



# Residential Building Design for High-Wind Coastal Areas

An Online Continuing Education Course for Engineers

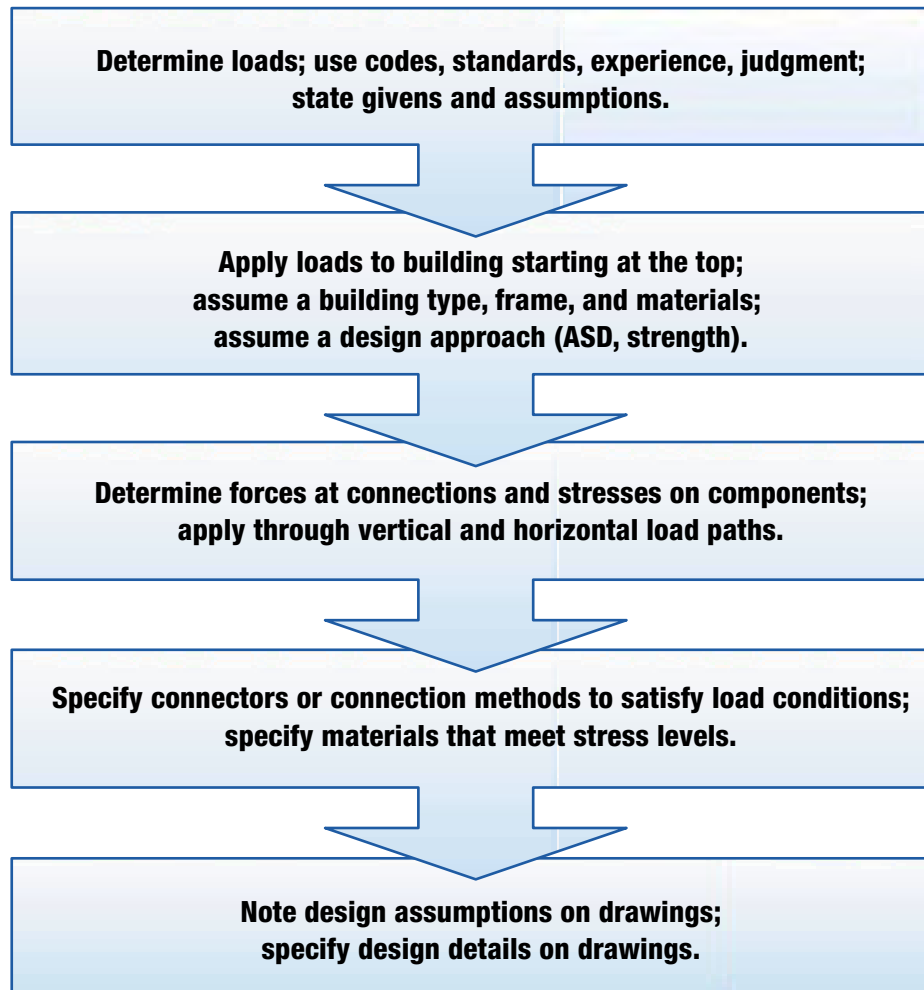
**Course Number: BD-8005**

**Credit: 8 Hours / 8 PDH / 8 CPD**

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## 1.The Design Process

The design of a residential structure begins with determining site-specific loads (which is outside the scope of this course). These loads then must be applied to the building; forces and stresses will be determined from these loads, and resistance to the forces and stresses in the form of connectors and materials will be selected. Figure 1 illustrates the general design process.



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**Figure 1**  
Coastal construction design process.

Each step of this process is covered as a separate section of this course. The many variations of designs, the location of buildings in different hazard areas, the varieties of building shapes, and other building parameters are discussed where appropriate in each of the design steps. A building located in either a V zone or a coastal A zone that is subject primarily to flood and wind hazards is used throughout this course as a demonstration of how to design a building in a coastal flood hazard area.

**NOTE**  
Designers should consider the consequences of damage to, or the failure of, critical design components.

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The design process involves the following:

- determining design loads
- determining the building's foundation, structural frame, and envelope
- determining the connections between individual elements
- determining the elevation, placement, and support for utilities
- selecting the appropriate materials

The entire design process is based on the fundamental premise that anticipated service **and natural hazard loads can and must be transferred through the building in a continuous path to the supporting soils. ANY** weakness in that continuous path is a potential point of failure of the building, and any failure creates the possibility for large property losses and the potential for loss of life.

This course does not cover all of the almost endless number of combinations of loads, materials, building shapes and functions, hazard zones, and elevations. The designer will find that engineering judgment will need to be applied to a range of problems during the design of a coastal residential building. Therefore, it is the intent of this to provide sufficient background and examples so that a designer can effectively design a residential building for construction in a coastal hazard area.

In this course, the recommended design method is Allowable Stress Design (ASD), so there are factors of safety (FS) built into the development of the material stresses and the forces at the connections. This design method has been chosen for this because ASD continues to be the predominant design method in light-frame, residential, wood construction. Most suppliers of wood framing hardware and connectors provide load limits for their products with factors of safety built into the limits. Load and Resistance Factor Design (LRFD) guidance is available for wood if the designer prefers this ultimate strength or limit state design method.

## **2. Step 1 – Determining Loads**

The types of loads that most commonly act on one- to three-story residential buildings during severe natural hazard events are as follows:

- dead loads
- live loads
- flood loads
- wind loads
- earthquake (seismic) loads
- snow loads

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Additional loads caused by long-term and short-term erosion and localized scour can play a significant part in the total loads that are imparted to the structure; therefore these conditions must be accounted for.

Load determination involves calculating each type of load. The most severe load combination required by the applicable building code or standard is then applied to the structure. Therefore, consideration must be given to the following loads and factors that affect loads:

**Dead loads** – The weight of the building and accessory equipment such as tanks, piping, electrical service panels and conduits, and HVAC equipment.

**Live loads** – Combined loads of occupants, furnishings, and non-fixed equipment.

**Flood loads** – Flood depth and velocity, wave effects, expected long-term and short-term erosion as well as localized scour, elevation of the building in relationship to the expected flood conditions, and floating debris impacts.

**Wind loads** – Roof shape and pitch, siting, topography and exposure, and building shape and orientation. The height of the structure also needs to be assessed.

**Seismic loads** – Mass (including elevation, location, and distribution) of the building, soil supporting the building, height of the building above the ground, and additional loads that the building may occasionally support (e.g., snow).

**Snow loads** – Roof shape and pitch, multi-level roofs, and building orientation. Also, drifting snow may cause unbalanced loading on the roof system.

An important part of design is deciding how these loads are imparted to the building. This means that the designer must decide where (and perhaps in what sequence) the loads are to be applied to the building.

### **3. Step 2 – Applying Loads to the Building**

The following concepts show how one design step leads to the next:

- All design loads create forces in and on the building. The forces are transferred through load paths.
- Load paths always end in the soil that supports the structure.
- Loads should be applied to the building beginning at the top.
- Loads should be determined for both the vertical and horizontal load paths.

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- Load transfer creates forces at connections and imparts stresses in the materials. Connections and materials must be strong enough to handle those forces and stresses.
  - The load path must be continuous; any break or weakness in the load path “chain” can result in damage or even structural failure.

### 3.1 Failure Modes

Building failures most frequently occur by one or more of the following:

#### Primary Failure Modes

**Uplift:** Vertical forces caused by wind or buoyancy exceed the weight of the structure and the strength of the soil anchorage. The building fails by being lifted off its foundation or because the foundation pulls out of the soil.

**Overturning:** The applied moments caused by wind, wave, earthquake, and buoyancy forces exceed the resisting moments of the building’s weight and anchorage. The building fails by rotating off its foundation or because the foundation rotates out of the soil.

**Sliding or Shearing:** Horizontal forces exceed the friction force or strength of the foundation. The building fails by sliding off its foundation, by shear failure of components transferring loads to its foundation, or by the foundation sliding.

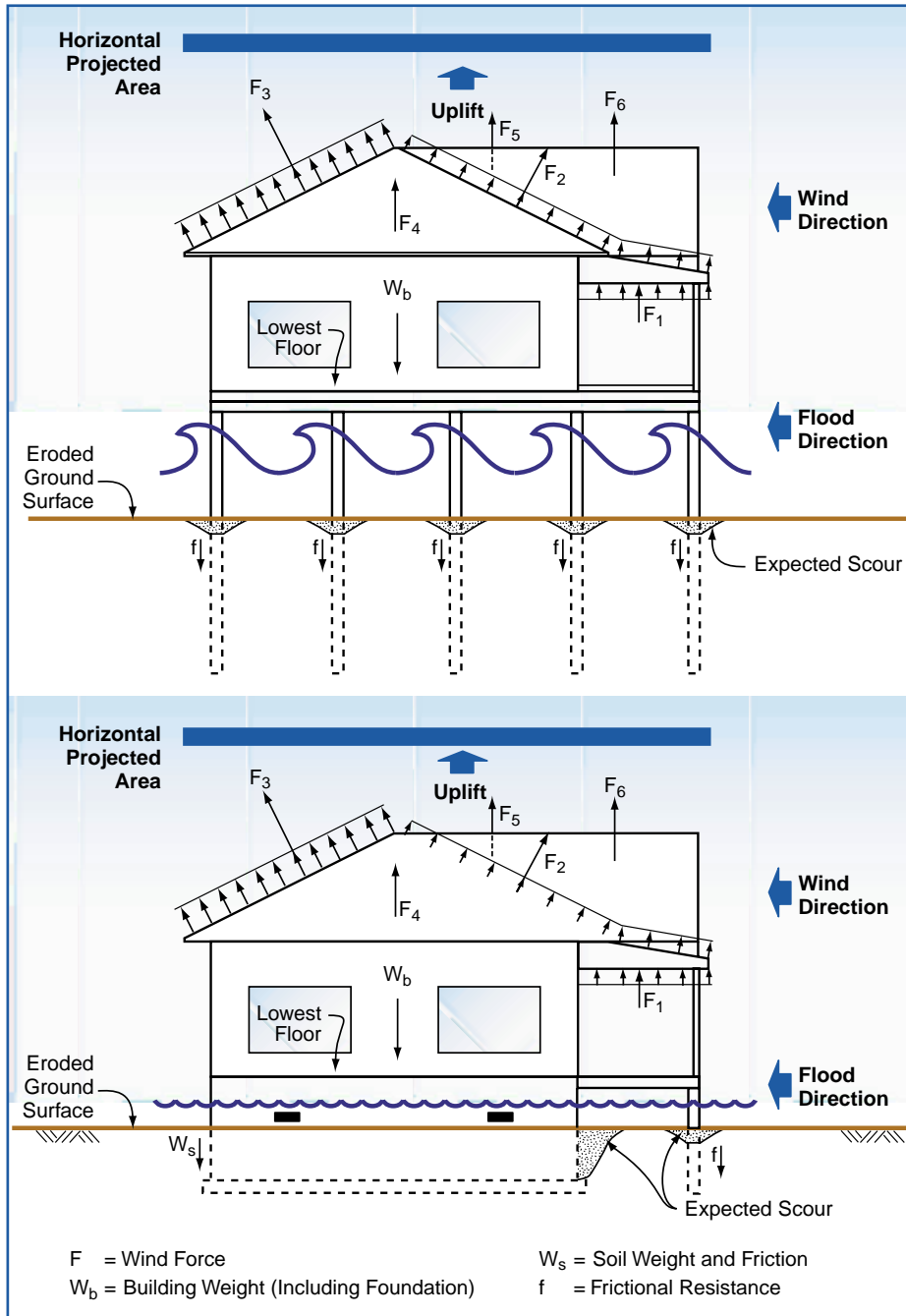
#### Secondary Failure Mode

**Collapse:** Collapse is a secondary mode of failure. Structural components fail or become out of plumb or level under uplift, overturning, or sliding. The building then becomes unstable and collapses.

Buildings under extremely heavy vertical downward loads, such as snow, can also fail in bending, shear, or compression of primary structural members. For purposes of this course, it is assumed the designer is familiar with the design concepts used to support these ordinary gravity loads.

#### 3.1.1 Uplift

Uplift failure occurs when the vertical forces are greater than the weight of the building, the strength of the structural frame (e.g., fasteners or connections), or the foundation anchorage. This type of failure can occur from high winds or buoyancy. Figure 2 illustrates how vertical uplift wind forces ( $F_1 - F_6$ ) from the roof areas shown in Figure 16 pull on the structural components.



**Figure 2**  
Uplift.

This course will show how to calculate forces with the projected area method, which will simplify calculations. The horizontal projected area, shown above the buildings in Figure 2, is used for calculating uplift. The horizontal projected area for each roof segment must be multiplied by the pressure per unit area for that segment and all of the forces summed to arrive at a total uplift force. This method is similarly applicable to other failure modes.

Field investigations indicate that the failure of houses with wood-framed roofs often occurs first at the roof, often at improper fastening between the roof sheathing and building frame. Proper fastening of the roof sheathing is also important because there is little dead load at the roof to resist uplift. After wind and/or rain has entered the building (in a hurricane or other storm event), forces on other building components increase and cause additional failure.

The progressive nature of failures is illustrated in Figure 3, in which the collapsed trusses are an indication that, once the sheathing was removed, the trusses lost the lateral support required for stability and for resistance to lateral wind forces.

**Figure 3**  
Hurricane Andrew (1992),  
Dade County, Florida. Roof  
structure failure due to  
inadequate bracing.



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