 6 ft = 330 lb/ft
- Total Load = **872 lb/ft**

Dead Load Example

- Determine the total dead load for an interior column of a three story concrete building with bays of 30 ft by 30 ft. Dead loads are 50 psf for the roof and floors.

Solution

- Tributary area at each level for the interior column is 30 ft by 30 ft = 900 ft^2
- The roof load = area x dead load = 900 ft^2 x 50 psf = 45,000 lbs
- The floor load = area x dead load = 2 floors x 900 ft^2 x 50 psf = 90,000 lbs
- Total column load = **135,000 lbs**

Live Loads

- Definition: Loads "produced by the use and occupancy of the building"
- May be uniform or concentrated
- Non-permanent loads, such as
  - People
  - Furniture
  - Vehicles
  - Minor equipment

Hess (2004)

Live Load Example

- A hotel is to contain a restaurant on the top floor and a ballroom on the second floor, and all other floors will contain guest rooms and corridors. Determine the live load to be used.

Solution

- Restaurant = 100 psf
- Ballroom = 100 psf
- Corridors = 100 psf
- Guest rooms = 40 psf
- Guest corridors = 40 psf

LL Reduction ASCE7-10, p. 15 Chapter 4; Table 4.1 pp. 17-19.

$$L = L_0\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right)$$

$for K_{LL}A_T \leq 400 ft^2$

L = reduced design live lod per sq. ft. of area supported by member

L_0 = unreduced design live load ...(Table 4 - 1)

K_{LL} = live load element factor (Table 4 - 2)

A_T = tributary area

Roof Live Loads L_r
Chapter 4, p. 15-16

$$L_r = 20R_1R_2$$

$$where\ R_1 = \begin{cases} 1 & \text{for } A_T \leq 200 ft^2 \\ 1.2 - 0.001A_T & \text{for } 200 ft^2 < A_T < 600 ft^2 \\ 0.6 & \text{for } A_T \geq 600 ft^2 \end{cases}$$

$$R2 = \begin{cases} 1 & \text{for } F \leq 4 \\ 1.2 - 0.05F & \text{for } 4 < F < 12 \\ 0.6 & \text{for F} \geq 12 \end{cases}$$

$F \equiv$ number of inches of rise per foot for a sloped roof

Area discussion

- ASCE7 used to distinguish between an influence area A_I and a tributary area A_T for live loads -- see the commentary. However, the latest ASCE7 modified the LL equation to include the tributary area only.
- Since some building codes still use the notion of influence area, we will discuss it.

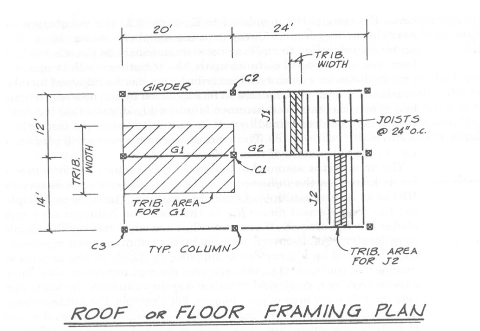


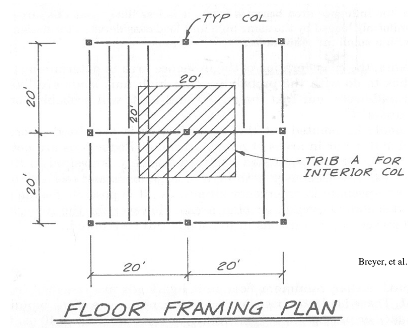
Figure 2.2

Breyer, et al. (2004)

Tributary Area Calculations

	A_T = trib. width × span	$A_I = A_T \times K_{LL}$
Joist J1	$A_T = 2 \times 12 = 24\ ft^2$	$A_I = 24 \times 2 = 48\ ft^2$
Joist J2	$A_T = 2 \times 14 = 28\ ft^2$	$A_I = 28 \times 2 = 56\ ft^2$
Girder G1	$A_T = (12/2 + 14/2)20 = 260\ ft^2$	$A_I = 260 \times 2 = 520\ ft^2$
Girder G2	$A_T = (12/2 + 14/2)24 = 312\ ft^2$	$A_I = 312 \times 2 = 624\ ft^2$
Interior column C1	$A_T = (12/2 + 14/2)(20/2 + 24/2) = 286\ ft^2$	$A_I = 286 \times 4 = 1144\ ft^2$
Exterior column C2	$A_T = (12/2)(20/2 + 24/2) = 132\ ft^2$	$A_I = 132 \times 4 = 528\ ft^2$
Corner column C3	$A_T = (14/2)(20/2) = 70\ ft^2$	$A_I = 70 \times 2 = 140\ ft^2$

Breyer, et al. (2004)



Breyer, et al. (2004)

Figure 2.3

Moving live loads

- How do we estimate the largest stress induced in a bridge or parking garage by moving loads?
- Influence lines
  - Notes will be provided
  - Mostly transportation applications
  - Will delay this discussion

(7.0) Snow Loads p. 29

- Also vertical loadings
- Map of ground snow loads provided pp. 34-35: modified for roof loading
- Slope of roof important
- Drift important

Snow Load Calculations

Flat Roof Snow Loads p_f

$$p_f[psf] = 0.7 C_e C_t I_s p_g$$

$C_e \equiv$ Exposure Factor, Table 7 - 2, p. 30; Exposure Section 26.7, p. 246

$C_t \equiv$ Thermal Factor, Table 7 - 3, p. 30

$I_s \equiv$ Importance Factor, Table 1.5 - 2, p. 5

Exposure Factor

Table 7-2 Exposure Factor, C_e

Terrain Category	Exposure of Roof[a] Fully Exposed	Partially Exposed	Sheltered
B (see Section 26.7)	0.9	1.0	1.2
C (see Section 26.7)	0.9	1.0	1.1
D (see Section 26.7)	0.8	0.9	1.0
Above the treeline in windswept mountainous areas.	0.7	0.8	N/A
In Alaska, in areas where trees do not exist within a 2-mile (3-km) radius of the site.	0.7	0.8	N/A

The terrain category and roof exposure condition chosen shall be representative of the anticipated conditions during the life of the structure. An exposure factor shall be determined for each roof of a structure.

[a]Definitions: Partially Exposed: All roofs except as indicated in the following text. Fully Exposed: Roofs exposed on all sides with no shelter[b] afforded by terrain, higher structures, or trees. Roofs that contain several large pieces of mechanical equipment, parapets that extend above the height of the balanced snow load (h_b), or other obstructions are not in this category. Sheltered: Roofs located tight in among conifers that qualify as obstructions.

[b]Obstructions within a distance of $10h_o$ provide "shelter," where h_o is the height of the obstruction above the roof level. If the only obstructions are a few deciduous trees that are leafless in winter, the "fully exposed" category shall be used. Note that these are heights above the roof. Heights used to establish the Exposure Category in Section 26.7 are heights above the ground.

Thermal Factor

Table 7-3 Thermal Factor, C_t

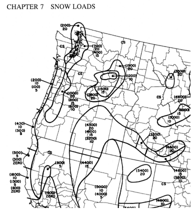
Thermal Condition[a]	C_t
All structures except as indicated below	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance (R-value) between the ventilated space and the heated space exceeds 25 °F × h × ft²/Btu (4.4 K × m²/W).	1.1
Unheated and open air structures	1.2
Structures intentionally kept below freezing	1.3
Continuously heated greenhouses[b] with a roof having a thermal resistance (R-value) less than 2.0 °F × h × ft²/Btu (0.4 K × m²/W)	0.85

[a]These conditions shall be representative of the anticipated conditions during winters for the life of the structure.

[b]Greenhouses with a constantly maintained interior temperature of 50 °F (10 °C) or more at any point 3 ft above the floor level during winters and having either a maintenance attendant on duty at all times or a temperature alarm system to provide warning in the event of a heating failure.

Snow Loads Figure [partial]

CHAPTER 7 SNOW LOADS



General

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent a low risk to human life in the event of failure	I •
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life. Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure. Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where their quantity exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	III
Buildings and other structures designated as essential facilities. Buildings and other structures, the failure of which could pose a substantial hazard to the community. Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity exceeds a threshold quantity established by the authority having jurisdiction to be dangerous to the public if released and is sufficient to pose a threat to the public if released.[a] Buildings and other structures required to maintain the functionality of other Risk Category IV structures.	IV

[a]Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in Section 1.5.2 that a release of the substances is commensurate with the risk associated with that Risk Category.

General

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads[a]

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.25	1.00	1.25
IV	1.20	1.25	1.00	1.50

[a]The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it is dependent on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Snow Loads Continued

Minimum Snow Load for Low - Slope Roofs, p_m [p.29]
Monoslope, hip & gable roofs
with slopes less than 15 degrees...
Where $p_g \leq 20\ psf,\ p_m = I_s p_g$
Where $p_g > 20\ psf,\ p_m = 20 I_s$

Sloped Roof Snow Loads[p. 31]
$p_s = C_s p_f$
Where $C_s \equiv$ Roof Slope Factor Figure 7 - 2 p. 36

Unbalanced Roof Loads p. 32

Rain - on - Snow Surcharge Load : p. 33
This may apply to Puget Sound area.

Lateral loads: Wind (26.0+), Seismic (11.0 +)

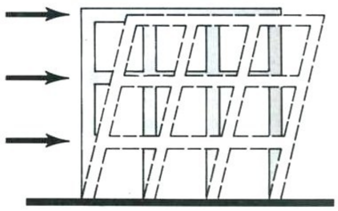


Figure 2–7. Lateral Load Stability

Summary

- Introduction to ASCE7-10
- Dead and Live Loads
  - Tributary areas--load path
  - Tables for use
  - Effect of moving live loads (cars) determined by influence line procedures
- Snow Loads
- Effect of lateral loads differs from vertical ones.

References

- *ASCE7*
- *Structural Systems Design*, Coleman [out of print]
- *Fundamentals of Structural Design*, L.A. Hill, Jr. [out of print]
- *Army Manual TM 5-809-10*