Structural Loads

Dead Loads: Gravity loads of constant magnitudes and fixed positions that act permanently on the structure. Such loads consist of the weights of the structural system itself and of all other material and equipment permanently attached to the structural system. Weights of permanent equipment, such as heating and air-conditioning systems, are usually obtained from the manufacturer.

Table 1. Typical Design Dead Loads

(a) Material Weights

Substance	Weight, lb/ft³ (kN/m³)
Steel	490 (77.0)
Aluminum	165 (25.9)
Reinforced concrete:	
Normal weight	150 (23.6)
Light weight	90–120 (14.1–18.9)
Brick	120 (18.9)
Wood	
Southern pine	37 (5.8)
Douglas fir	34 (5.3)

Table 1. Typical Design Dead Loads

(b) Building Component Weights

Component	Weight, lb/ft² (kN/m²)
Ceilings	
Gypsum plaster on suspended metal lath	10 (0.48)
Acoustical fiber tile on rock lath and channel ceiling	5 (0.24)
Floors	
Reinforced concrete slab per inch of thickness	
Normal weight	$12\frac{1}{2}$ (0.60)
Lightweight	6–10 (0.29–0.48)
Roofs	
Three-ply felt tar and gravel	$5\frac{1}{2}$ (0.26)
2-in insulation	3 (0.14)
Walls and partitions	
Gypsum board (1-in thick)	4 (0.19)
Brick (per inch of thickness)	10 (0.48)
Hollow concrete block (12 in thick)	
Heavy aggregate	80 (3.83)
Light aggregate	55 (2.63)
Clay tile (6-in thick)	30 (1.44)
2 × 4 studs 16 in on center, $\frac{1}{2}$-in gypsum wall on both sides	8 (0.38)

Dead Load Adjustments

Adjustments are made in the distribution of dead loads due to the placement of utility lines under the floor system and fixtures (lights, ducts, etc.) on the floor ceiling, which is the floor for the next story if one exists. Rather than worry about the actual weight and location of such routine building additions, the structural engineer will normally assess an increase in the floor dead load of 10 to 15 lbs/ft^2 (psf) to ensure that the strength of the floor, beams, and columns are adequate.

In addition, designers try to position beams directly under heavy masonry walls to carry this weight directly into the supports or columns. If this is not possible, then the load is smeared as an additional floor load pressure of 10 to 40 lbs/ft^2, depending on the masonry wall size.

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Live Loads: Structural (typically gravity) loads of varying magnitudes and/or positions caused by the use of the structure.

Furthermore, the position of a live load may change, so each member of the structure must be designed for the position of the load that causes the maximum stress in that member.

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Building Loads

The magnitudes of building design live loads are usually specified in building codes. Live loads for buildings are usually specified as uniformly distributed surface loads in pounds per square foot or kilopascals (kN/m^2; 1 Pa = 1 N/m^2). Distributed live loads are given in Table 2.

Design concentrated live loads are given in the USCS (US Customary System) units in Table 3.

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Table 2. Typical Design Live Loads

Occupancy Use	Live Load, lb/ft^2 (kN/m^2)
Assembly areas and theaters	
Fixed seats (fastened to floor)	60 (2.87)
Lobbies	100 (4.79)
Stage floors	150 (7.18)
Libraries	
Reading rooms	60 (2.87)
Stack rooms	150 (7.18)
Office buildings	
Lobbies	100 (4.79)
Offices	50 (2.40)
Residential	
Habitable attics and sleeping areas	30 (1.44)
Uninhabitable attics with storage	20 (0.96)
All other areas	40 (1.92)
Schools	
Classrooms	40 (1.92)
Corridors above the first floor	80 (3.83)

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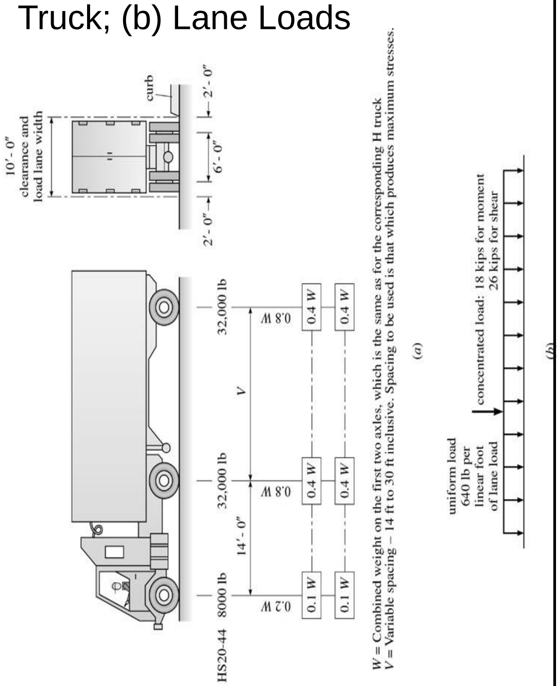
Table 3. Typical Concentrated Live Loads

Area or Structural Component	Concentrated Live Load
Elevator Machine Room on 4-in^2	300 lbs
Office Floors	2000 lbs
Center or Stair Tread on 4-in^2	300 lbs
Sidewalks	8000 lbs
Accessible Ceilings	200 lbs

Bridge Loads

Live loads due to vehicular traffic on highway bridges are specified by the American Association of State Highway and Transportation Officials (AASHTO) Specification. Since the heaviest loading on highway bridges is usually caused by trucks, the AASHTO Specification defines two systems of standard loads, *HS trucks and lane loading*, to represent the vehicular loads for design purposes as shown in the following figure.

Bridge Loading: (a) HS 20 – 44 Truck; (b) Lane Loads



Impact Load Factors

When live loads are applied rapidly to a structure, they cause larger stresses than those that would be produced if the same loads would have been applied gradually. This dynamic effect of the load is referred to as ***impact***.

Live loads expected to cause such a dynamic effect on structures are increased by impact factors.

Building Load Impact

Building load impact factors are given in the table below. These impact loads are added to the design loads to approximate the dynamic effect of load on a static analysis (**I** ≡ impact factor).

Loading Case	% I
Elevator Supports & Machinery	100
Light machinery supports	20
Reciprocating machine supports	50
Hangers supporting floors & balconies	33
Crane support girders	25

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Bridge Impact Load Multiplier

AASHTO specifies the following expression for highway bridges:

$$I = \frac{50}{L + 125} \leq 0.3 \quad \text{(U.S. Units)}$$

$$I = \frac{15}{L + 38.1} \leq 0.3 \quad \text{(SI Units)}$$

I ≡ impact factor

L ≡ length in feet (or meters) of the portion of the span loaded to cause the maximum stress in the member

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Since loaded span length inversely affects bridge impact, this simply means that a short span bridge will experience greater dynamic impact than a long span bridge.

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Roof Live Loads

Largest roof loads typically caused by repair and maintenance

pitch ≡ rise/span

$$L_r = 20\, R_1\, R_2$$

$$12 < L_r \leq 20$$

L_r ≡ horizontal projection roof live load

R_1, R_2= live load reduction factors

R_1 – accounts for size of tributary area of roof column A_t

R_2 – effect of the roof rise

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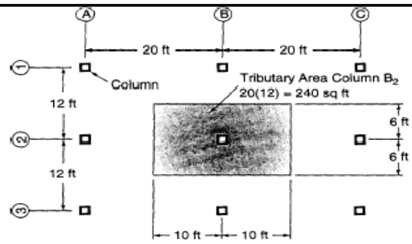

$$R_1 = \begin{cases} 1.0 & A_t \le 200\,ft^2 \\ 1.2 - 0.001A_t & 200\,ft^2 < A_t < 600\,ft^2 \\ 0.6 & A_t \ge 600\,ft^2 \end{cases}$$

$$R_2 = \begin{cases} 1.0 & F \le 4 \\ 1.2 - 0.05F & 4 < F < 12 \\ 0.6 & F \ge 12 \end{cases}$$

F = rise in inches per foot of span

= pitch x 32 – dome or arch roof

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Environmental Loads: Structural loads caused by the environment in which the structure is located; special examples of live loads. Rain, snow, ice, wind and earth-quake loadings are examples of environmental loads.

Rain Loads: Ponding – water accumulates on roof faster than it runs off thus increasing the roof loads. Typically, roofs with slopes of 0.25 in/ft or greater are not subjected to ponding unless roof drains become clogged.

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Wind loads are produced by the flow of wind around structures. Wind load magnitudes vary in proportion to the distance from the base of the structure, peak wind speed, type of terrain, importance factor, and side of building and roof slope.

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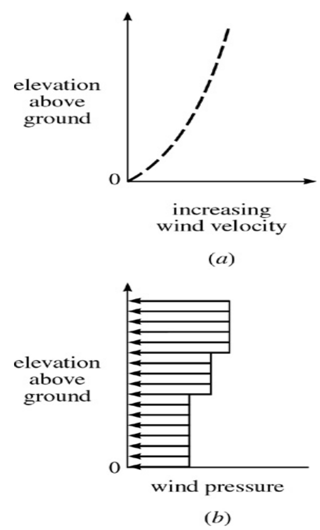

Variation of Wind Velocity with Distance Above Ground

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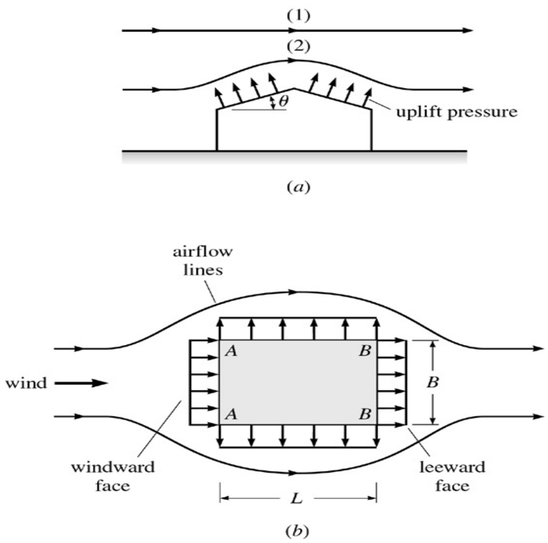

Uplift pressure on sloping roof; wind speed on line 2 is larger than line 1 due to greater path length. Increased velocity reduces pressure on top of roof creating a pressure differential between inside and outside of the building.

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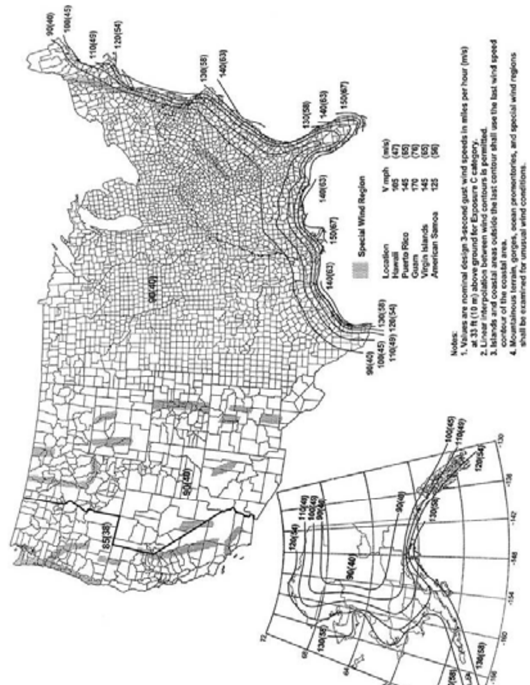
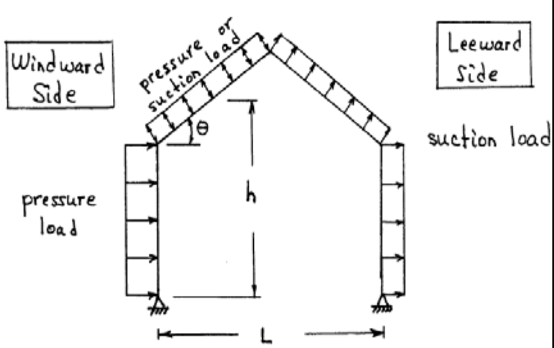


Wind Speed Map of US



Roof loading on the windward side is a suction load for small angles θ and h/L ratios. Increas-ing θ for a fixed value of h/L will lead to the windward roof load being a pressure load. Con-versely, increasing h/L for a fixed θ will result in a suction roof load on the windward side.

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Earthquake Forces

An **earthquake** is a sudden un-dulation of a portion of the earth's surface. Although the ground surface moves in both horizontal and vertical directions during an earthquake, the magnitude of the vertical component of ground motion is usually small and does not have a significant impact on most structures.

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(NOTE: This last statement is being vigorously reconsidered in light of recent earthquakes in California and Japan.)

It is the horizontal component of ground motion that causes structural damage and that must be considered in designs of structures located in earthquake-prone areas.

Vertical motions that result in differential upward movements do cause large stresses in structures.

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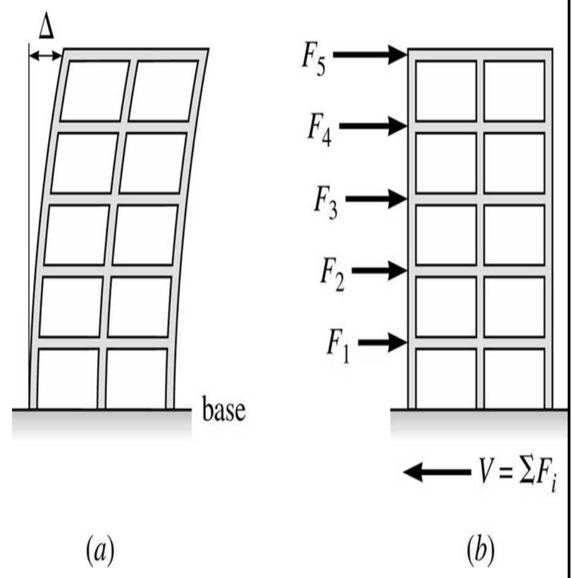

Lateral Force Distribution due to Lateral Earthquake Motion

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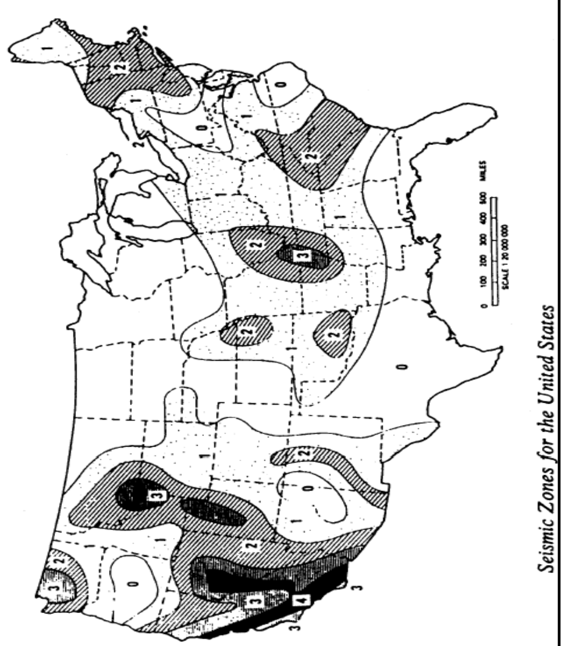

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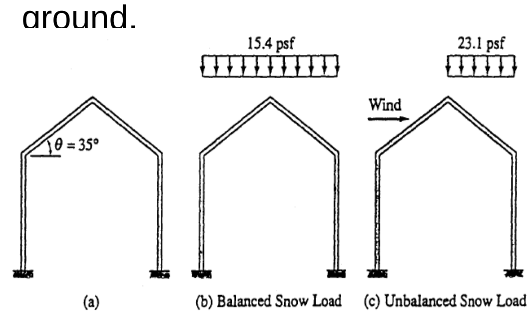
Snow Loads

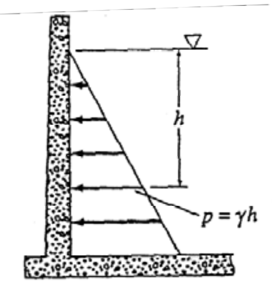
Design snow load for a structure is based on the ground snow load for its geographic location, exposure to wind, and its thermal, geometric, and functional characteristics. In most cases, there is less snow on the roof than on the ground.



Hydrostatic and Soil Pressures

Hydrostatic pressure acts normal to the submerged surface of the structure, with its magnitude varying linearly with height, as shown in the figure below.

γ = unit weight



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Miscellaneous Loads

- Ice loads
- Flooding
- Blast loads
- Thermal forces
- Centrifugal forces
- Longitudinal loads due to braking of large trucks or trains on bridges, ships entering a harbor, or cranes on a rail

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