2. Combinations of Loads

2.1 General. Buildings and other structures shall be designed using the provisions of either 2.3 or 2.4. Either 2.3 or 2.4 shall be used exclusively for proportioning elements of a particular construction material throughout the structure.

2.2 Symbols and Notation:

D = dead load.
E = earthquake load;
F = load due to fluids with well-defined pressures and maximum heights;
F_a = flood load
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L = live load.
L_r = roof live load;
R = rain load.
S = snow load
T = self-straining force;
W = wind load

2.3 Combining Factored Loads Using Strength Design

2.3.1 Applicability. The load combinations and load factors given in 2.3.2 shall be used only in those cases in which they are specifically authorized by the applicable material design standard.

2.3.2 Basic Combinations. Structures, components, and foundations shall be designed so that their design strength equals or exceeds the effects of the factored loads in the following combinations:

1. 1.4(D + F)
2. 1.2(D+F+T) + 1.6(L+H) + 0.5(L, or S or R)
3. 1.2D + 1.6(L, or S or R) + (0.5L or 0.8W)
4. 1.2D + 1.6W + 0.5L + 0.5(L, or S or R)
5. 1.2D + 1.0E +0.5L + 0.2S
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

Exceptions

1. The load factor on L in combinations (3), (4), and (5) shall equal 1.0 for garages, areas occupied as places of public assembly, and all areas where the live load is greater than 100 lb/ft² (pounds-force per square foot) (4.79 kN/m²).
2. The load factor on H shall be set equal to zero in combinations (6) and (7) if the structural action due to H counteracts that due to W or E. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H but shall be included in the design resistance.

Each relevant strength limit state shall be investigated. Effects of one or more loads not acting shall be investigated. The most unfavorable effects from both wind and earthquake loads shall be investigated, where appropriate, but they need not be considered to act simultaneously. Refer to Sec. 9.2.2 for specific definition of the earthquake load effect E.[1]

2.3.3 Load Combinations Including Flood Load. When a structure is located in a flood zone (Section 5.3.1), the following load combinations shall be considered:

1. In V-Zones or Coastal A-Zones, 1.6W in combinations (4) and (6) shall be replaced by $1.6W + 2.0F_a$.

2. In non-coastal A-Zones, 1.6W in combinations (4) and (6) shall be replaced by $0.8W + 1.0F_a$.

2.4 Combining Nominal Loads Using Allowable Stress Design

2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations, whichever produces the most unfavorable effect in the building, foundation, or structural member being considered. Effects of one or more loads not acting shall be considered.

1. D
2. D + L + F + H + T + (L, or S or R)
3. D + (W or 0.7 E) + L + (L, or S or R)
4. 0.6D + W + H
5. 0.6D + 0.7E + H

The most unfavorable effects from both wind and earthquake loads shall be considered, where appropriate, but they need not be assumed to act simultaneously. Refer to Sec. 9.2.2 for the specific definition of the earthquake load effect E.[1]

2.4.2 Load Combinations Including Flood Load. When a structure is located in a flood zone, the following load combinations shall be considered:

1. In V-Zones or Coastal A-Zones (Section 5.3.1), $1.5F_a$ shall be added to other loads in combinations (3) and (4), and E shall be set equal to zero in (3).
2. In non-coastal A-Zones, $0.75F_a$ shall be added to combinations (3) and (4), and E shall be set equal to zero in (3).

2.4.3 Load Reduction. When structural effects due to two or more loads in combination with dead load, but excluding earthquake load, are investigated in load

[1] The same E from Sec. 9 is used for both Sec. 2.3.2 and Sec. 2.4.1. Refer to the Commentary for Sec. 9.

combinations of 2.4.1 and 2.4.2, the combined effects due to the two or more loads multiplied by 0.75 plus effects due to dead loads shall not be less than the effects from the load combination of the dead load plus the load producing the largest effects

Increases in allowable stress shall not be used with these loads or load combinations unless it can be demonstrated that such an increase is justified by structural behavior caused by rate or duration of load

The load combinations including earthquake loads shall follow the requirements in Section 9

2.5 Load Combinations for Extraordinary Events. Where required by the applicable code, standard, or the authority having jurisdiction, strength and stability shall be checked to ensure that structures are capable of withstanding the effects of extraordinary (i.e. low-probability) events such as fires, explosions and vehicular impact

3 Dead Loads

3.1 Definition. Dead loads consist of the weight of all materials of construction incorporated into the building including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment including the weight of cranes.

3.2 Weights of Materials and Constructions. In determining dead loads for purposes of design, the actual weights of materials and constructions shall be used, provided that in the absence of definite information, values approved by the authority having jurisdiction shall be used.

3.3 Weight of Fixed Service Equipment. In determining dead loads for purposes of design, the weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, and heating, ventilating, and air conditioning systems, shall be included.

4. Live Loads

4.1 Definition. Live loads are those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load. Live loads on a roof are those produced (1) during maintenance by workers, equipment, and materials and (2) during the life of the structure by movable objects such as planters and by people.

4.2 Uniformly Distributed Loads

4.2.1 Required Live Loads. The live loads used in the design of buildings and other structures shall be the maximum loads expected by the intended use or occupancy but shall in no case be less than the minimum uniformly distributed unit loads required by Table 4-1.

4.2.2 Provision for Partitions. In office buildings or other buildings, where partitions will be erected or rearranged, provision for partition weight shall be made, whether or not partitions are shown on the plans, unless the specified live load exceeds 80 lb/ft^2 (3.83 kN/m^2).

4.3 Concentrated Loads. Floors and other similar surfaces shall be designed to support safely the uniformly distributed live loads prescribed in 4.2 or the concentrated load, in pounds (kilonewtons), given in Table 4-1, whichever produces the greater load effects. Unless otherwise specified, the indicated concentration shall be assumed to be uniformly distributed over an area 2.5 feet (762 mm) square [6.25 ft^2 (0.58 m^2)] and shall be located so as to produce the maximum load effects in the structural members.

Any single panel point of the lower chord of exposed roof trusses or any point along the primary structural members supporting roofs over manufacturing, commercial storage and warehousing, and commercial garage floors shall be capable of carrying safely a suspended concentrated load of not less than 2000 lb (poundforce) (8.90 kN) in addition to dead load. For all other occupancies, a load of 200 lb (0.89 kN) shall be used instead of 2000 lb (8.90 kN).

4.4 Loads on Handrails, Guardrail Systems, Grab Bar Systems, Vehicle Barrier Systems, and Fixed Ladders

4.4.1 Definitions.

Handrail: a rail grasped by hand for guidance and support. A handrail assembly includes the handrail, supporting attachments and structures.

Fixed Ladder: A ladder that is permanently attached to a structure, building, or equipment.

Guardrail system: a system of building components near open sides of an elevated surface for the purpose of minimizing the possibility of a fall from the elevated surface by people, equipment or material.

Grab bar system: a bar provided to support body weight in locations such as toilets, showers and tub enclosures.

Vehicle barrier system: a system of building components near open sides of a garage floor or ramp or building walls which act as restraints for vehicles.

4.4.2 Loads.

(a) Handrail assemblies and guardrail systems shall be designed to resist a load of 50 lb/ft (pound-force per linear foot) (0.73 kN/m) applied in any direction at the top and to transfer this load through the supports to the structure. For one- and two-family dwellings, the minimum load shall be 20 lb/ft (0.29 kN/m).

Further, all handrail assemblies and guardrail systems shall be able to resist a single concentrated load of 200 lb (0.89 kN), applied in any direction at any point along the top, and have attachment devices and supporting structure to transfer this loading to appropriate structural elements of the building. This load need not be assumed to act concurrently with the loads specified in the preceding paragraph.

Intermediate rails (all those except the handrail), balusters, and panel fillers shall be designed to withstand a horizontally applied normal load of 50 lb (0.22 kN) on an area not to exceed 1'-0" square (305 mm square), including openings and space between rails. Reactions due to this loading are not required to be superimposed with those of either preceding paragraph.

(b) Grab bar systems shall be designed to resist a single concentrated load of 250 lb (1.11 kN) applied in any direction at any point.

(c) Vehicle barrier systems for passenger cars shall be designed to resist a single load of 6,000 lb (26.70 kN) applied horizontally in any direction to the barrier system, and shall have anchorages or attachments capable of transferring this load to the structure. For design of the system the load shall be assumed to act at a minimum height of 1'-6" (460 mm) above the floor or ramp surface on an area not to exceed 1'-0" square (305 mm square), and is not required to be assumed to act concurrently with any handrail or guardrail loadings specified in the preceding paragraphs of 4.4.2. Garages accommodating trucks and buses shall be designed in accordance with an approved method which contains provision for traffic railings.

(d) The minimum design live load on fixed ladders with rungs shall be a single concentrated load of 300 lbs., and shall be applied at any point to produce the maximum load effect on the element being considered. The number and position of additional concentrated live load units shall be a minimum of one unit of 300 lbs. for every 10 feet of ladder height.

(e) Where rails of fixed ladders extend above a floor or platform at the top of the ladder, each side rail extension shall be designed to resist a concentrated live load of 100 lbs. in any direction at any height up to the top of the side rail extension. Ship ladders, with treads instead of rungs, shall have minimum design loads as stairs, defined in Table 4-1.

4.5 Loads Not Specified

For occupancies or uses not designated in 4.2, or 4.3, the live load shall be determined in accordance with a method approved by the authority having jurisdiction.

4.6 Partial Loading

The full intensity of the appropriately reduced live load applied only to a portion of a structure or member shall be accounted for if it produces a more unfavorable effect than the same intensity applied over the full structure or member.

4.7 Impact Loads. The live loads specified in 4.2.1 and 4.4.2 shall be assumed to include adequate allowance for ordinary impact conditions. Provision shall be made in the structural design for uses and loads that involve unusual vibration and impact forces.

4.7.1 Elevators. All elevator loads shall be increased by 100% for impact and the structural supports shall be designed within the limits of deflection prescribed by ANSI/ASME A17.1 and ANSI/ASME A17.2.

4.7.2 Machinery. For the purpose of design, the weight of machinery and moving loads shall be increased as follows to allow for impact: (1) elevator machinery, 100%, (2) light machinery, shaft- or motor-driven, 20%, (3) reciprocating machinery or power-driven units, 50%, (4) hangers for floors or balconies, 33%. All percentages shall be increased where specified by the manufacturer.

4.8 Reduction in Live Loads. The minimum uniformly distributed live loads, L_o in Table 4-1, may be reduced according to the following provisions.

4.8.1 General. Subject to the limitations of 4.8.2 through 4.8.5, members for which a value of $K_{LL}A_T$ is 400 ft^2 (37.16 m^2) or more are permitted to be designed for a reduced live load in accordance with the following formula:

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right) \qquad \text{Eq 4-1}$$

In SI

$$L = L_o\left(0.25 + \frac{4.57}{\sqrt{K_{LL}A_T}}\right)$$

Where:

L = reduced design live load per square foot (meter) of area supported by the member

L_o = unreduced design live load per square foot (meter) of area supported by the member (see Table 4-1)

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

A_T = tributary area, in square feet (square meters)

L shall not be less than $0.50L_o$ for members supporting one floor and L shall not be less than $0.40L_o$ for members supporting two or more floors.

4.8.2 Heavy Live Loads. Live loads that exceed 100 lb/ft^2 (4.79 kN/m^2) shall not be reduced except the live loads for members supporting two or more floors may be reduced by 20%.

4.8.3 Passenger Car Garages. The live loads shall not be reduced in passenger car garages except the live loads for members supporting two or more floors may be reduced by 20%.

4.8.4 Special Occupancies. Live loads of 100 lbs/ft^2 (4.79 kN/m^2) or less shall not be reduced in public assembly occupancies.

4.8.5 Special Structural Elements. Live loads shall not be reduced for one-way slabs except as permitted in Section 4.8.2. Live loads of 100 lbs/ft^2 (4.79 kN/m^2) or less shall not be reduced for roof members except as specified in 4.9.

4.9 Minimum Roof Live Loads

4.9.1 Flat, Pitched, and Curved Roofs. Ordinary flat, pitched, and curved roofs shall be designed for the live loads specified in Eq. 4-2 or other controlling combinations of loads as discussed in Section 2, whichever produces the greater load. In structures such as greenhouses, where special scaffolding is used as a work surface for workmen and materials during maintenance and repair operations, a lower roof load than specified in Eq. 4-2 shall not be used unless approved by the authority having jurisdiction.

$$L_r = 20R_1R_2 \text{ where } 12 \le L_r \le 20 \qquad \text{(Eq 4-2)}$$

in SI:

$L_r = 0.96R_1R_2$ where $0.58 \le L_r \le 0.96$]

where L_r = roof live load per square foot of horizontal projection in pounds per square foot (kN/m^2).

The reduction factors R_1 and R_2 shall be determined as follows

$$R_1 = \begin{cases} 1 & \text{for } A_t \le 200 \text{ ft}^2 \ (18.58 \text{ m}^2) \\ 1.2 - 0.001A_t & \text{for } 200 \text{ ft}^2 < A_t < 600 \text{ ft}^2 \\ 0.6 & \text{for } A_t \ge 600 \text{ ft}^2 \ (55.74 \text{ m}^2) \end{cases}$$

in SI.

$$R_1 = \begin{cases} 1 & \text{for } A_t \le 18.58 \text{ m}^2 \\ 1.2 - 0.01076A_t & \text{for } 18.58 \text{ m}^2 < A_t < 55.74 \text{ m}^2 \\ 0.6 & \text{for } A_t \ge 55.74 \text{ m}^2 \end{cases}$$

where A_t = tributary area in square feet (square meters) supported by any structural member and

$$R_2 = \begin{cases} 1 & \text{for } F \le 4 \\ 1.2 - 0.05F & \text{for } 4 < F < 12 \\ 0.6 & \text{for } F \ge 12 \end{cases}$$

where, for a pitched roof, F = number of inches of rise per foot (in SI F= 0.12 x slope, with slope expressed in percentage points) and, for an arch or dome, F = rise-to-span ratio multiplied by 32

4.9.2 Special-Purpose Roofs Roofs used for promenade purposes shall be designed for a minimum live load of 60 lb/ft^2 (2.87 kN/m^2) Roofs used for roof gardens or assembly purposes shall be designed for a minimum live load of 100 lb/ft^2 (4.79 kN/m^2). Roofs used for other special purposes shall be designed for appropriate loads, as approved by the authority having jurisdiction.

4.10 Crane Loads.

The crane live load shall be the rated capacity of the crane Design loads for the runway beams, including connections and support brackets, of moving bridge cranes and monorail cranes shall include the maximum wheel loads of the crane and the vertical impact, lateral, and longitudinal forces induced by the moving crane

4.10.1 Maximum Wheel Load. The maximum wheel loads shall be the wheel loads produced by the weight of the bridge, as applicable, plus the sum of the rated capacity and the weight of the trolley with the trolley positioned on its runway at the location where the resulting load effect is maximum.

4.10.2 Vertical Impact Force. The maximum wheel loads of the crane shall be increased by the percentages shown below to determine the induced vertical impact or vibration force

Monorail cranes (powered)	25
Cab-operated or remotely operated bridge cranes (powered)	25
Pendant-operated bridge cranes (powered)	10
Bridge cranes or monorail cranes with hand-geared bridge, trolley and hoist	0

4.10.3 Lateral Force. The lateral force on crane runway beams with electrically powered trolleys shall be calculated as 20 percent of the sum of the rated capacity of the crane and the weight of the hoist and trolley. The lateral force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction perpendicular to the beam, and shall be distributed with due regard to the lateral stiffness of the runway beam and supporting structure

4.10.4 Longitudinal Force. The longitudinal force on crane runway beams except for bridge cranes with hand-geared bridges, shall be calculated as 10 percent of the maximum wheel loads of the crane. The longitudinal force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction parallel to the beam.

4.11 References

The following standards are referenced to in this section

[1] American National Standard Practice for the Inspection of Elevators, Escalators, and Moving Walks (Inspectors' Manual), ANSI A17.2-1988.

[2] American National Standard Safety Code for Elevators and Escalators, ANSI/ASME A17.1-1993.

[3] American National Standard for Assembly Seating, Tents, and Air-Supported Structures, ANSI/NFPA 102-1992.

TABLE 4-1

Minimum Uniformly Distributed Live Loads, L_o and Minimum Concentrated Live Loads

Occupancy or Use	Uniform psf (kN/m²)	Conc. lbs. (kN)
Apartments (see residential)		
Access floor systems		
Office use	50 (2 4)	2,000 (8 9)
Computer use	100 (4 79)	2,000 (8 9)
Armories and drill rooms	150 (7 18)	
Assembly areas and theaters		
Fixed seats (fastened to floor)	60 (2.87)	
Lobbies	100 (4 79)	
Movable seats	100 (4 79)	
Platforms (assembly)	100 (4 79)	
Stage floors	150 (7 18)	
Balconies (exterior)	100 (4 79)	
On one- and two-family residences only, and not exceeding 100 ft² (9 3 m²)	60 (2 87)	
Bowling alleys, pool rooms and similar recreational areas	75 (3 59)	
Catwalks for maintenance access	40 (1 92)	300 (1 33)
Corridors		
First floor	100 (4 79)	
Other floors, same as occupancy served except as indicated		
Dance halls and ballrooms	100 (4 79)	
Decks (patio and roof)		
Same as area served, or for the type of occupancy accommodated		
Dining rooms and restaurants	100 (4 79)	
Dwellings (see residential)		
Elevator machine room grating (on area of 4 in.² (2 580 mm²))		300 (1 33)
Finish light floor plate construction (on area of 1 in.² (645 mm²))		200 (0 89)
Fire escapes	100 (4 79)	
On single-family dwellings only	40 (1 92)	
Fixed Ladders		See Sec 4 4
Garages (passenger cars only)	50 (2 40)	Note (1)
Trucks and buses	Note (2)	
Grandstands (see stadium and arena bleachers)		
Gymnasiums, main floors and balconies	100 (4 79) Note (4)	
Handrails, guardrails and grab bars	See Section 4 4	
Hospitals		
Operating rooms, laboratories	60 (2 87)	1,000 (4 45)
Private rooms	40 (1 92)	1,000 (4 45)
Wards	40 (1.92)	1,000 (4 45)
Corridors above first floor	80 (3 83)	1,000 (4 45)
Hotels (see residential)		
Libraries		
Reading rooms	60 (2.87)	1 000 (4 45)
Stack rooms	150 (7.18) Note (3)	1,000 (4 45)
Corridors above first floor	80 (3 83)	1,000 (4 45)
Manufacturing		
Light	125 (6.00)	2,000 (8.90)
Heavy	250 (11.97)	3,000 (13.40)
Marquees and Canopies	75 (3.59)	
Office Buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first floor corridors	100 (4 79)	2.000 (8.90)
Offices	50 (2.40)	2,000 (8 90)
Corridors above first floor	80 (3 83)	2,000 (8.90)

TABLE 4-1

Minimum Uniformly Distributed Live Loads, L_o and Minimum Concentrated Live Loads

Occupancy or Use	Uniform psf (kN/m²)	Conc. lbs. (kN)
Penal Institutions		
Cell blocks	40 (1 92)	
Corridors	100 (4 79)	
Residential		
Dwellings (one- and two-family)		
Uninhabitable attics without storage	10 (0.48)	
Uninhabitable attics with storage	20 (0 96)	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs and balconies	40 (1 92)	
Hotels and multifamily houses		
Private rooms and corridors serving them	40 (1 92)	
Public rooms and corridors serving them	100 (4 79)	
Reviewing stands, grandstands and bleachers	100 (4 79) Note (4)	
Roofs	See Sections 4.3 and 4 9	
Schools		
Classrooms	40 (1.92)	1,000 (4 45)
Corridors above first floor	80 (3 83)	1,000 (4 45)
First floor corridors	100 (4 79)	1,000 (4 45)
Scuttles, skylight ribs, and accessible ceilings		200 (9 58)
Sidewalks, vehicular driveways, and yards, subject to trucking	250 (11 97) Note (5)	8,000 (35 60) Note (6)
Stadiums and Arenas		
Bleachers	100 (4 79) Note (4)	
Fixed Seats (fastened to floor)	60 (2 87) Note (4)	
Stairs and exitways	100 (4 79)	Note (7)
One- and two-family residences only	40 (1 92)	
Storage areas above ceilings	20 (0 96)	
Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Light	125 (6 00)	
Heavy	250 (11 97)	
Stores		
Retail		
First floor	100 (4.79)	1,000 (4 45)
Upper floors	75 (3.59)	1,000 (4 45)
Wholesale, all floors	125 (6 00)	1,000 (4 45)
Vehicle barriers	See Section 4 4	
Walkways and elevated platforms (other than exitways)	60 (2 87)	
Yards and terraces, pedestrians	100 (4.79)	

(1) Floors in garages or portions of building used for the storage of motor vehicles shall be designed for the uniformly distributed live loads of Table 4-1 or the following concentrated load. (1) for passenger cars accommodating not more than nine passengers 2000 lb (8 90 kN) acting on an area of 20 in.² (12 900 mm²), (2) mechanical parking structures without slab or deck, passenger car only, 1500 lb (6.70 kN) per wheel

(2) Garages accommodating trucks and buses shall be designed in accordance with an approved method which contains provisions for truck and bus loadings

(3) The weight of books and shelving shall be computed using an assumed density of 65 lb/ft³ (pounds per cubic foot, sometimes abbreviated pcf) (10.21 kN/m³) and converted to a uniformly distributed load, this load shall be used if it exceeds 150 lb/ft² (7.18 kN/m²).

(4) In addition to the vertical live loads, horizontal swaying forces parallel and normal to the length of seats shall be included in the design according to the requirements of ANSI/NFPA 102

(5) Other uniform loads in accordance with an approved method which contains provisions for truck loadings shall also be considered where appropriate

(6) The concentrated wheel load shall be applied on an area of 20 in.² (12 900 mm²)

(7) Minimum concentrated load on stair treads (on area of 4 sq in (2 580 mm²)) is 300 lbs (1.33 kN)

Table 4-2

Live Load Element Factor, K_{LL}

Element	K_{LL}
Interior Columns	4
Exterior Columns without cantilever slabs	4
Edge Columns with cantilever slabs	3
Corner Columns with cantilever slabs	2
Edge Beams without cantilever slabs	2
Interior Beams	2
All Other Members Not Identified Above including: Edge Beams with cantilever slabs Cantilever Beams Two-way Slabs Members without provisions for continuous shear transfer normal to their span	1

Note 1. In lieu of the values above, K_{LL} is permitted to be calculated.

5. Soil and Hydrostatic Pressure and Flood Loads

5.1 Pressure on Basement Walls. In the design of basement walls and similar approximately vertical structures below grade, provision shall be made for the lateral pressure of adjacent soil. Due allowance shall be made for possible surcharge from fixed or moving loads When a portion or the whole of the adjacent soil is below a free-water surface, computations shall be based on the weight of the soil diminished by buoyancy, plus full hydrostatic pressure

Basement walls shall be designed to resist lateral soil loads. Soil loads specified in Table 5-1 shall be used as the minimum design lateral soil loads unless specified otherwise in a soil investigation report approved by the authority having jurisdiction The lateral pressure from surcharge loads shall be added to the lateral earth pressure load. The lateral pressure shall be increased if soils with expansion potential are present at the site as determined by a geotechnical investigation

5.2 Uplift on Floors and Foundations. In the design of basement floors and similar approximately horizontal elements below grade, the upward pressure of water, where applicable, shall be taken as the full hydrostatic pressure applied over the entire area The hydrostatic head shall be measured from the underside of the construction. Any other upward loads shall be included in the design

Where expansive soils are present under foundations or slabs-on-ground the foundations slabs, and other components shall be designed to tolerate the movement or resist the upward pressures caused by the expansive soils, or the expansive soil shall be removed or stabilized around and beneath the structure.

5.3 Flood Loads. The provisions of this section apply to buildings and other structures located in areas prone to flooding as defined on a flood hazard map

5.3 1 Definitions The following definitions apply to the provisions of Section 5 3

Approved acceptable to the authority having jurisdiction.

Base Flood: the flood having a 1% chance of being equalled or exceeded in any given year

Base Flood Elevation (BFE): the elevation of flooding, including wave height, having a 1% chance of being equaled or exceeded in any given year.

Breakaway Wall: any type of wall using approved materials and construction techniques, which does not provide structural support to a structure, and which is designed and constructed to fail under specified circumstances without damage to the structure or to the supporting foundation system

Coastal A Zone an area within a Special Flood Hazard Area, landward of a V Zone or landward of an open coast without mapped V zones To be classified as a Coastal A Zone the principal source of flooding must be astronomical tides, storm surges, seiches or tsunamis, not riverine flooding.

Coastal High Hazard Area (V Zone): an area within a Special Flood Hazard Area, extending from offshore to the inland limit of a primary frontal dune along an open coast, and any other area which is subject to high velocity wave action from storms or seismic sources This area is designated on FIRMs as V, VE, VO, or V1-30

Design Flood the greater of the following two flood events 1) the Base Flood, affecting those areas identified as Special Flood Hazard Areas on the community s FIRM, or 2) the flood corresponding to the area designated as a Flood Hazard Area on a community's Flood Hazard Map or otherwise legally designated

Design Flood Elevation (DFE): the elevation of the Design Flood, including wave height, relative to the datum specified on a community's Flood Hazard Map.

Flood Hazard Area: the area subject to flooding during the Design Flood.

Flood Hazard Map: The map delineating Flood Hazard Areas adopted by the authority having jurisdiction

Flood Insurance Rate Map (FIRM): an official map of a community, on which the Federal Insurance Administration has delineated both Special Flood Hazard Areas and the risk premium zones applicable to the community

Special Flood Hazard Area (Area of Special Flood Hazard): the land in the floodplain subject to a one-percent or greater chance of flooding in any given year. These areas are delineated on a community's Flood Insurance Rate Map (FIRM) as A Zones (A, AE, A1-30, A99, AR, AO, or AH) or V Zones (V, VE, VO or V1-30).

TABLE 5-1
DESIGN LATERAL SOIL LOAD

Description of Backfill Material	Unified Soil Classification	Design Lateral Soil Load[a] psf per foot of depth (kN/m^2 per meter of depth)
Well-graded, clean gravels, gravel-sand mixes	GW	35 (5 50) Note c
Poorly graded clean gravels; gravel-sand mixes	GP	35 (5 50) Note c
Silty gravels, poorly graded gravel-sand mixes	GM	35 (5 50) Note c
Clayey gravels, poorly graded gravel-and-clay mixes	GC	45 (7 07) Note c
Well-graded, clean sands; gravelly-sand mixes	SW	35 (5 50) Note c
Poorly graded clean sands; sand-gravel mixes	SP	35 (5 50) Note c
Silty sands, poorly graded sand-silt mixes	SM	45 (7 07) Note c
Sand-silt clay mix with plastic fines	SM-SC	85 (13 35) Note d
Clayey sands, poorly graded sand-clay mixes	SC	85 (13 35) Note d
Inorganic silts and clayey silts	ML	85 (13.35) Note d
Mixture of inorganic silt and clay	ML-CL	85 (13.35) Note d
Inorganic clays of low to medium plasticity	CL	100 (15.71)
Organic silts and silt-clays, low plasticity	OL	Note b
Inorganic clayey silts, elastic silts	MH	Note b
Inorganic clays of high plasticity	CH	Note b
Organic clays and silty clays	OH	Note b

Note a. Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.
Note b. Unsuitable as backfill material.
Note c. For relatively rigid walls, as when braced by floors, the design lateral soil load shall be increased for sand and gravel type soils to 60 psf (9.43 kN/m^2) per foot (meter) of depth. Basement walls extending not more than 8 feet (2.44 m) below grade and supporting light floor systems are not considered as being relatively rigid walls.
Note d. For relatively rigid walls, as when braced by floors, the design lateral load shall be increased for silt and clay type soils to 100 psf (15.71 kN/m^2) per foot (meter) of depth. Basement walls extending not more than 8 feet (2.44 m) below grade and supporting light floor systems are not considered as being relatively rigid walls.

5.3.2 Design Requirements

5.3.2.1 Design loads Structural systems of buildings or other structures shall be designed, constructed, connected and anchored to resist flotation, collapse and permanent lateral movement due to action of wind loads and loads from flooding associated with the design flood including hydrostatic, hydrodynamic and impact loads (see Section 2).

5.3.2.2 Breakaway Walls. When walls and partitions located below the design flood elevation in a coastal high hazard area are required to break away, such walls and their connections to the structure shall be designed for not less than 10 psf (0.48 kN/m^2) nor more than 20 psf (0.96 kN/m^2), except if the design wind load is greater, on the vertical projected area. Breakaway walls which exceed a design loading resistance of 20 psf (0.96 kN/m^2) shall not be used unless the design meets the following conditions

1. Breakaway wall collapse shall result from a water load less than that which occurs during the base flood and

2. The elevated portion of the building and supporting foundation system shall resist collapse, displacement, and other structural damage due to the effects of wind and water loads acting simultaneously on all building components (structural and non-structural)

5.3.3 Loads During Flooding

5.3.3.1 Load Basis. In flood hazard areas the structural design shall be based on the design flood

5.3.3.2 Hydrostatic Loads. Hydrostatic loads caused by a depth of water to the level of the design flood elevation shall be applied over all surfaces involved, both above and below ground level, except that for surfaces exposed to free water, the design depth shall be increased by one foot (0.30 m).

Reduced uplift and lateral loads on surfaces of enclosed spaces below the design flood elevation shall apply only if provision is made for entry and exit of floodwater (See Section 5.3.4.4)

5.3.3.3 Hydrodynamic Loads. Where water velocities do not exceed 10 feet per second (3.05 m/s), dynamic effects of the moving water shall be converted into equivalent hydrostatic loads by increasing the design flood elevation for design purposes by an equivalent surcharge depth, d_h, on the headwater side and above the ground level only, equal to

$$d_h = \frac{aV^2}{2g} \qquad \text{(Eq. 5-1)}$$

Where V = average velocity of water in feet per second (meters per second)

g = acceleration due to gravity, 32.2 feet per second per second (9.81 m/s^2)

a = coefficient of drag or shape factor (not less than 1.25)

The equivalent surcharge depth shall be added to the design flood elevation design depth and the resultant hydrostatic pressures applied to, and uniformly distributed across, the vertical projected area of the building or structure which is perpendicular to the flow. Surfaces parallel to the flow or surfaces wetted by the tailwater shall be subject to the hydrostatic pressures for depths to the design flood elevation only.

Where water velocities exceed 10 feet per second (3.05 m/s), dynamic effects of the moving water shall be determined by a detailed analysis utilizing basic concepts of fluid mechanics.

5.3.3.4 Wave Loads Wave loads shall be determined by one of the following three methods: (1) using the analytical procedures outlined in this section, (2) by more advanced numerical modeling procedures, or (3) by laboratory test procedures (physical modeling).

Wave loads are those loads which result from water waves propagating over the water surface and striking a building or other structure. Design and construction of buildings and other structures subject to wave loads shall account for the following loads: waves breaking on any portion of the building or structure, uplift forces caused by shoaling waves beneath a building or structure, or portion thereof, wave runup striking any portion of the building or structure; wave-induced drag and inertia forces; wave-induced scour at the base of a building or structure, or its foundation. Wave loads shall be included for both V Zones and A Zones. In V zones, waves are 3 feet (0.91 m) high, or higher; in coastal floodplains landward of the V Zone, waves are less than 3 feet high (0.91 m).

Non-breaking and broken wave loads shall be calculated using the procedures described in Sections 5.3.3.2 and 5.3.3.3 to calculate hydrostatic and hydrodynamic loads.

Breaking waves loads shall be calculated using the procedures described in Sections 5.3.3.4.1 through 5.3.3.4.4. Breaking wave heights used in the procedures described in Sections 5.3.3.4.1 through 5.3.3.4.4 shall be

calculated for V Zones and Coastal A Zones using Equations 5-2 and 5 3

$$H_b = 0.78\, d_s \qquad \text{(Eq 5-2)}$$

Where

H_b = breaking wave height in feet (m)
d_s = local stillwater depth in feet (m)

The local stillwater depth shall be calculated using Equation 5-3, unless more advanced procedures or laboratory tests permitted by this section are used

$$d_s = 0.65\,(BFE - G) \qquad \text{(Eq. 5-3)}$$

Where

BFE = Base Flood Elevation in feet (m)
G = Ground elevation in feet (m)

5.3.3.4.1 Breaking wave loads on vertical pilings and columns. The net force resulting from a breaking wave acting on a rigid vertical pile or column shall be assumed to act at the stillwater elevation and shall be calculated by the following:

$$F_D = 0.5\, \gamma_w\, C_D\, D\, H_b^2 \qquad \text{(Eq. 5-3)}$$

Where:

F_D = net wave force, in pounds (kN)
γ_w = unit weight of water, in pounds per cubic foot (kN/m^3), = 62 4 pcf (9.80 kN/m^3) for fresh water and 64.0 pcf (10 05 kN/m^3) for salt water
C_D = coefficient of drag for breaking waves, = 1 75 for round piles or columns, and = 2.25 for square piles or columns
D = pile or column diameter, in feet (m) for circular sections, or for a square pile or column, 1.4 times the width of the pile or column in feet (m).
H_b = breaking wave height, in feet (m)

5.3.3.4.2 Breaking wave loads on vertical walls Maximum pressures and net forces resulting from a normally incident breaking wave acting on a rigid vertical wall shall be calculated by the following:

$$P_{max} = C_p\, \gamma_w\, d_s + 1.2\, \gamma_w\, d_s \qquad \text{(Eq. 5-4)}$$

and

$$F_t = 1.1\, C_p\, \gamma_w\, d_s^2 + 2.4\, \gamma_w\, d_s^2 \qquad \text{(Eq 5-5)}$$

Where:

P_{max} = maximum combined dynamic ($C_p\, \gamma_w\, d_s$) and static ($1.2\, \gamma_w\, d_s$) wave pressures, also referred to as shock pressures in pounds per square foot (kN/m^2)
F = total breaking wave force per unit length of structure, also referred to as shock, impulse or wave impact force in pounds/foot (kN/m), acting near the stillwater elevation
C_p = dynamic pressure coefficient ($1.6 < C_p < 3.5$ -- see Table 5-2)
γ_w = unit weight of water, in pounds per cubic foot (kN/m^3) = 62.4 pcf (9 80 kN/m^3) for fresh water and 64.0 pcf (10 05 kN/m^3) for salt water
d_s = stillwater depth in feet (m) at base of building or other structure where the wave breaks

This procedure assumes the vertical wall causes a reflected or standing wave against the waterward side of the wall, with the crest of the wave at a height of $1.2\, d_s$ above the stillwater level. Thus, the dynamic (static and total pressure distributions against the wall, and the resulting force, are as shown in Figure 5-1.

This procedure also assumes the space behind the vertical wall is dry, with no fluid balancing the static component of the wave force on the outside of the wall If free water exists behind the wall, the hydrostatic component of the wave pressure and force disappears and the dynamic wave pressure and net force shall be computed by:

$$P_{max} = C_p\, \gamma_w\, d_s \qquad \text{(Eq 5-6)}$$

and

$$F_t = 1.1\, C_p\, \gamma_w\, d_s^2 \qquad \text{(Eq 5-7)}$$

Where

P_{max} = maximum dynamic wave pressure in pounds per square foot (kN/m^2)
F_t = total breaking wave force per unit length of structure, also referred to as shock, impulse or wave impact force in pounds/foot (kN/m), acting near the stillwater elevation
C_p = dynamic pressure coefficient ($1.6 < C_p < 3.5$ -- see Table 5-2)
γ_w = unit weight of water, in pounds per cubic foot (kN/m^3), = 62.4 pcf (9 80 kN/m^3) for fresh water and 64.0 pcf (10.05 kN/m^3) for salt water
d_s = stillwater depth in feet (m) at base of building or other structure where the wave breaks

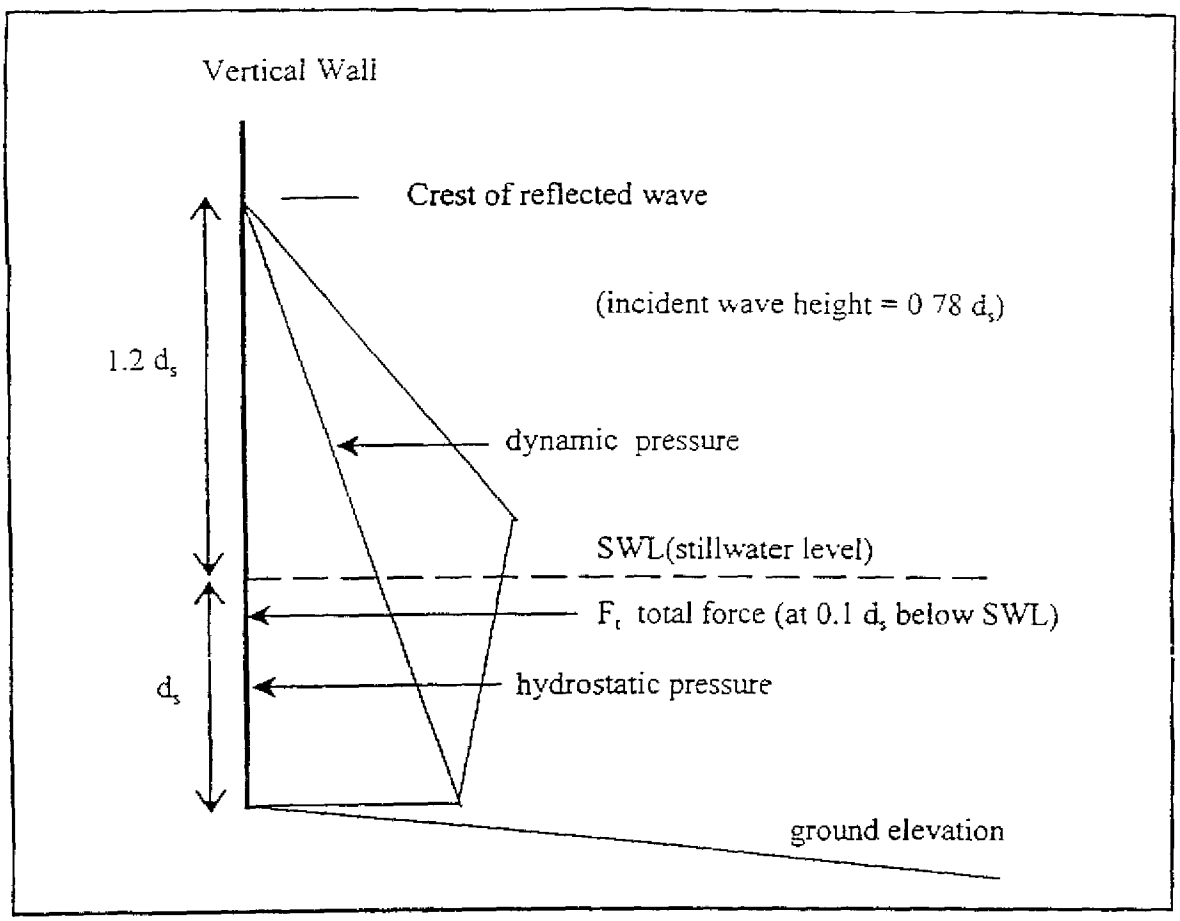

Figure 5-1
Normally Incident Breaking Wave Pressures and Net Force Against a Vertical Wall

5.3.3.4.3 Breaking wave loads on non-vertical walls. Breaking wave forces given by Eq. 5-5 and Eq. 5-7 shall be modified in instances where the walls or surfaces upon which the breaking waves act are non-vertical. The horizontal component of breaking wave force shall be given by:

$$F_{av} = F_t \sin^2 \theta \qquad \text{(Eq. 5-8)}$$

Where:

F_{av} = horizontal component of breaking wave force in pounds/foot (kN/m)
F_t = total breaking wave force acting on a vertical surface in pounds/foot (kN/m)
θ = vertical angle between non-vertical surface and the horizontal

5.3.3.4.4 Breaking wave loads from obliquely incident waves. Breaking wave forces given by Eq. 5-5 and Eq 5-7 shall be modified in instances where waves are obliquely incident. Breaking wave forces from non-normally incident waves shall be given by:

$$F_{\alpha} = F_t \sin^2 \alpha \qquad \text{(Eq. 5-9)}$$

Where

F_{oi} = horizontal component of obliquely incident breaking wave force in pounds/foot (kN/m)

F_i = total breaking wave force (normally incident waves) acting on a vertical surface in pounds/foot (kN/m)

α = horizontal angle between the direction of wave approach and the vertical surface

5.3.3.5 Impact Loads. Impact loads are those which result from debris, ice and any object transported by floodwaters striking against buildings and structures or parts thereof

Minimum impact load is a concentrated load acting horizontally at the most critical location at or below the base flood elevation produced by a 1000 pound (4.5 kN) object travelling at the velocity of the floodwater and acting on a one square foot (0 09 m^2) surface of the structure It shall be assumed that the velocity of the object is reduced to zero in one second

5.3.4 Special Flood Hazard Areas - A Zones. The following aspects of A Zone design and construction shall be accounted for in the design. elevation above the design flood elevation, anchorage, floodproofing, enclosures below the design flood elevation, and scour.

5.3.4.1 Elevation. Buildings or structures within an A Zone shall be elevated so that the lowest habitable floor, including basement, is located at or above the elevation shown in Table 5-3

Exception Non-residential buildings floodproofed in accordance with Section 5 3 4 3 or 5.3 4.4.

All structural components subject to hydrostatic and hydrodynamic loads and impact loads from water-borne objects during the occurrence of flooding to the design flood elevation shall be capable of resisting such forces. including the effect of buoyancy.

5.3 4.2 Anchorage. The structural systems of buildings or other structures shall be designed, connected and anchored to prevent flotation, collapse and permanent lateral movement resulting from wind loads, impact loads, hydrodynamic loads and hydrostatic loads, including the effects of buoyancy, from flooding equal to the design flood elevation.

5.3.4.3 Non-Residential Flood-resistant Construction. As an alternative to meeting the elevation provision of Section 5.3.4.1, non-residential buildings or other structures located in non-coastal high hazard areas shall be floodproofed so that the structure is watertight. Walls and floors below an elevation one foot (0.30 m) above the elevation prescribed in Table 5-3 shall be substantially impermeable to the passage of water. Openings in floodproofed walls and floors shall be provided with watertight closures and shall have adequate structural capacity to resist all applicable loads

5.3.4.4 Enclosures Below the Design Flood Elevation. Enclosed spaces below the design flood elevation shall not be used for any purpose other than parking of vehicles, building access or storage Enclosed spaces which do not meet the requirements of Section 5 3.4 3 shall be provided with vents, valves or other openings which will automatically equalize the hydrostatic forces on exterior and interior walls by allowing for the entry and exit of flood waters.

To provide for equalization of hydrostatic forces a minimum of two openings having a total net area of not less than one square inch for every square foot (0 007 m^2 for every square meter) of enclosed area subject to flooding shall be provided. The bottom of all openings shall not be higher than 12 inches (0 30 m) above grade Openings shall not be equipped with screens, louvers, valves or other coverings or devices unless they permit the automatic entry and exit of floodwaters.

5.3.4.5 Scour. The effects of scour shall be included in the design of the foundations of buildings or other structures in special flood hazard areas -- A Zones.

Foundation embedment shall be below the depth of potential scour

5.3.5 Coastal High Hazard Areas - V Zones. Loadings in V Zones are more severe than loadings in A Zones, and the design shall take into account the following. elevation above the design flood elevation, foundation type. obstructions below the design flood elevation, and the effects of erosion and scour.

5.3.5.1 Elevation. Buildings or structures erected within a coastal high hazard area shall be elevated so that the lowest portion of the lowest horizontal structural members supporting the lowest floor with the exception of footings. mat or raft foundations, piles, pile caps, columns, grade beams and bracing shall be located at or above the elevation shown in Table 5-4.

Buildings or structures erected in coastal high hazard areas shall be supported on piles or columns. The piles or columns and their foundation and structure attached thereto shall be anchored to resist flotation, collapse and permanent lateral movement due to the effects of wind, water and impact loads acting simultaneously on all building components.

All structural components subject to wind loads, hydrostatic and hydrodynamic loads and impact loads from water-borne objects during the occurrence of flooding to the design flood elevation shall be capable of resisting such

forces, including the effects of buoyancy

5.3.5.2 Space Below Design Flood Elevation. Spaces below the design flood elevation shall be free of obstruction

Exceptions

(1) Footings, mat or raft foundations, piles, pile caps, columns, grade beams and bracing that provide structural support for the building.

(2) Structural systems of entrances and required exits

(3) Incidental storage of portable or mobile items that are readily moveable in the event of a storm

(4) Walls or partitions shall not be used to enclose all or part of the space, unless they are not part of the structural support of the building and are designed to breakaway or collapse without causing collapse, displacement or other damage to the structural system of the building in accordance with Section 5.3 2.2 Insect screening, open wood lattice, and similar screening which allow the passage of water shall not be used unless these systems comply with Section 5 3 2.2

5.3.5.3 Erosion and Scour. The effects of long-term erosion, storm-induced erosion and local scour shall be included in the design of foundations of buildings or other structures in coastal high hazard areas. Foundation embedment shall be below the depth of potential scour