# Chapter 5
# FLOOD LOADS

## 5.1 GENERAL

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

## 5.2 DEFINITIONS

The following definitions apply to the provisions of this chapter:

**APPROVED:** Acceptable to the authority having jurisdiction.

**BASE FLOOD:** The flood having a 1 percent chance of being equaled or exceeded in any given year.

**BASE FLOOD ELEVATION (BFE):** The elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year.

**BREAKAWAY WALL:** Any type of wall subject to flooding that is not required to provide structural support to a building or other structure, and that is designed and constructed such that, under base flood or lesser flood conditions, it will collapse in such a way that: (1) it allows the free passage of floodwaters, and (2) it does not damage the structure or 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, and the potential for breaking wave heights greater than or equal to 1.5 ft (0.46 m) must exist during the base flood.

**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 that is subject to high-velocity wave action from storms or seismic sources. This area is designated on Flood Insurance Rate Maps (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 and Mitigation 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 1 percent or greater chance of flooding in any given year. These areas are delineated on a community's FIRM as A-Zones (A, AE, A1-30, A99, AR, AO, or AH) or V-Zones (V, VE, VO, or V1-30).

## 5.3 DESIGN REQUIREMENTS

**5.3.1 Design Loads.** Structural systems of buildings or other structures shall be designed, constructed, connected, and anchored to resist flotation, collapse, and permanent lateral displacement due to action of flood loads associated with the design flood (see Section 5.3.3) and other loads in accordance with the load combinations of Chapter 2.

**5.3.2 Erosion and Scour.** The effects of erosion and scour shall be included in the calculation of loads on buildings and other structures in flood hazard areas.

**5.3.3 Loads on Breakaway Walls.** Walls and partitions required by ASCE/SEI 24, to break away, including their connections to the structure, shall be designed for the largest of the following loads acting perpendicular to the plane of the wall:

1. The wind load specified in Chapter 6.
2. The earthquake load specified in Chapter 9.
3. 10 psf (0.48 kN/m$^2$).

The loading at which breakaway walls are intended to collapse shall not exceed 20 psf (0.96 kN/m$^2$) unless the design meets the following conditions:

1. Breakaway wall collapse is designed to result from a flood load less than that which occurs during the base flood.
2. The supporting foundation and the elevated portion of the building shall be designed against collapse, permanent lateral displacement, and other structural damage due to the effects of flood loads in combination with other loads as specified in Chapter 2.

## 5.4 LOADS DURING FLOODING

**5.4.1 Load Basis.** In flood hazard areas, the structural design shall be based on the design flood.

**5.4.2 Hydrostatic Loads.** Hydrostatic loads caused by a depth of water to the level of the DFE 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 1 ft (0.30 m).

Reduced uplift and lateral loads on surfaces of enclosed spaces below the DFE shall apply only if provision is made for entry and exit of floodwater.

**5.4.3 Hydrodynamic Loads.** Dynamic effects of moving water shall be determined by a detailed analysis utilizing basic concepts of fluid mechanics.

**EXCEPTION:** Where water velocities do not exceed 10 ft/s (3.05 m/s), dynamic effects of moving water shall be permitted to be converted into equivalent hydrostatic loads by increasing the DFE for design purposes by an equivalent surcharge depth, $d_h$, on the headwater side and above the ground level only, equal to

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

where

$V$ = average velocity of water in ft/s (m/s)
$g$ = acceleration due to gravity, 32.2 ft/s (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 DFE design depth and the resultant hydrostatic pressures applied to, and uniformly distributed across, the vertical projected area of the building or structure that is perpendicular to the flow. Surfaces parallel to the flow or surfaces wetted by the tail water shall be subject to the hydrostatic pressures for depths to the DFE only.

**5.4.4 Wave Loads.** Wave loads shall be determined by one of the following three methods: (1) by 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 that 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; and 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 ft (0.91 m) high, or higher; in coastal floodplains landward of the V-Zone, waves are less than 3 ft high (0.91 m).

Nonbreaking and broken wave loads shall be calculated using the procedures described in Sections 5.4.2 and 5.4.3 that show how to calculate hydrostatic and hydrodynamic loads.

Breaking wave loads shall be calculated using the procedures described in Sections 5.4.4.1 through 5.4.4.4. Breaking wave heights used in the procedures described in Sections 5.4.4.1 through 5.4.4.4 shall be calculated for V-Zones and Coastal A-Zones using Eqs. 5-2 and 5-3.

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

where

$H_b$ = breaking wave height in ft (m)
$d_s$ = local still water depth in ft (m)

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

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

where

BFE = BFE in ft (m)
$G$ = ground elevation in ft (m)

**5.4.4.1 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 still water elevation and shall be calculated by the following:

$$F_D = 0.5 \gamma_w C_D D H_b^2 \qquad (5\text{-}4)$$

where

$F_D$ = net wave force, in lb (kN)
$\gamma_w$ = unit weight of water, in lb per cubic ft (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 ft (m) for circular sections, or for a square pile or column, 1.4 times the width of the pile or column in ft (m)
$H_b$ = breaking wave height, in ft (m)

**5.4.4.2 Breaking Wave Loads on Vertical Walls.** Maximum pressures and net forces resulting from a normally incident breaking wave (depth-limited in size, with $H_b = 0.78 d_s$) acting on a rigid vertical wall shall be calculated by the following:

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

and

$$F_t = 1.1 C_p \gamma_w d_s^2 + 2.4 \gamma_w d_s^2 \qquad (5\text{-}6)$$

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 lb/ft$^2$ (kN/m$^2$)
$F_t$ = net breaking wave force per unit length of structure, also referred to as shock, impulse, or wave impact force in lb/ft (kN/m), acting near the still water elevation
$C_p$ = dynamic pressure coefficient ($1.6 < C_p < 3.5$) (see Table 5-1)
$\gamma_w$ = unit weight of water, in lb per cubic ft (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
$d_s$ = still water depth in ft (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 still water level. Thus, the dynamic static and total pressure distributions against the wall are as shown in Fig. 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, a portion of the hydrostatic component of the wave pressure and force disappears (see Fig. 5-2) and the net force shall be computed by Eq. 5-7 (the maximum combined wave pressure is still computed with Eq. 5-5).

$$F_t = 1.1 C_p \gamma_w d_s^2 + 1.9 \gamma_w d_s^2 \qquad (5\text{-}7)$$

where

$F_t$ = net breaking wave force per unit length of structure, also referred to as shock, impulse, or wave impact force in lb/ft (kN/m), acting near the still water elevation
$C_p$ = dynamic pressure coefficient ($1.6 < C_p < 3.5$) (see Table 5-1)
$\gamma_w$ = unit weight of water, in lb per cubic ft (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

$d_s$ = still water depth in ft (m) at base of building or other structure where the wave breaks

**5.4.4.3 Breaking Wave Loads on Nonvertical Walls.** Breaking wave forces given by Eqs. 5-6 and 5-7 shall be modified in instances where the walls or surfaces upon which the breaking waves act are nonvertical. The horizontal component of breaking wave force shall be given by

$$F_{nv} = F_t \sin^2 \alpha \tag{5-8}$$

where

$F_{nv}$ = horizontal component of breaking wave force in lb/ft (kN/m)
$F_t$ = net breaking wave force acting on a vertical surface in lb/ft (kN/m)
$\alpha$ = vertical angle between nonvertical surface and the horizontal

**5.4.4.4 Breaking Wave Loads from Obliquely Incident Waves.** Breaking wave forces given by Eqs. 5-6 and 5-7 shall be modified in instances where waves are obliquely incident. Breaking wave forces from non-normally incident waves shall be given by

$$F_{oi} = F_t \sin^2 \alpha \tag{5-9}$$

where

$F_{oi}$ = horizontal component of obliquely incident breaking wave force in lb/ft (kN/m)

$F_t$ = net breaking wave force (normally incident waves) acting on a vertical surface in lb/ft (kN/m)

$\alpha$ = horizontal angle between the direction of wave approach and the vertical surface

**5.4.5 Impact Loads.** Impact loads are those that result from debris, ice, and any object transported by floodwaters striking against buildings and structures, or parts thereof. Impact loads shall be determined using a rational approach as concentrated loads acting horizontally at the most critical location at or below the DFE.

## 5.5 CONSENSUS STANDARDS AND OTHER REFERENCED DOCUMENTS

This section lists the consensus standards and other documents which are adopted by reference within this chapter:

**ASCE/SEI**
**American Society of Civil Engineers**
**Structural Engineering Institute**
**1801 Alexander Bell Drive**
**Reston, VA 20191-4400**

**ASCE/SEI 24**
Section 5.3.3
*Flood Resistant Design and Construction, 1998*

**TABLE 5-1 VALUE OF DYNAMIC PRESSURE COEFFICIENT, $C_p$**

| Building Category | $C_p$ |
|---|---|
| I | 1.6 |
| II | 2.8 |
| III | 3.2 |
| IV | 3.5 |

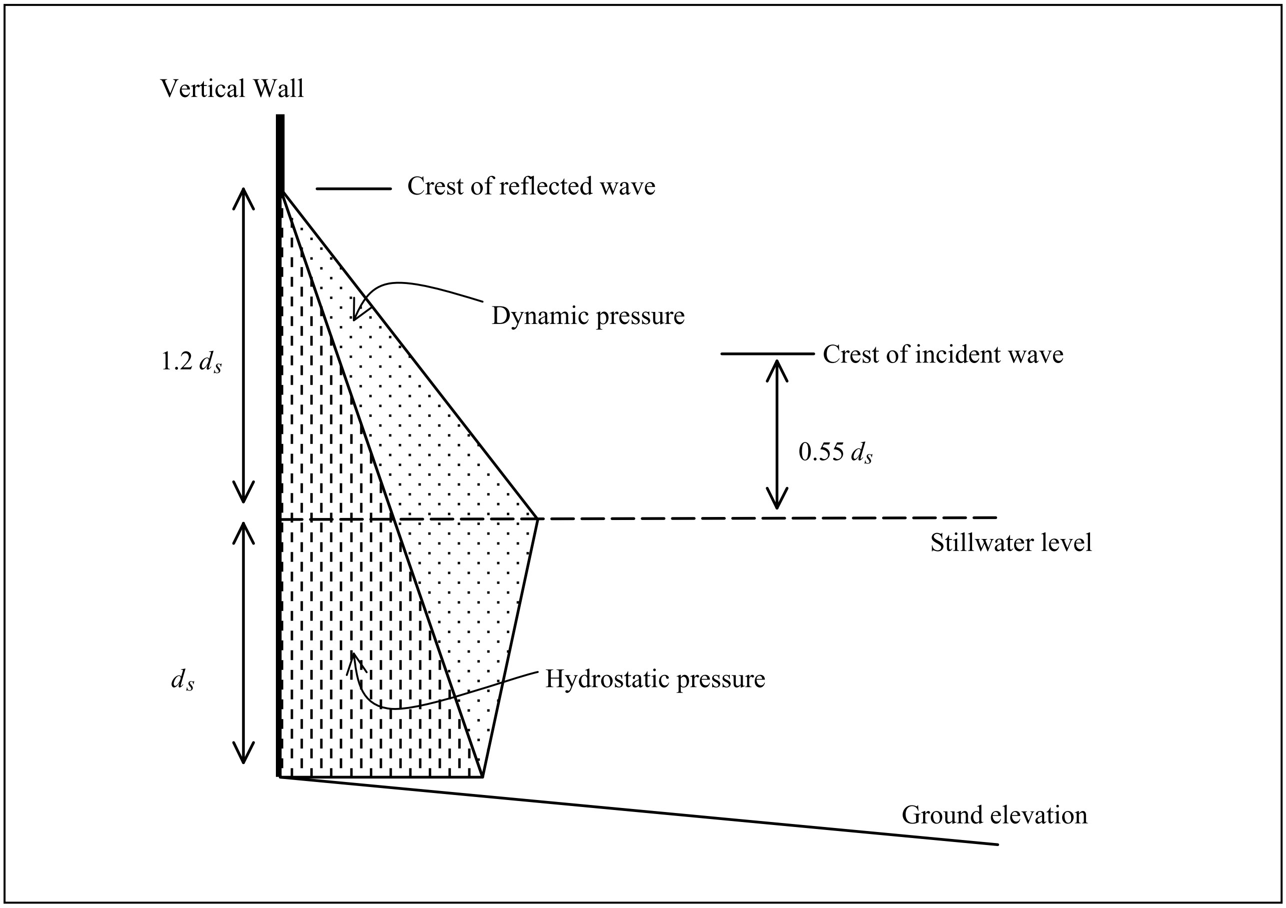


**FIGURE 5-1 NORMALLY INCIDENT BREAKING WAVE PRESSURES AGAINST A VERTICAL WALL (space behind vertical wall is dry)**

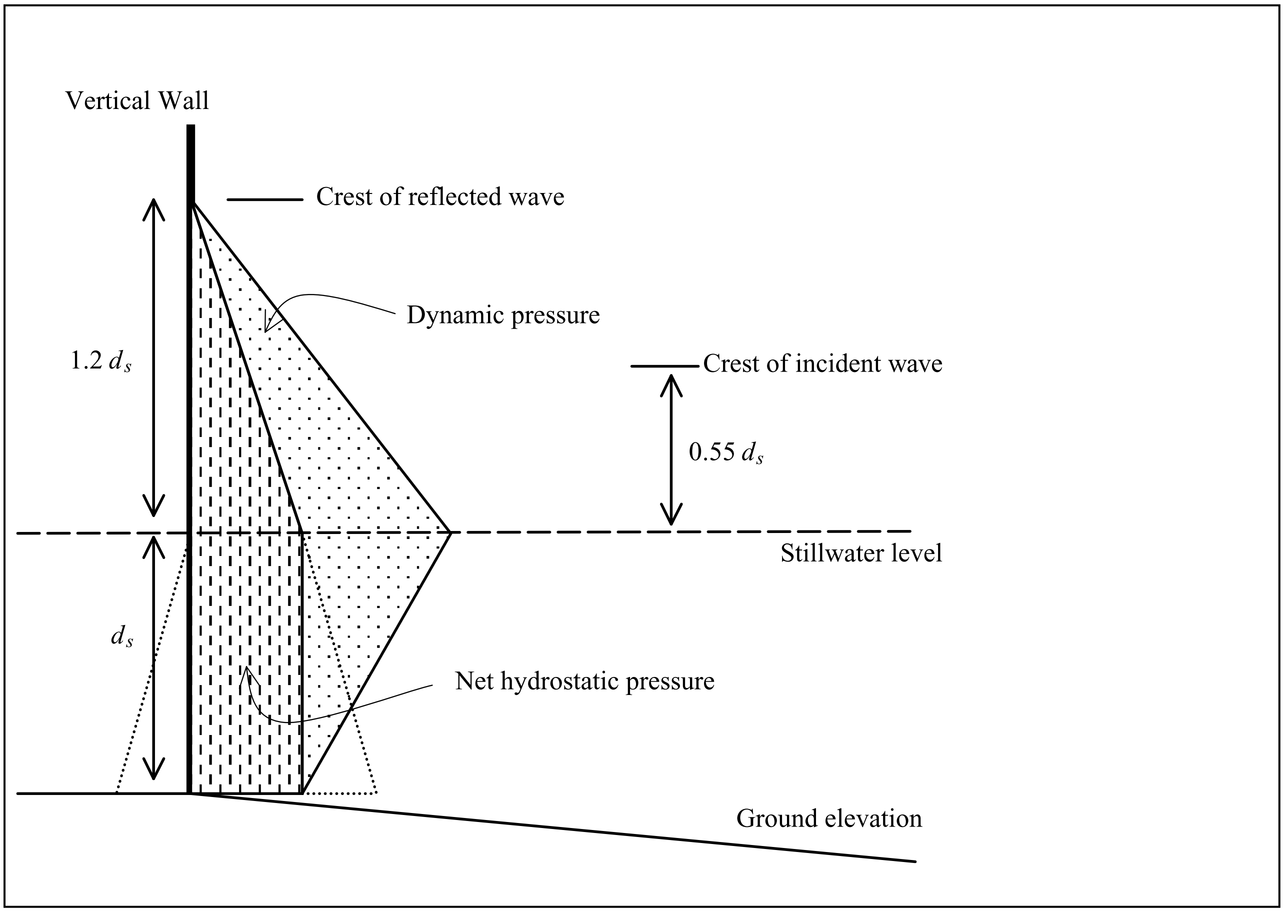


**FIGURE 5-2 NORMALLY INCIDENT BREAKING WAVE PRESSURES AGAINST A VERTICAL WALL (still water level equal on both sides of wall)**