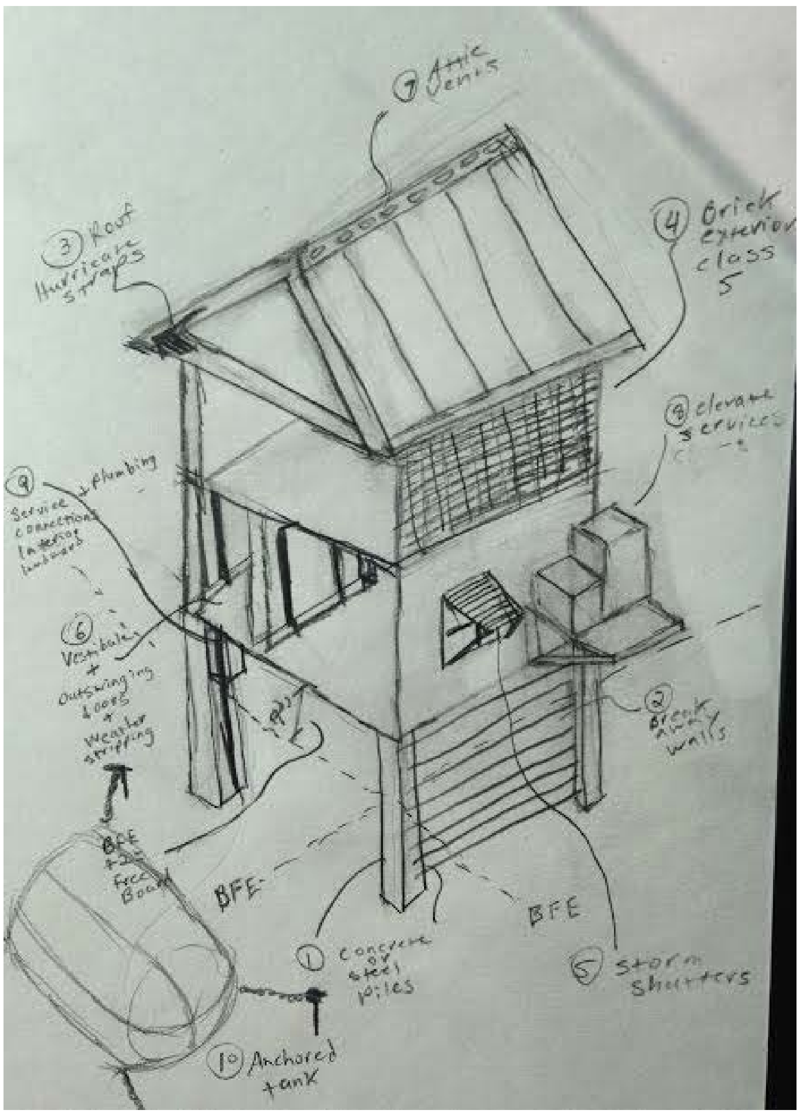
SPMPS

# House Recommendations for Resiliency

# ARC 466 –ARCH DESIGN 4

# MARCH 11, 2015

## GROUP #4





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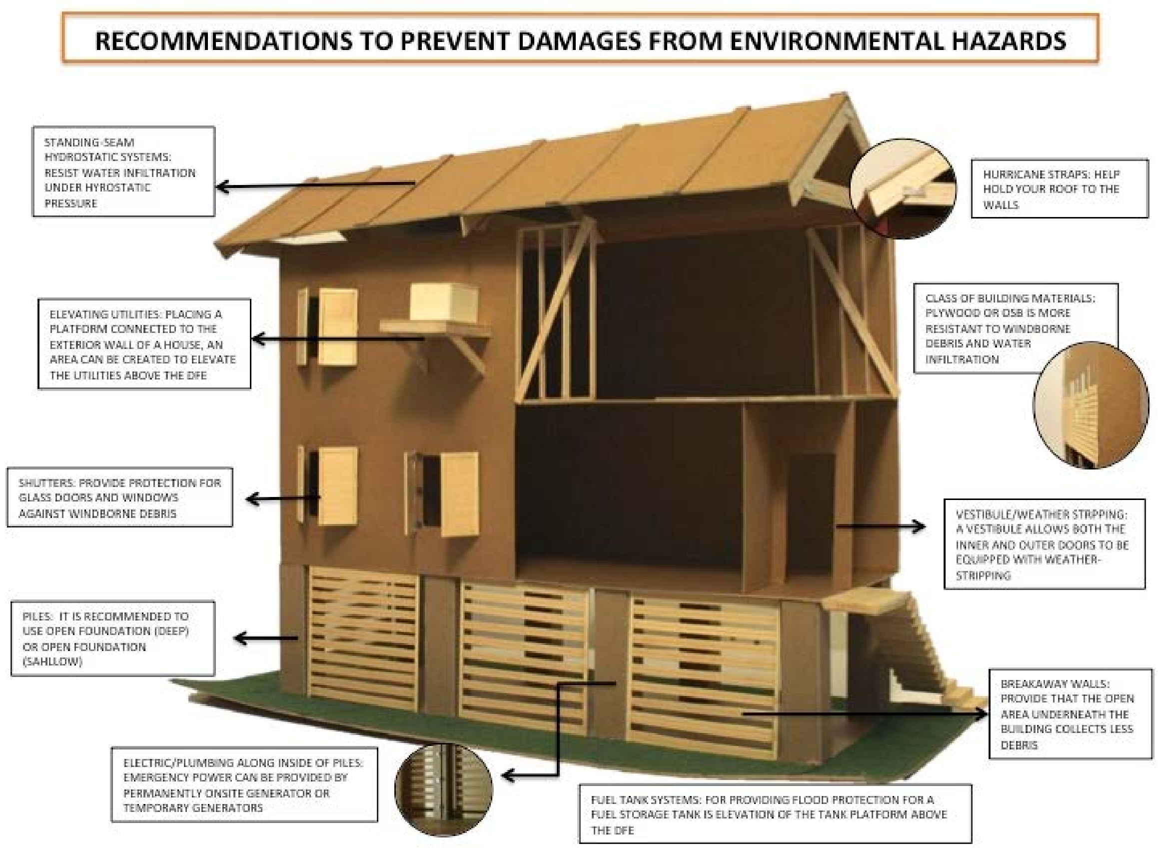
# OUTLINE

# SUMMARY

This document may be used as a resource to develop a model set of recommendations for homeowners to rebuild and/or design a replacement home that reduces risks from natural hazards and disasters.

Buildings in vulnerable areas are provided with a range of recommendations that meet the developmental standards in the Federal Government's regulating industries. The documents reviewed are **FEMA Coastal Construction Standards, HUD Minimum Property Standards, Residential Code of NYS and Property Maintenance Code of NY**.

Throughout the findings, the conflicts between standards have been identified and addressed. The 10 most important recommendations are geared toward increased awareness for designs that will reduce the potential for damage resulting from any natural hazard or disaster.



# METHODOLOGY

An organized, documented set of procedures and guidelines established here may be used to develop a rebuild design of a 3 bedroom home in a recent storm-affected area. The 10 most important recommendations for homeowners provide a “recipe” approach to carry out a procedure to meet a quality standard of mitigation.

There are minimum design requirements for loads, materials, and material resistances for a given building design and they are normally specified in the locally adopted building code.

There is a systematic approach to any design, depending on the site in which the building is located. You must asses a variety of aspects, such as risk factor, location, building usage, funding and availability and cost of insurance.
First, determine the natural hazard risk.

By using the following flow charts:

Assessing risk to coastal buildings and building sites requires identifying or delineating hazardous areas and considering the following factors: Types of hazards known to affect a region or geographic variations in hazard occurrence and severity Methods and assumptions underlying existing hazard identification maps or products “Acceptable” level of risk.

Chart 1:

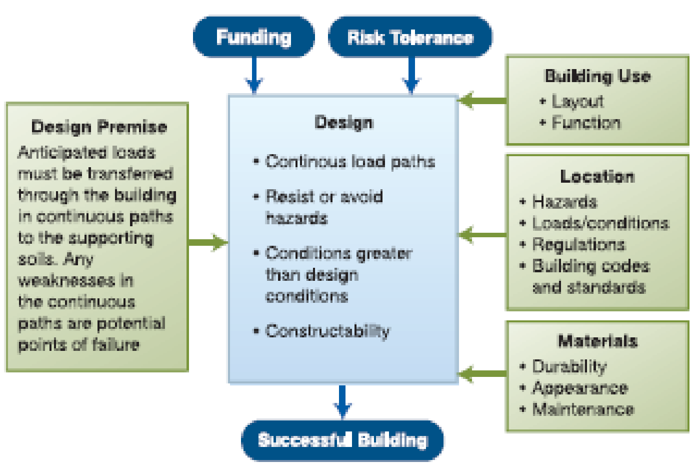



Figure 7-1.
Design framework for a successful building, incorporating cost, risk tolerance, use, location, materials, and hazard resistance

Volume II contains many design equations, but they do not cover all of the design calculations that are necessary and are provided only as examples.

## Chart 2:

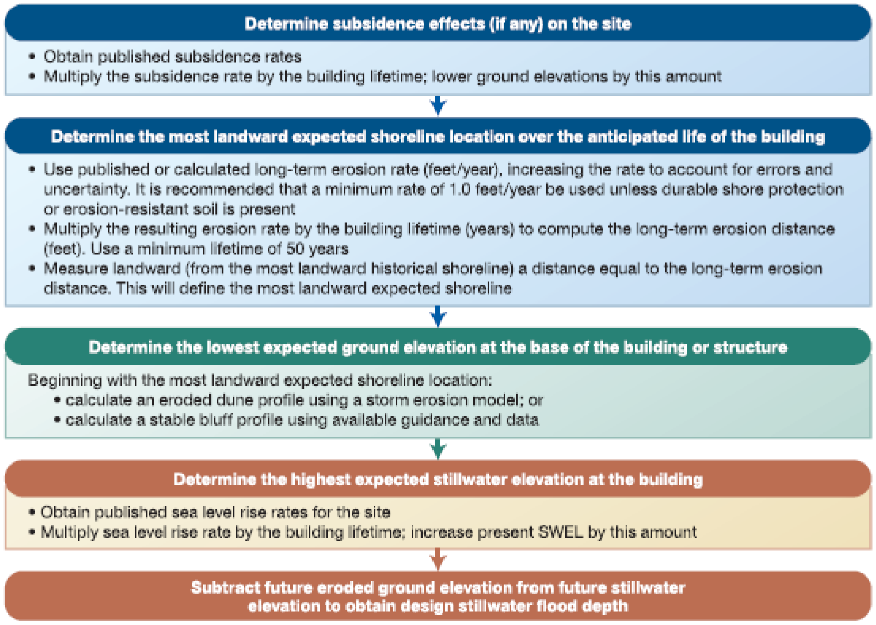


Figure 8-3. Flowchart for estimating maximum likely design stillwater flood depth at the site

## Chart 3:

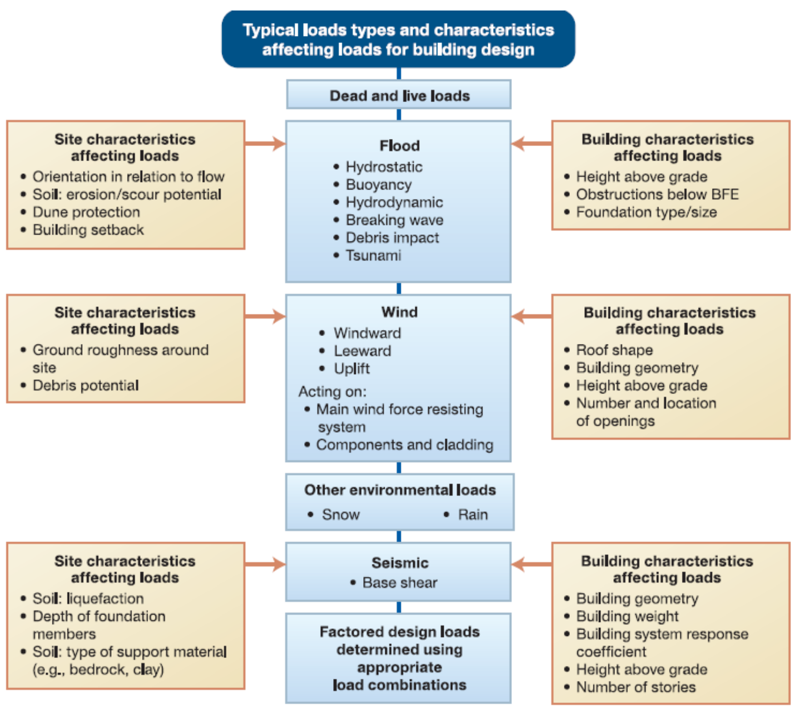


Chart 4:

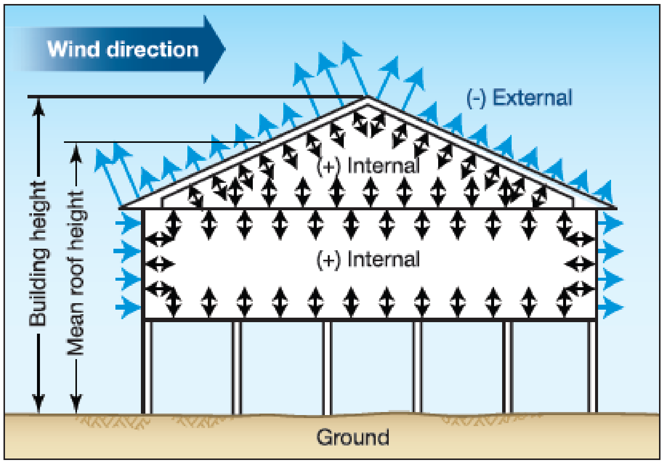



Figure 8-18.
Distribution of roof, wall, and internal pressures on one-story, pile-supported building

Chart 5:

Table 7-2. Sample NFIP Flood Insurance Premiums for Buildings in Zone A; $250,000 Building/$100,000 Contents Coverage

| Floor Elevation above BFE | Reduction in Annual Flood Premium | Annual Premium | Savings |
|---|---|---|---|
| 0 | 0% | $ 1,622 | $ 0 |
| 1 foot | 45% | $ 897 | $ 725 |
| 2 feet | 61% | $ 638 | $ 984 |
| 3 feet | 66% | $ 548 | $ 1,074 |
| 4 feet | 67% | $ 530 | $ 1,092 |

Rates as of May 2011 per the National Flood Insurance Program Flood Insurance Manual (FEMA 2011) for a Zone V structure free of obstruction. Rates include building ($250,000), contents ($100,000), and associated fees, including increased cost of compliance.

Each and every design will vary depending on all the above listed factors. Each location has specific code and zone regulations that must be met which are overseen by the governing area.

# RECOMMENDATIONS

## A - SUBSTRUCTURE

### Foundation

#### 1-Piles

- Using reference to Table 4-10 of the FEMA P-550, Second Edition/December 2009, it is recommended to use open foundation (deep) or open foundation (shallow), in order to cover the A zones in coastal areas. We can see from this table that there are 7 different types of foundations which can be used that will meet the requirements stated above.

**Table 4-10. Recommended Foundation Types Based on Zone**

| Foundation | | Case | V Zones | A Zones in Coastal Areas | |
|---|---|---|---|---|---|
| | | | | Coastal A Zone | A Zone |
| Open Foundation (deep) | Braced timber pile | A | ✔ | ✔ | ✔ |
| | Steel pipe pile with concrete column and grade beam | B | ✔ | ✔ | ✔ |
| | Timber pile with concrete column and grade beam | C | ✔ | ✔ | ✔ |
| | Timber pile with concrete grade and elevated beams and concrete columns | H | ✔ | ✔ | ✔ |
| Open Foundation (shallow) | Concrete column and grade beam | D | NR | ✔ | ✔ |
| | Concrete column and grade beam with integral slab | G | NR | ✔ | ✔ |
| Closed Foundation (shallow) | Reinforced masonry – crawlspace | E | ✘ | NR | ✔ |
| | Reinforced masonry – stem wall | F | ✘ | NR | ✔ |

✔ = Acceptable
NR = Not Recommended
✘ = Not Permitted

- By using Table 10-3 from the "Coastal Construction Manual" we are able to determine the type of material the piles should be built out of by comparing the advantages and special considerations. The best recommended material for the foundation piles would be concrete or steel piles. These two different materials are recommended for several reasons; concrete piles: are resistant to corrosion, can be drive through some types of hard materials, and are suitable for friction end- bearing piles. Steel piles, have high resistance to bending, available in many lengths, and sizes, and have a high resistance to bending.

**Table 10-3. Advantages and Special Considerations of Three Types of Pile Materials**

| Material | Advantages | Special Considerations |
|---|---|---|
| Wood | • Comparatively low initial cost<br>• Readily available in most areas<br>• Easy to cut, saw and drill<br>• Permanently submerged piles resistant to decay<br>• Relatively easy to drive in soft soil<br>• Suitable for friction and end bearing pile | • Difficult to splice<br>• Subject to eventual decay when in soil or intermittently submerged in water<br>• Vulnerable to damage from driving (splitting)<br>• Comparatively low compressive load<br>• Relatively low allowable bending stress |
| Concrete | • Available in longer lengths than wood piles<br>• Corrosion resistant<br>• Can be driven through some types of hard material<br>• Suitable for friction and end-bearing piles<br>• Reinforced piles have high bending strength<br>• High bending strength allows taller or more heavily loaded pile foundations to be constructed without grade beams | • High initial cost<br>• Not available in all areas<br>• Difficult to make field adjustments for connections<br>• Because of higher weight, require special consideration in high seismic areas |
| Steel | • High resistance to bending<br>• Easy to splice<br>• Available in many lengths, sections, and sizes<br>• Can be driven through hard subsurface material<br>• Suitable for friction and end-bearing piles<br>• High bending strength, which allows taller or more heavily loaded pile foundations to be constructed without grade beams | • Vulnerable to corrosion<br>• May be permanently deformed if struck by heavy object<br>• High initial cost<br>• Some difficulty with attaching wood framing |

## 2-Break away Walls

Breakaway walls are recommended, because these enclosures provide that the open area underneath the building collects less debris in the event that the water or wind elevates.

The NFIP regulations state: the area below an elevated building can be used only for parking, building access, and storage. These areas must not be finished or used for recreational or habitable purposes. No mechanical, electrical, or plumbing equipment is to be installed below the BFE. However, post-construction conversion of enclosures to habitable space remains a common violation of floodplain management requirements and is difficult for communities and States to control.

Although these enclosures and items in them are likely to be damaged or destroyed even during minor flood events, they are not covered by flood insurance and, if damaged, the owner may incur significant costs to repair or replace them. Also, they may increase one's flood insurance premiums for the entire building.

There are two types of enclosures:

***Enclosures with breakaway walls*** are designed to collapse under flood loads and act independently from the elevated building, leaving the foundation intact (Figure 2-19). All enclosures below elevated buildings in Zone V must have breakaway walls. Enclosures in Zone A and Coastal A Zones may have breakaway walls, but the walls must have flood openings to comply with Zone A requirements.

***Enclosures and closed foundations that do not have breakaway walls*** can be constructed below elevated buildings in Zone A but are not recommended in Coastal A Zones. The walls of enclosures and foundation walls below elevated buildings in Zone A must have flood openings to allow the free entry and exit of floodwaters (Figure 2-20).

Figure 2-20.
Flood opening in an enclosure with breakaway walls, Hurricane Ike (Galveston Bay shoreline, San Leon, TX)

Figure 2-21.
Louvers installed beneath an elevated house are a good alternative to breakaway walls
SOURCE: FEMA P-499 2010

## B -SHELL

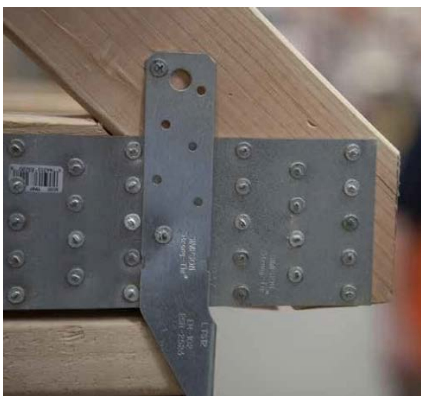
**Roof**

**3-Standing-Seam Hydrostatic (i.e., water-barrier) Systems**

These panel systems are designed to resist water infiltration under hydrostatic pressure. They have standing seams, which raise the joint between panels above the water line. The seam is sealed with sealant tape or sealant in case it becomes inundated with water backed up by an ice dam or driven by high wind.

**4-Hurricane straps**

There are many types of roof design. Regardless of your type of roof, hurricane straps are designed to help hold your roof to the walls. While you are in the attic, inspect for hurricane straps of galvanized metal. Hurricane straps may be difficult for homeowners to install. You may need to call a professional to retrofit your home with hurricane straps. Check with your local government-building officials to see if hurricane straps are required in your area.



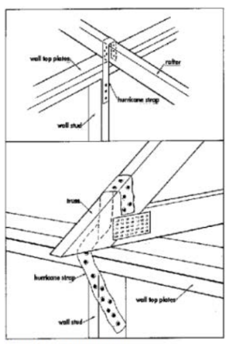


Figure 4. Hurricane Straps

## Exterior Walls

### 5-Class of Building Materials

-For exterior wall materials we can refer to the “Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program.” From Table 1 in this technical bulletin we will get a description of the type of classes certain types of building materials fall into with resistance to floodwater damage. The recommendation for flood zone A materials used should fall within the classes 4 and 5.

Table 1. Class Descriptions of Materials

| NFIP | Class | Class Description |
|---|---|---|
| ACCEPTABLE | 5 | Highly resistant to floodwater[1] damage, including damage caused by moving water.[2] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[3] Materials in this class are permitted for partially enclosed or outside uses with essentially unmitigated flood exposure. |
| | 4 | Resistant to floodwater[1] damage from wetting and drying, but less durable when exposed to moving water.[2] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[3] Materials in this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection. |
| UNACCEPTABLE | 3 | Resistant to clean water[4] damage, but not floodwater damage. Materials in this class may be submerged in clean water during periods of flooding. These materials can survive wetting and drying, but may not be able to be successfully cleaned after floods to render them free of most[3] harmful pollutants. |
| | 2 | Not resistant to clean water[4] damage. Materials in this class are used in predominantly dry spaces that may be subject to occasional water vapor and/or slight seepage. These materials cannot survive the wetting and drying associated with floods. |
| | 1 | Not resistant to clean water[4] damage or moisture damage. Materials in this class are used in spaces with conditions of complete dryness. These materials cannot survive the wetting and drying associated with floods. |

-Within Table 2 of the same technical bulletin the construction materials are broken up into their designated classes. By having this table we are able to select recommendations for building materials that are most resistant to flood damage. (Table 2 illustrated below is only 1 of 5 pages, refer to, “Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program,” for the entire table of flood damage resistant materials.)

Table 2. Types, Uses, and Classifications of Materials

| Types of Building Materials | Uses of Building Materials | | Classes of Building Materials | | | | |
|---|---|---|---|---|---|---|---|
| | | | Acceptable | | Unacceptable | | |
| | Floors | Walls/ Ceilings | 5 | 4 | 3 | 2 | 1 |
| **Structural Materials (floor slabs, beams, subfloors, framing, and interior/exterior sheathing)** | | | | | | | |
| Asbestos-cement board | | ■ | ■ | | | | |
| Brick | | | | | | | |
| Face or glazed | | ■ | ■ | | | | |
| Common (clay) | | ■ | | ■ | | | |
| Cast stone (in waterproof mortar) | | ■ | ■ | | | | |
| Cement board/fiber-cement board | | ■ | ■ | | | | |
| Cement/latex, formed-in-place | ■ | | | ■ | | | |
| Clay tile, structural glazed | | ■ | ■ | | | | |
| Concrete, precast or cast-in-place | ■ | ■ | ■ | | | | |
| Concrete block[1] | | ■ | ■ | | | | |
| Gypsum products | | | | | | | |
| Paper-faced gypsum board | | ■ | | | ■ | | |
| Non-paper-faced gypsum board | | ■ | | ■ | | | |
| Greenboard | | ■ | | | | ■ | |
| Keene's cement or plaster | | ■ | | | ■ | | |
| Plaster, otherwise, including acoustical | | ■ | | | | ■ | |
| Sheathing panels, exterior grade | | ■ | | | ■ | | |
| Water-resistant, fiber-reinforced gypsum exterior sheathing | | ■ | | ■ | | | |
| Hardboard (high-density fiberboard) | | | | | | | |
| Tempered, enamel or plastic coated | | ■ | | | | ■ | |
| All other types | | ■ | | | | | ■ |
| Mineral fiberboard | | ■ | | | | | ■ |
| Oriented-strand board (OSB) | | | | | | | |
| Exterior grade | ■ | ■ | | | | ■ | |
| Edge swell-resistant OSB | ■ | ■ | | | | ■ | |
| All other types | ■ | ■ | | | | | ■ |
| Particle board | ■ | | | | | | ■ |
| Plywood | | | | | | | |
| Marine grade | ■ | ■ | ■ | | | | |
| Preservative-treated, alkaline copper quaternary (ACQ) or copper azole (C-A) | ■ | ■ | | ■ | | | |

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-It is recommended that the exterior face of studs be fully clad with plywood or oriented strand board (OSB) sheathing so the sheathing can withstand design wind pressures that produce both in-plane and out-of plane loads because a house that is fully sheathed with plywood or OSB is more resistant to wind-borne debris and water infiltration if the wall cladding is lost.

## Windows

### 6-Shutters

If glazing systems are not used it is highly recommended to use a system of shutters. Why Are Storm Shutters Needed? If glazing is not resistant to windborne debris, then shutters are an important part of a hurricane-resistant home. They provide protection for glass doors and windows against windborne debris, which is often present in hurricanes. Keeping the building envelope intact (i.e., no window or door breakage) is vital to the integrity of a home. If the envelope is breached, sudden pressurization of the interior may result in major structural or non-structural damage (e.g., roof loss) and will lead to significant interior and contents damage from wind-driven rain. The addition of shutters will not eliminate the potential for wind-driven rain entering the building, but will improve the building's resistance to it. Table 6.2 gives us recommendations for shutter types; we can compare: cost, advantages, and disadvantages. According to the table below it is best to use permanent motor driven shutters, if cost is not an issue, if the budget restricts motor driven permanent shutters, accordion, manual closing shutter should be used. Installing storm shutters over all exposed windows and other glass surfaces is one of the easiest and most effective ways to protect your home. You should cover all windows, French doors, sliding glass doors, and skylights. There are many types of manufactured storm shutters available. For more information on manufactured shutters, check with your local building supplies retailer.

**Shutter Type Cost Advantages**

| Shutter Type | Cost | Advantages | Disadvantages |
|---|---|---|---|
| Wood structural panels | Low | Inexpensive | Must be installed and taken down every time they are needed; must be adequately anchored to prevent blow-off; difficult to install on upper levels; storage space is needed. |
| Metal or polycarbonate panels | Low/ Medium | Easily installed on lower levels | Must be installed and taken down every time they are needed; difficult to install on upper levels; storage space is needed. |
| Accordion, manual closing | Medium/ High | Always in place; ready to be closed | Always in place; ready to be closed. Must be closed manually from the outside; difficult to access on upper levels. |
| Permanent, motor-driven | High | Easily opened and closed from the inside | Expensive. (It is important to find a motorized shutter that allows the shutter to be manually raised in order to allow the interior to vent following the storm and prior to electrical power restoration.) |

6.2: PROTECTION OF OPENINGS– SHUTTERS AND GLAZING

4 of 6 HOME BUILDER'S GUIDE TO COASTAL CONSTRUCTION

12/10

Storm shutters:

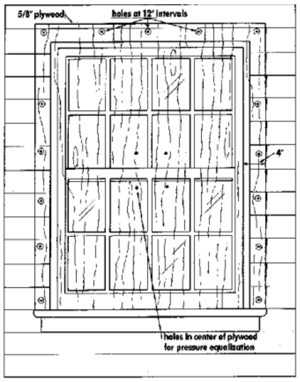



Figure 8. Plywood Storm Shutters

## Exterior Doors

### 7-Vestibule/Weather Stripping

-According to the “Coastal Construction Manual,” chapter 11, Designing the Building Envelope, recommendations can be made for exterior door assemblies to achieve good wind performance, it is necessary to avoid strength degradation caused by corrosion and termites. To avoid corrosion problems with metal doors or frames, anodized aluminum or galvanized doors and frames and stainless steel frame anchors and hardware are recommended for buildings within 3,000 feet of an ocean shoreline (including sounds and back bays). Galvanized steel doors and frames should be painted for additional protection. Fiberglass doors may also be used with wood frames.

-From section 11.2.1.4 the following elements are given that can minimize infiltration around exterior doors.

- **Vestibule**. Adding a vestibule allows both the inner and outer doors to be equipped with weather-stripping. The vestibule can be designed with water-resistant finishes (e.g., tile), and the floor can be equipped with a drain. In addition, installing exterior threshold trench drains can be helpful (openings must be small enough to avoid trapping high-heeled shoes). Trench drains do not eliminate the problem because water can penetrate at door edges.

- **Weather-stripping**. A variety of pre-manufactured weather-stripping elements are available, including drips, door shoes and bottoms, thresholds, and jamb/ head weather-stripping. More information is available in Fact Sheet 6.1 in FEMA P-499.

## D - SERVICES

**Plumbing/HVAC/Electric**

It is very important to adhere to guidelines regarding the placement of the plumbing and HVAC systems. It must be installed in an area that is above the DFE.

> The code states: The two methods of providing interior mechanical equipment include but are not limited to furnaces, boilers, water heaters, and distribution ductwork. High winds normally do not affect interior mechanical equipment. Floodwaters, however, can cause significant damage to furnaces, boilers, water heaters, and distribution ductwork.

The following methods of reducing flood damage to interior equipment are recommended:

> Elevate the equipment and the ductwork above the DFE by hanging the equipment from the existing first floor or placing it in the attic or another location above the DFE.

The Basic Protection Methods are ***elevation*** or ***component protection***.

Key Issues:

Hazards, requirements, and recommendations – Special considerations must be made when installing utility systems in coastal homes. ***Proper placement and connection*** of utilities and mechanical equipment can ***significantly reduce the costs of damage caused by coastal storms*** and will ***enable homeowners to reoccupy*** their homes soon after electricity, sewer, and water are restored to a neighborhood.

**8-Elevating Utilities**

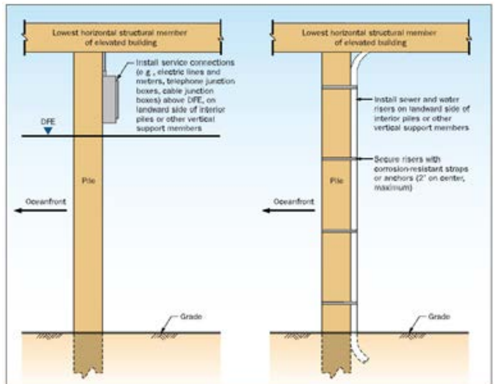
Elevation refers to the location of a component and/or utility system above the Design Flood Elevation (DFE). By placing a platform connected to the exterior wall of a house, an area can be created to elevate the utilities above the DFE.

## 9-Electric/Plumbing Along Inside of Piles

Electrical placement is an important focus because floodwaters can extinguish gas-powered flames, short circuit the equipment's electric system, and inundate equipment and ductwork with sediment.

Many times, a severe wind event often interrupts electric service, designers and homeowners need to make a decision about the need for backup power. Emergency power can be provided by permanently installed onsite generators or by temporary generators brought to the site after the event. For permanently installed units, the following is recommended:

Electrical lines and box dislocated by hurricane forces.




Recommended installation techniques for electrical and plumbing lines and other utility components.

## Fire Protection

The protection and awareness of fire prevention is essential to avoiding another hazard. Below you will find the standards for protection of these areas. As always, the rule of thumb for placement of these systems is above the DFE.

## 10-Fuel Tank Systems

Elevation The most effective technique for providing flood protection for a fuel storage tank is elevation of the tank on a platform above the DFE. Figure 3.2.3A shows a tank on an elevated platform. The depth of the footing will be dependent upon the hazards at the site. The following outlines some additional considerations when protecting fuel systems:  The tank should be anchored to the platform with straps, which would constrain the tank in wind, earthquake, and other applicable forces.  In coastal zones, the straps should be made of non-corrosive material to prevent rusting.  In velocity flow areas, the platform should be supported by posts or columns that are adequately designed for all loads including flood and wind loads.  The posts or columns should have deep concrete footings embedded below expected erosion and scour lines.  The piles, posts, or columns should be cross-braced to withstand the forces of velocity flow, wave action, wind, and earthquakes; cross-bracing should be parallel to the direction of flow to allow for free flow of debris.  In non-velocity flow floodplains, elevation can also be achieved by using compacted fill to raise the level of the ground above the DFE and by strapping the tank onto a concrete slab at the top of the raised ground. Figure 3.2.3B shows a tank located atop fill.

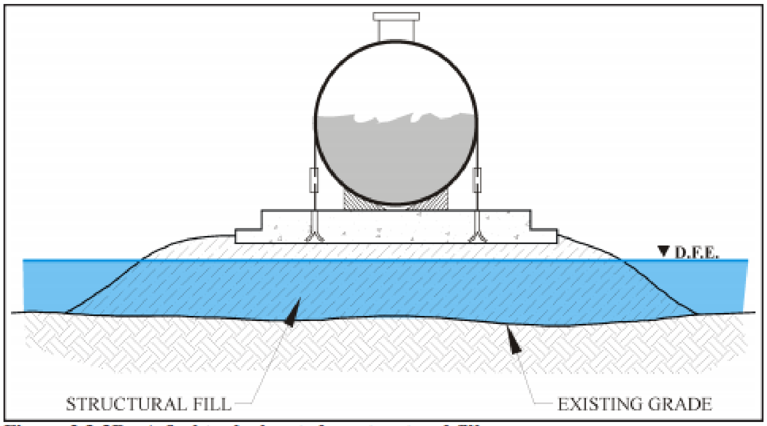


Figure 3.2.3B: A fuel tank elevated on structural fill

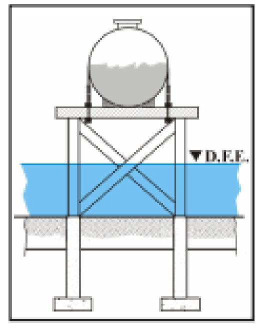


Figure 3.2.3A: A fuel tank elevated above the DFE on a platform in a velocity flow area

# INNOVATIVE TECHNOLOGIES

Window Energy Efficiency

1- **Window film** According to "Home Builder's Guide to Coastal Construction," the best construction method to be used to protect windows from windborne debris is **Polycarbonate glazing systems**. They are also used in place of traditional laminated glazing systems. Polycarbonate systems typically consist of plastic resins which are molded into sheets which provide lightweight, clear glazing panels with high impact-resistance qualities. The strength of the polycarbonate sheets is much higher than non-laminated glass (i.e., more than 200 times stronger) or acrylic sheets or panels (more than 30 times stronger). Several brands of polycarbonates used as glazing (such as Lexan® and Makrolon®) are commonly available. Both impact-resistant windows and shutter systems may be constructed using polycarbonates.

2- **Insulated Vinyl Siding** Two new products give vinyl siding a competitive edge by increasing its energy efficiency and enhancing its impact resistance. One product is an insulative foam underlayment, custom contoured to fit snugly behind hundreds of different brands and styles of vinyl siding. The other is line of vinyl siding products fused to a foam backing material, to create an all-in-one siding and insulation system.

Progressive Foam Technologies, Inc. makes contoured foam underlayment under the brand name "Thermowall". The material is shaped to precisely fit behind nearly any manufacturer's siding profile sold in the United States. Installed over exterior walls just before placement of the siding, the underlayment provides a continuous solid backing that helps vinyl siding resist impacts that might otherwise cause cracks or dents. By adding an additional foam insulation layer, the R-values of exterior walls are increased by R-2.8 to 3.3, depending on the profile, not including the vinyl siding. The manufacturer states that the foam is made from environmentally benign expanded polystyrene (EPS), which has thermal expansion properties nearly identical to vinyl siding, and moderate vapor permeability to allow the siding to breathe.

Crane Performance Siding uses a similar concept to create lines of solid-core siding products including Craneboard and Techwall Plus. These products fuse a contoured polystyrene backing material to a vinyl exterior facing for a solid insulated wall system with an overall R-rating of 4 to 4.5, depending on the product selected. The manufacturer states that the product also helps to bridge wall irregularities, and interlocks tightly at seams to create a straight, solid finished wall appearance without the waviness sometimes associated with vinyl siding. The panel sections are up to 18 inches high, covering nearly twice as much area as most vinyl panels, allowing installation to proceed more quickly. Application of insulative sheathing and exterior finish surfacing is accomplished in one step

Mold & Moisture

3- **Water-resistant Polyethylene Subfloor Systems** Polyethylene flooring systems that are specially designed for use over concrete floors can alleviate moisture problems associated with placing wood sub-flooring in direct contact with concrete slabs. The systems are made of a molded polyethylene base. The base prevents the migration of moisture, while its undulating, raised pattern (one pattern resembles plastic cleats while another is zig-zag) creates an airspace between subfloor and concrete.

Natural Disasters

4- **Shear wall panels** In areas prone to earthquakes and high winds, codes for shear wall design now require builders to use let-in bracing or costly plywood site-built assemblies. Two manufacturers are now helping to streamline construction of shear walls by providing pre-manufactured modular products that are cost effective and easy to design, specify, install, and inspect.

Simpson Strong Tie produces a wood panel called the Strong-Wall Shearwall, made with ½" Oriented Strand Board (OSB) sheathing and 3" glue-lam studs. Metal strips and connecting hardware secure the panel to the building's structural framing, creating a continuously secured rigid unit in areas where shear walls are specified. Frames are available in various common heights and widths, with a 4' wide, 8' high sheathed panel weighing around 130 lbs.

An all-steel system called Hardy Frame is manufactured by Simplified Structural Systems in Ventura CA. Their design uses perimeter and diagonal bracing of 14 gauge galvanized high-tensile steel with 20-gauge studs 16" on center and 3-1/2" thick. Connections are welded. Frames are available in widths from 18" to 80", according to seismic zone or wind load. A typical unsheathed 4' x 8' frame weighs 107 pounds.

5- **Manufactured ground anchor systems** Manufactured homes are not usually installed with permanent foundations, but instead sit on short piers that resist mostly gravity loads. Ground anchors are plates or augers imbedded in the soil that limit lateral building movement down through tension members tied back to the home's chassis. In this way, high wind (hurricane, tornado), earthquake and flood forces are resisted through the coherent mass of the earth acting with the anchors. Properly applied, these systems are a cost-effective way to limit structural failure compared to conventional manufactured housing foundations, saving lives and property.

In a complete ground anchor foundation system, the house is supported by several steel I-beams which are supported by an array of short piers. Tensile members, usually diagonal, connect the main beams with each anchor assembly. An anchor consists of a rod between the anchor head and anchor base, which is buried 3' to 9' into terra firma and allows the combined mass of the retained soil to resist uplift and lateral forces. Types of ground anchors include "manta ray" plate anchors, "rock anchors" for rock embedment, single and double helix anchors that are augered into place, and rods or chains that anchor into a poured structural fill. Tension members may be steel rods, straps or link chains. Most systems offer stabilizer plates to limit the anchor heads horizontal displacement.

The most common ground anchors are auger, or helix-type systems. They are applicable to several types of piers, and feature anchors with a single- or double-helix base and an optional lateral stabilizer near the anchor head. The helix is a 4" or 6" circular plate in the shape of a short spiral. Steel straps hold the home's chassis to the anchor heads. Variations include steel rod anchors which may be encased in a poured structural fill collar, or "rock anchors" which may be installed in solid rock.

Earth-Lok is a "Manta ray"-type anchor system designed for earthquakes. It features a large (up to 6" x 6") anchor plate that can be driven up to 18' into the ground. The plate is then rotated with a gad, or second steel rod, and pulled back to lock. A galvanized threaded rod holds the plate to the home's chassis, which is clamped to a series of steel pyramidal supports. Only certified crews can install the system.

Another system, Ground-Loc, makes use of link chains or allthread rods tying the home's chassis into an anchoring material poured into excavated cavities in the earth. Working with piers by others, the manufacturer provides pier-to-chassis clamps and allthread rods to tie the carrying beams together. One model converts the foundation to a permanent foundation, thus qualifying the home as real property, enabling a low-interest mortgage.