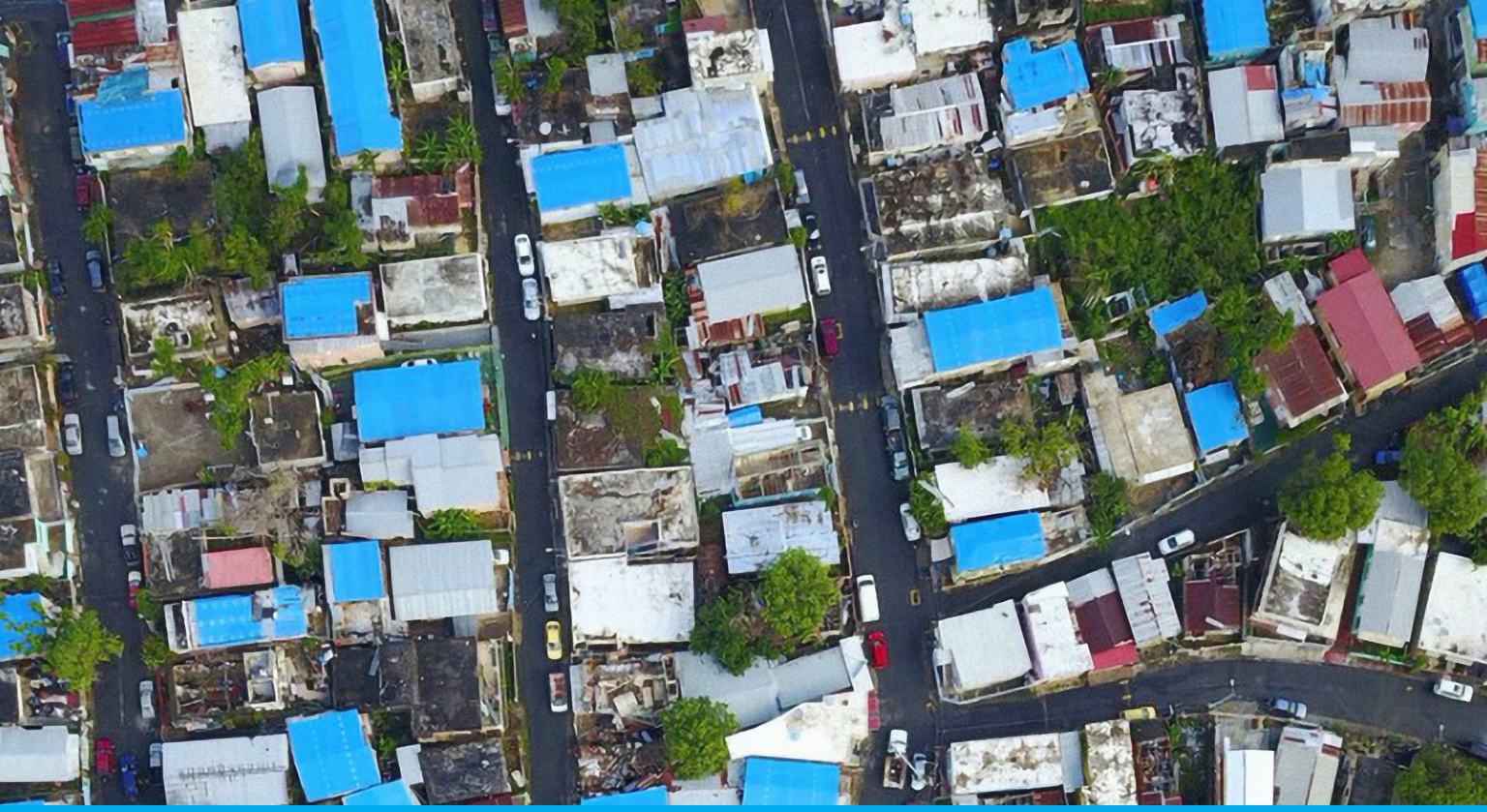


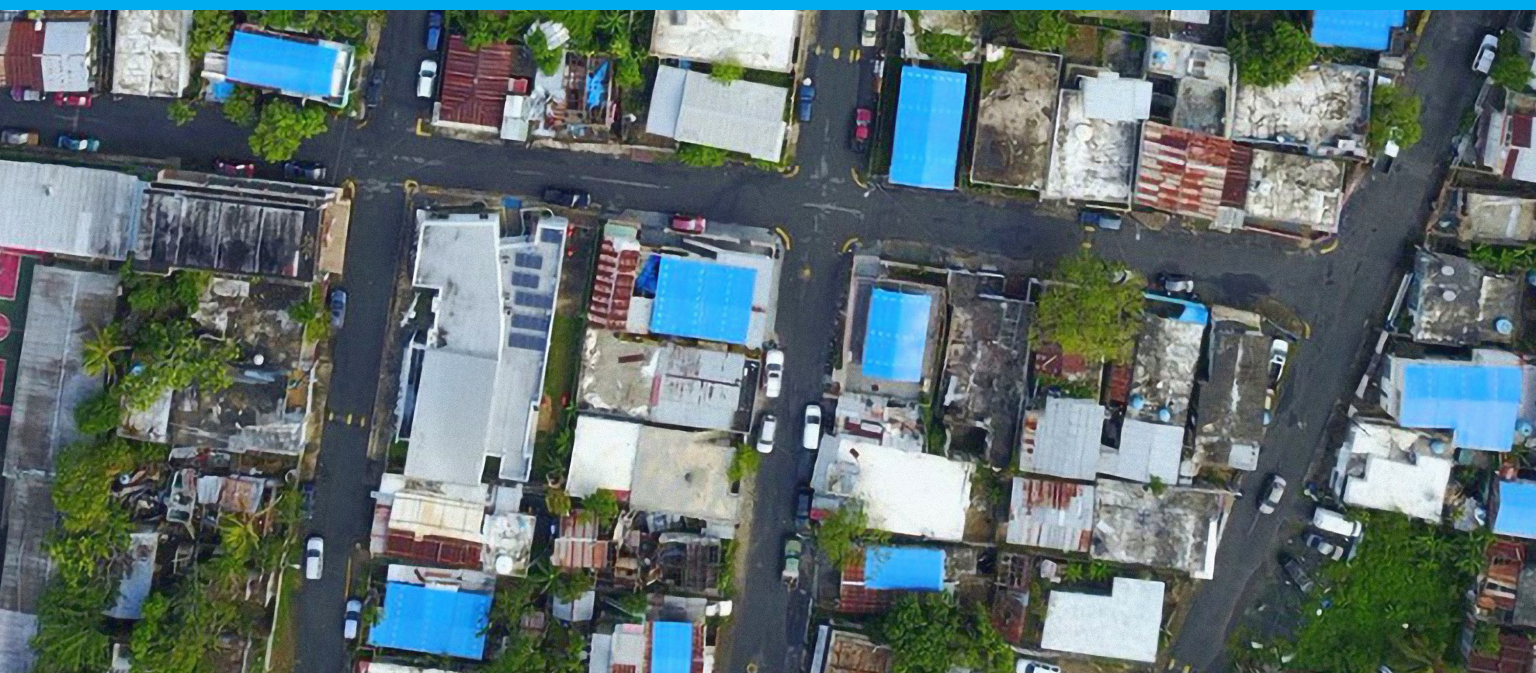
KEEP SAFE

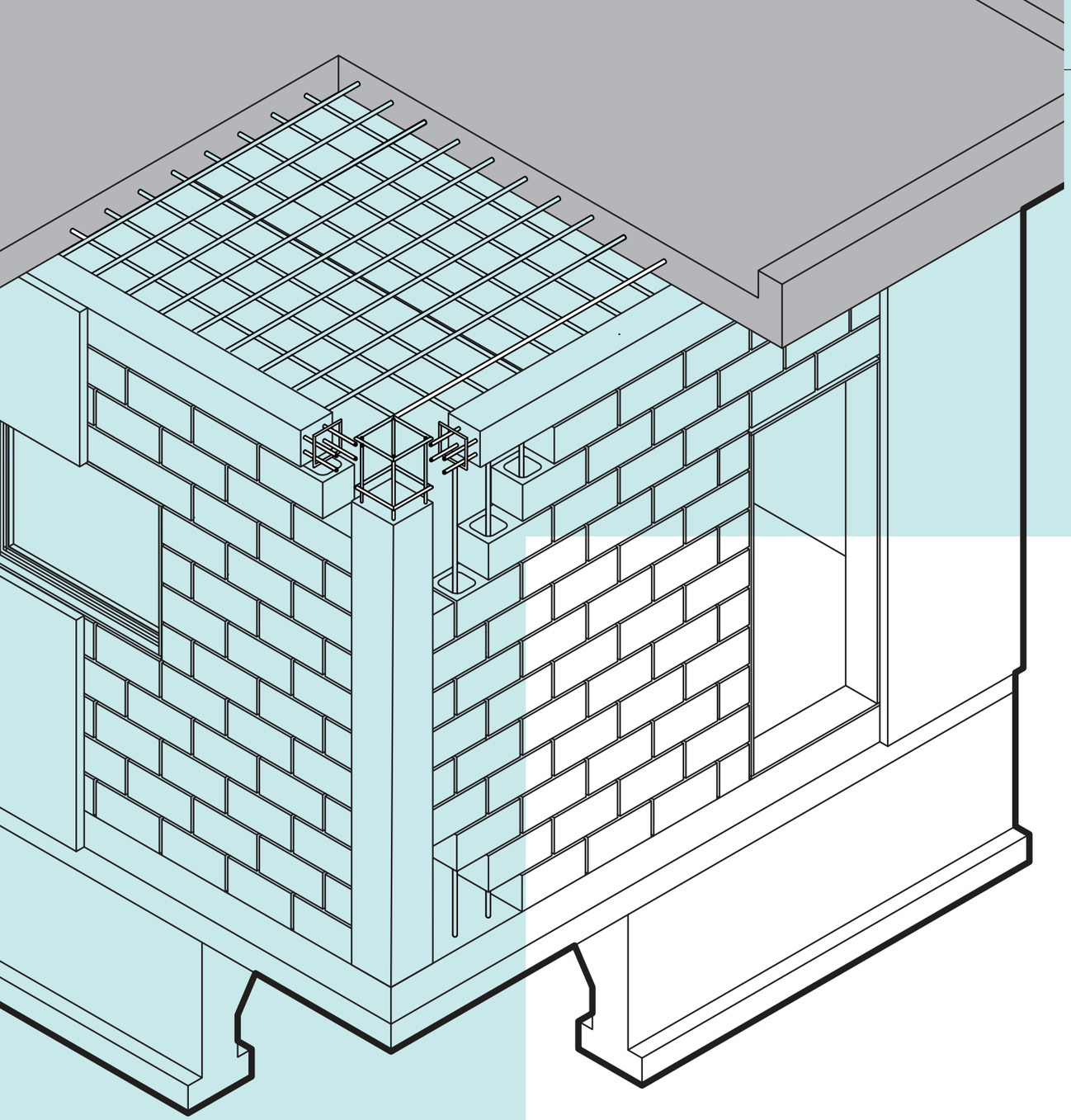
A GUIDE FOR RESILIENT HOUSING DESIGN IN ISLAND COMMUNITIES

Enterprise®

UNIVERSIDAD DE PUERTO RICO 1903

ASOCIACIÓN DE CONSTRUCTORES DE PUERTO RICO





CHAPTER

2

BUILDING PROTECTION

This chapter focuses on strategies that strengthen housing facilities from natural hazards like wind and seismic risk.

TYPES OF STRATEGIES LISTED IN THIS SECTION

STRATEGY #	04	05	06	07	08	09
STRATEGY NAME/TITLE	ASSESS THE PRIORITIES FOR YOUR HOME OR BUILDING'S STRUCTURAL CONDITION PRIOR TO EVENT	BUILD A STRONG FOUNDATION	BUILD STRONGER WALLS	BUILD A STURDY ROOF	ANCHOR, SEAL AND PROTECT BUILDING OPENINGS	FLOOD PROOF HOME
DESCRIPTION	Frequent monitoring and regular maintenance of your home will prevent small problems from becoming big ones in a disaster. This strategy focuses on how to identify your home's vulnerabilities and prioritize maintenance and repairs.	A strong building starts with the foundation, meaning the way it is anchored to the ground. This strategy focuses on what makes a foundation strong.	Strong walls enable the foundation and roof to function together as a resilient structural system. This strategy focuses on how to design strong walls for your home.	A roof shelters you from rain and sunlight throughout the year, and should be strong enough to withstand disasters. This strategy focuses on how to design a strong roof for your home.	A house has many openings, including entry doors, windows, skylights, and garages as well as vents. Properly anchored and sealed openings protect a home from natural disasters. This strategy focuses on protecting your home by appropriately selecting and securing openings.	This strategy focuses on ways to floodproof a home to minimize water damage. See the Resources section below to check your home's vulnerability to coastal flooding.
	$	$$	$-$$	$$-$$$$	$-$$	$-$$$

STRATEGIES TO REDUCE BUILDING VULNERABILITY TO NATURAL HAZARDS

FEMA found that 357,492 homes were damaged to some degree by Hurricane Maria, which comprises approximately 23% of the island's housing stock. Damage is categorized from "affected" to "destroyed." Even "minor damage" means that people may need to move out, and a home with "major damage" is unsafe to live in, possibly for months or even longer.

For retrofits as well as new construction, investing in mitigation measures before the next natural disaster can protect lives, reduce operating costs on an ongoing basis, save money on repair and rebuilding, and lessen the odds that relocation will be necessary. In 2017, the National Institute of Building Sciences (NIBS) estimated that every $1 invested in mitigation saves $4 in recovery costs for single buildings; mitigation at the community level saves $6 for every $1 spent. Upholding codes and standards are a key to achieving these returns, and Puerto Rico now requires compliance with the International Code Council's 2018 International Codes.

Each home has particular vulnerabilities based on its structure as well as its site. This chapter explains how to assess and identify building elements that benefit most from mitigation measures. Understanding what makes the foundation, walls, and roof of your home strong, and how to anchor openings and evaluate floodproofing options that can help you devise an overall approach to protect your home while addressing multiple hazards at once.

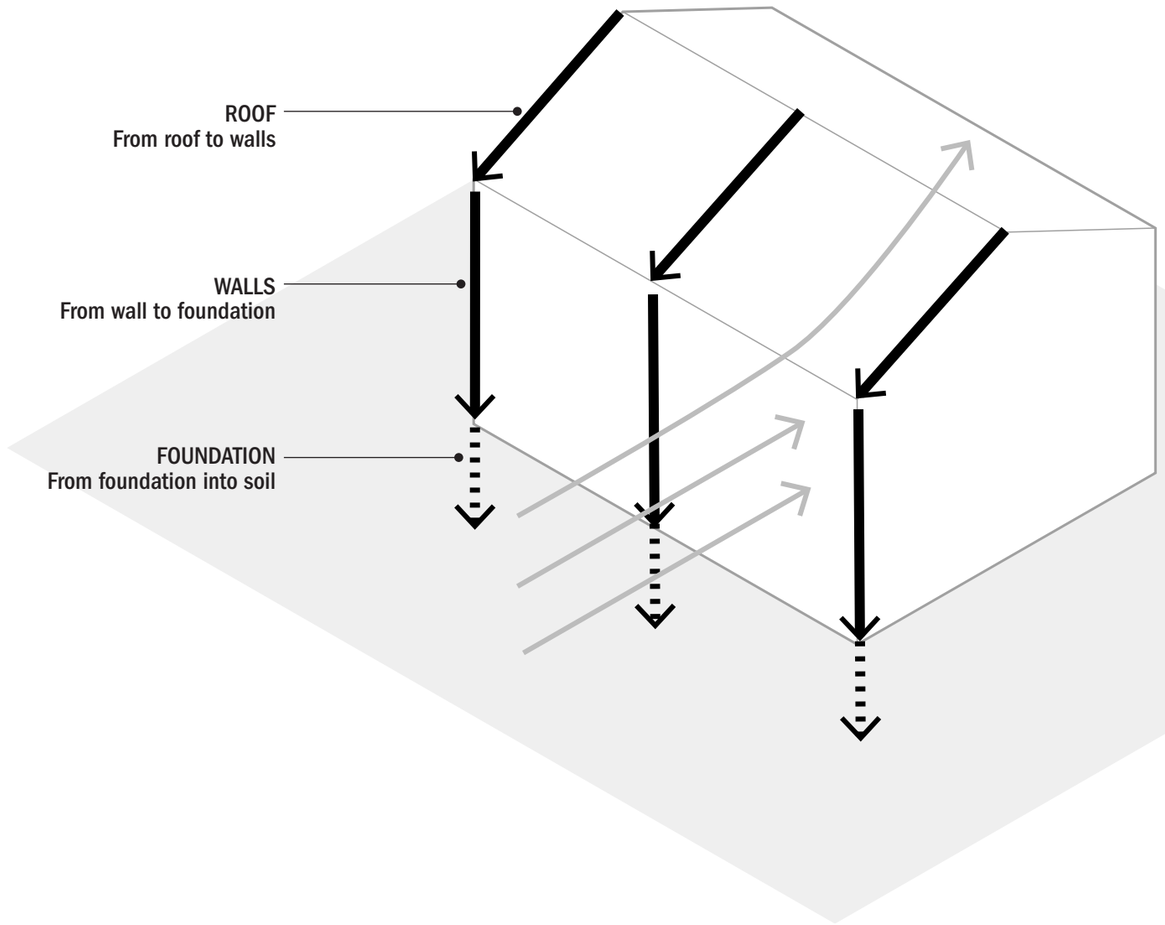
The foundation, the structural system beneath the walls and roof, the envelope (the walls, roof, windows, doors, and everything else that separates inside from outside), and the mechanical systems are tied together in a "continuous load path," which acts like a chain that holds building elements together. Maintaining a continuous load path means no single element must bear the forces of the event by itself. This is the key principle in ensuring that housing can withstand threats that originate above ground, such as a cyclone, or below, such as an earthquake.

INTRODUCTION

Protection Glossary of Terms

- **Anchor bolts:** a bolt is a fastener that is usually used with a nut, for connecting two or more parts. The anchor bolts are usually placed inside the concrete mix before hardening, in a way that the threaded part of the bolt remains outside where an element will be connected to it. Anchoring bolts can be used to connect the wood sill plates of a wood frame. Anchor bolts, in combination with an expansion, can be used after the concrete has hardened by making a drill hole; the expansion will anchor the bolt to the hole in the concrete.
- **Metal ties:** steel elements that substitute the use of nails directly into wood to connect them. These steel elements are placed over two or more pieces of wood to be united and are then fastened using screws, bolts, or nails, as specified. Tie-downs come in different shapes and are used for different purposes in home construction.
- **Fasteners:** all kinds of mechanical elements used to join elements, like timbers of steel columns, and that can later be removed. Nails, screws, and bolts are examples of fasteners.

CONTINOUS LOAD PATH



As hurricanes gain strength, structures must be able to withstand greater wind force.

There are four ways in which wind can affect your home's structure:

- Uplift (wind flows over the roof of the home that create a lifting effect).
- Racking (wind exerts horizontal pressure that can cause the home to tilt).
- Sliding (wind exerts horizontal pressure which can cause home to slide off its foundation).
- Overturning (when the home is unable to rack or slide, wind can cause the walls to rotate off the foundation).

STRATEGY

04 ASSESS THE PRIORITIES FOR YOUR HOME OR BUILDING'S STRUCTURAL CONDITION PRIOR TO EVENT

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The condition and strength of a home's structure depends on continuous monitoring and frequent maintenance. This strategy focuses on how to evaluate a structure by identifying points of weakness and implementing solutions. Consult with a building professional (can be a contractor, engineer, or architect) to get the most thorough inspection possible.

Strategy in Action

1. Inspect Your Home

A. By Type

B. By Vulnerability

Daguao Naguabo
Centro Comunitario

WHAT YOU NEED TO KNOW

- Homes can suffer structural damage due to natural disasters, lack of maintenance, and normal wear and tear.
- Inspect your home or building (interior and exterior) at least once a year.
- Keep the chart below in a safe location to share with a design or engineering professional.

SUPPORTING STRATEGIES

02 Reinforce Site with Vegetation

05 Build a Strong Foundation

06 Build Stronger Walls

08 Anchor, Seal and Protect Building Openings

09 Flood Proof Home

11 Increase Ventilation

13 Control Moisture and Mold

14 Manage Pests

22 Prevent Wastewater Backflow in Homes

23 Develop a Household Emergency Plan

DISCLAIMER

This is a guidance framework only and not intended to be a complete engineering inspection tool. A licensed engineering professional should be consulted to carry out a comprehensive engineering investigation.

Ensure foundation is compliant with code: 2018 IRC and IBC (as adopted by the PRBC) structural provisions and ASCE 7-16 and ASCE 24-24 (adopted by reference to IBC and IRC).

ANNUAL INSPECTION CHART

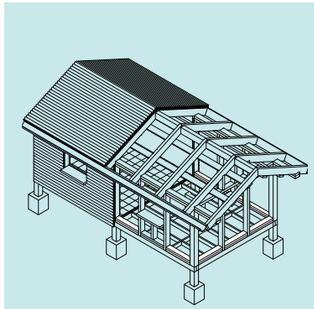
DATE	INSPECTED BY	INTERIOR NOTES	EXTERIOR NOTES
..... /..... /2019			
..... /..... /2020			
..... /..... /2021			
..... /..... /2022			
..... /..... /2023			
..... /..... /2024			
..... /..... /2025			
..... /..... /2026			
..... /..... /2027			

STRATEGY 04

ASSESS THE PRIORITIES FOR YOUR HOME OR BUILDING'S STRUCTURAL CONDITION PRIOR TO EVENT

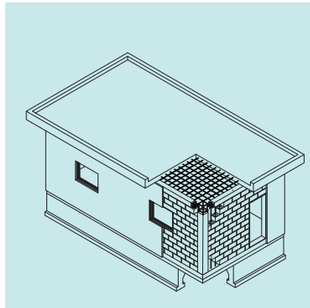
STEP 1 - INSPECT YOUR HOME

A. BY TYPE Each type of construction has its own particular vulnerabilities. Watch out for the following signs of deterioration.



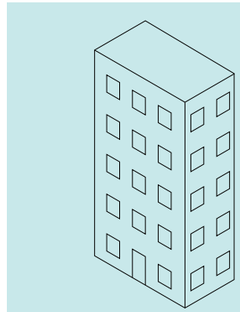
SINGLE FAMILY WOOD

- Termite damage
- Humidity
- Rusted joints
- Roof membrane cracks
- Lack of roof sealants
- Rusted or loose nails and/or screws



SINGLE FAMILY CONCRETE

- Cracks and fissures
- Exposed interior rebar and corrosion
- Loose or rusted joints
- Appropriate and good condition in fastening of windows and doors or other apertures



MULTIFAMILY

- Central cores and the maintenance rooms
- Cracks and fissures
- Humidity
- Exposed interior rebar and corrosion
- Rusted joints
- Weak balconies
- Failing roof sealants
- Appropriate and good condition in fastening of windows and doors or other apertures

OPERATIONS AND MAINTENANCE TIPS

- Inspect your facility annually for variety of vulnerabilities.
- Establish a routine to maintain building systems and repair cracks and fissures.
- Regularly paint the home to keep structure safe.
- Eliminate any electrical systems that could come into contact with water.
- Eliminate any gas related hazard-leaks or loose tanks.

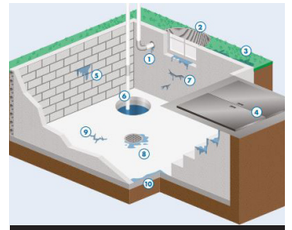
B. BY WEAKNESS The best way to maintain a building is to understand each vulnerability and implement the solution that best targets it.

TERMITES

Eat organic material and weaken strength of wood. Includes porches, soil near foundations and trees.

SOLUTION

- Regularly inspect all wood components in your home for small, pin-sized holes and/or sawdust mounds.
- Check porches, wooden columns and beams, doors and cabinetry.
- Call a professional to exterminate termites.



CRACKS AND FISSURES

Allow water and air to enter the building, leading to larger cracks and fissures and more structural damage.

SOLUTION

- Inspect regularly home structure, soil condition and corroded rusts, as they can all cause cracks, particularly after natural disasters.
- Fix immediately as they can cause permanent damage to the home.
- Avoid using nails, instead drill holes on the wall prior to inserting the screw. Use expansion for screws on concrete surfaces unless using tabcon.

CORROSION

Salt residue in the air and interaction between different metals lead to weak joints.

Check anchorage, nails and screws, specially those around structure joints - the place one member meets another, like a column meeting a beam.

SOLUTION

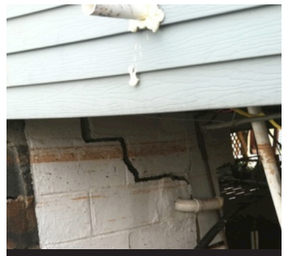
- Regularly apply waterproof sealants to metal components and substitute any corroded screws/plates.

HUMIDITY

Allows moisture to enter the building, leading to mold and structural damage.

SOLUTION

- Inspect home structure, regularly particularly after natural disasters.
- See Strategy 10 to measure humidity in your home.



EXPOSED STRUCTURAL COMPONENTS

If finishes tear off, they can expose the building structure to the elements. Contact with water or salt in air can cause rebar to corrode and deteriorate.

Inspect beams, columns and foundation for exposed rebar.

SOLUTION

- Call a professional to fix the problem and reinforce the structure.

DEFERRED MAINTENANCE

Lack of building and systems maintenance can permanently damage the structure.

Electrical cables should be checked for exposed wires that can end up in short-circuits and fire. Also verify breakers for burnt-out fuses. Go to Strategy 20 for more info on electrical Systems.

Leaks at potable water, A/C and sewage lines can expose structural elements to humidity and deterioration. Go to St. 16 for more info on checking for leaks.

Overgrown trees and bushes can pose damage to a building's structure. A tall tree with overturned/rotten roots can be easily uprooted by wind and fall over a roof. Untrimmed bushes can attract pests that might debilitate columns, beams and foundation.

Gas leaks can be extremely dangerous. An old gas tank is more likely to have a loose valve.

SOLUTION

- Regularly paint to reduce material deterioration.
- Cut vegetation that can damage the structure.
- Eliminate electrical systems that could potentially create flammability concerns for the building.
- Hire a licensed electrician/ plumber to solve any issues regarding power lines, water systems and gas.

STRATEGY

05 BUILD A STRONG FOUNDATION

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DISCLAIMER

Consult with licensed building professionals to design and build a foundation. Stay in touch with the design professionals that designed and constructed your home's foundation as an important resource when it is time for maintenance.

Ensure foundation is compliant with 2018 International Code Council codes - IBC and IRC (as adopted by the PRBC) - and structural provisions and ASCE 7-16 and ASCE 24-14.

A strong building starts with the foundation, meaning the way it is anchored to the ground. This strategy focuses on what makes a foundation strong.

Strategy in Action

1.Foundation Design Principles

2. Establish the Type of Foundation

3. Design the Foundation

4. Choose Flooring

WHAT YOU NEED TO KNOW

A foundation is the base of a home. It holds walls and roofs, and maintains a continuous load path by transferring the loads from the structure into the layers of soil below.

The International Code Council Code (I-Codes) and the building standards of the National Flood Insurance Program (NFIP) require that a foundation must be designed prevent:

- **Floatation**
- **Collapse**
- **Lateral movement**

To accomplish this, a foundation must:

- Resist lateral and uplift loads from floods, high winds, and earthquakes.
- Be protected against flood-borne and wind-borne debris impacts.
- Be resistant to erosion and scour that can undermine the foundation.

The components of a strong foundation are:

- Strong, flood-damage-resistant, and decay-resistant materials (reinforced concrete or preservative treated wood).
- Elements sized for appropriate structure loads and local soil conditions.
- Proper connections and anchors to transfer loads between the foundation and the rest of the structure.

Consider the following when designing the foundation:

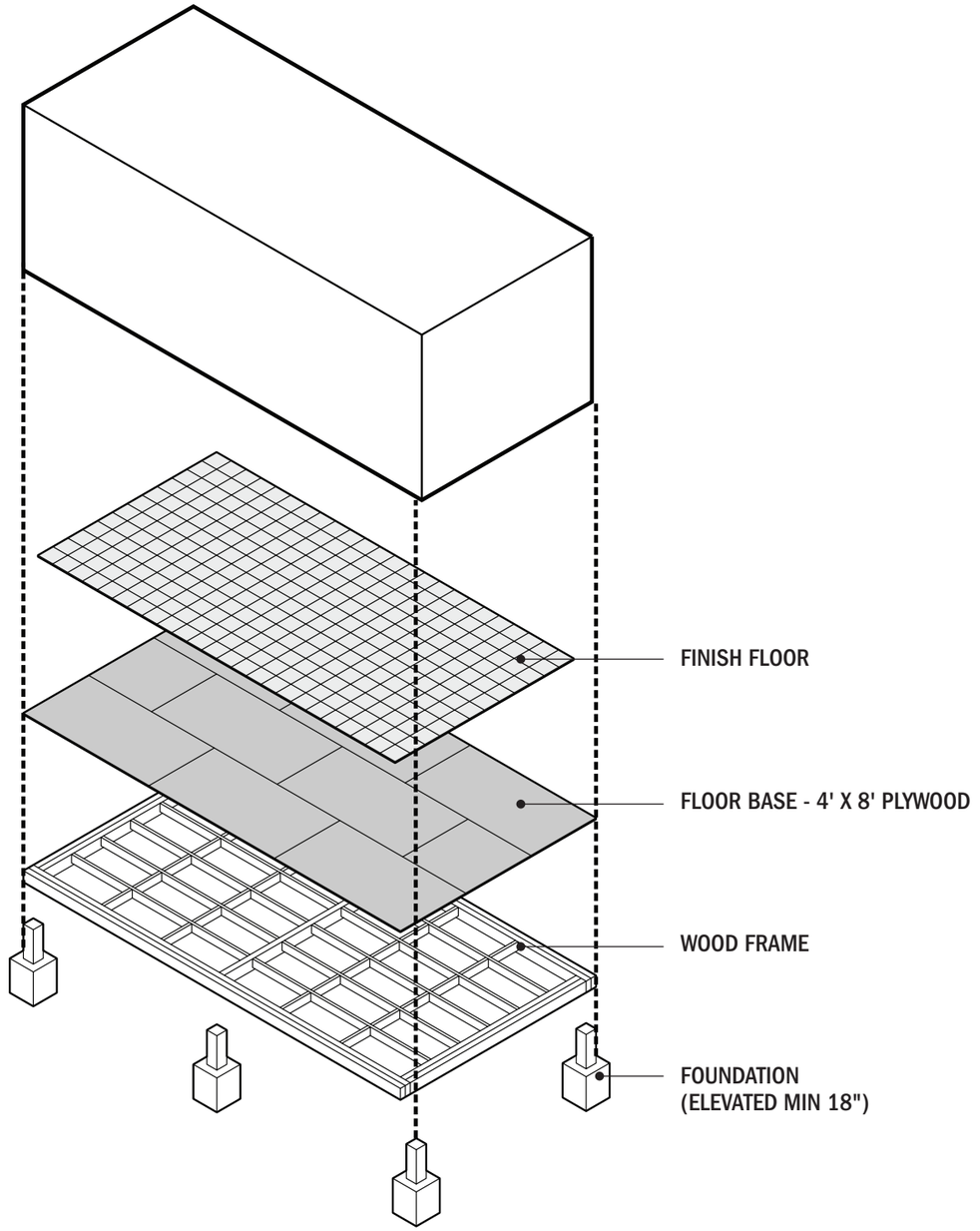
- Its own weight and of persons and equipment to be inside or on the roof.
- Design wind speed.
- Seismic design category.
- Flood Zone – See Strategy 01: Reinforce Site.
- Soil type – Bearing capacity and level of compaction.
- Water table – How much water is beneath the supporting soil.
- Budget

Foundations often fail due to:

- Weak structural connections to the walls or floors above them.
- Improper concrete mixture, inadequate and/or exposed rebar in concrete foundations. (Inadequate design of concrete foundations can lead to cracking and fragments dangerously breaking off during a storm or seismic event).
- Decay and incorrect footing connections in timber foundations
- Soil that is not appropriately prepared which includes compacting and proper sizing of footings for structural support.

SUPPORTING STRATEGIES

04 Assess the Priorities for Your Home or Building	**01** Reinforce Site with Infrastructure	**06** Build Strong Walls
07 Build a Sturdy Roof	**09** Flood Proof Home	**25** Establish Family Emergency Plan



STRATEGY

05 BUILD A STRONG FOUNDATION

STEP 1 - FOUNDATION DESIGN PRINCIPLES

Cracked Foundation

Failed foundation due to weak structural connections

Stuart Adams FEMA

Failed foundation due to inappropriate concrete mix

Failed foundation due to inappropriate soil

Anchor bolts, tie-downs and fasteners must be flood-damage and corrosion-resistant. Use stainless steel, especially near the coastline, or galvanized steel.

Although wood is often cheaper, concrete is superior to wood foundations, as it is more resistant to humidity, wind, fire and termites.

Install french drains around draining docks to collect and drain out excess water that reaches the foundation through the soil. French drains are perforated PVC pipes that are buried over a fine mesh and covered with gravel. For more info on French Drains, please refer to Strategy 1: Reinforce Site.

Use sewers or dry wells to collect excess runoff/rainwater. Avoid draining on hillsides and cut/filled areas to minimize erosion. For more info on siting and surface stormwater management, go to Strategy 01: Reinforce Site.

Refer to IBC 1805.4.2 Foundation Drain - “Where a drain tile or perforated pipe is used, the invert of the pipe or tile shall not be higher than the floor elevation. The top of joints or the top of perforations shall be protected with an approved filter membrane material. The pipe or tile shall be placed on not less than 2 inches of gravel or crushed stone complying with Section 1805.4.1, and shall be covered with not less than 6 inches of the same material.”

STRATEGY

05 BUILD A STRONG FOUNDATION

DISCLAIMER

Consult with licensed building professionals to design and build a foundation. Stay in touch with the design professionals that designed and constructed your home's foundation as an important resource when it is time for maintenance.

Ensure foundation is compliant with 2018 International Code Council codes - IBC and IRC (as adopted by the PRBC) - and structural provisions and ASCE 7-16 and ASCE 24-14.

STEP 2 - ESTABLISH THE TYPE OF FOUNDATION

Ask an engineer what is the best type of foundation for your home. The foundation depends on site and structural needs.

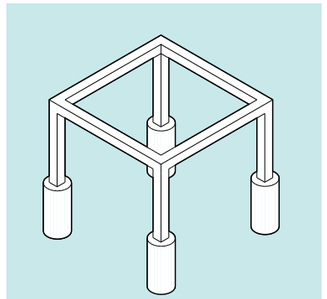
Foundation Styles in Coastal Areas

STYLE	ZONE V	COASTAL A ZONE (UMWA)	ZONE A
Open/deep	Acceptable	Acceptable	Acceptable
Open/shallow	Not permitted	Acceptable	Acceptable
Closed/shallow	Not permitted	Not Recommended	Acceptable
Closed/deep	Not permitted	Not Recommended	Acceptable

A. SITE ASSESSMENT

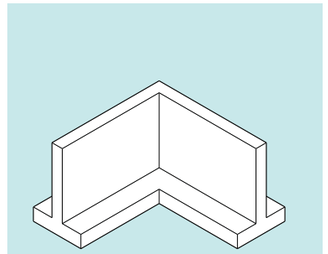
- Ground investigation should be done before determining foundation. A qualified professional tests the composition and capacity of soil to resist seismic force and flood.
- A strong foundation should be "locked" - which means it must not allow lateral movement. Bracing may be needed depending on soil quality, presence of bedrock, water table height, and other local topographical features. Approach will also vary from single to multi-story building, which is why it is crucial to consult with both a soil and construction professional.

B. STRUCTURAL NEEDS



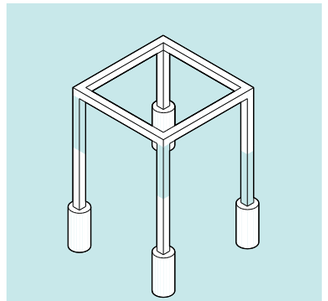
SHALLOW

- Used when the structural loads are low and the surface soil layer is strong in terms of bearing capacity.
- Embedment of shallow foundations typically 3' below the finished grade level [the soil/land surface].
- Shallow foundations such as grade slabs and crawlspace wall footings transfer the load to shallow soil layers.



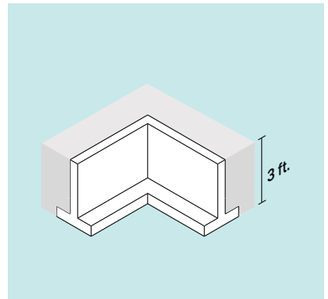
DEEP

- Used when the structural loads are bigger, or when the surface soil bearing capacity is insufficient.
- Typically used in muddy soils, sites vulnerable to erosion, or flood zones.
- Used for multifamily buildings.
- Deep foundations such as piles transfer the load to deeper soil layers or down to bedrock.



OPEN

- Allows water to pass through, minimizing the chance of water collecting in unwanted areas.
- Reduces the lateral flood loads the foundation must resists.
- Less prone to damage from flood debris, because debris is less likely to get trapped.



CLOSED

- Does not allow water to pass through, which can create an obstruction to flow.
- Creates larger obstructions to moving floodwater, increasing the level of scour.
- Typically constructed using perimeter walls.

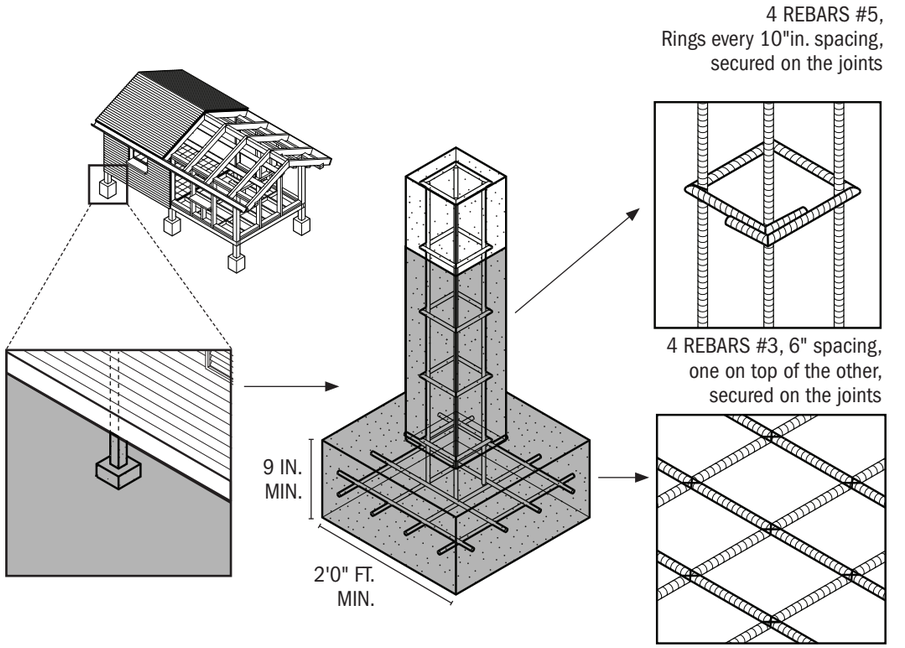
C. MAINTENANCE NEEDS

- Have a qualified professional inspect the foundation (joints, site grading drainage and landscaping) once a year. Regular inspections by a professional increases the probability that your home will withstand a natural disaster.
- Paint the wood and exposed steel with corrosion- and mold-resistant paint and primer once a year so air and salt do not corrode it.
- Choose "treated wood" at lumber yard whenever possible.
- Seal wood with polyurethane, copper naphthenate, sanding sealer or other waterproof sealant annually after the rainy season. Be sure to seal the ends and any areas where the wood has been notched or bored.
- Follow manufacturer recommendations when using sealants and dispose of sealants responsibly.

STRATEGY

05 BUILD A STRONG FOUNDATION

COLUMNS – OPEN/SHALLOW OR DEEP



4 REBARS #5, Rings every 10"in. spacing, secured on the joints

4 REBARS #3, 6" spacing, one on top of the other, secured on the joints

PROS

- Elevates the house.
- Complies with wet floodproofing requirements.
- Reduces flood loads on structure.

CONS

- Vulnerable to erosion and flood loads.
- Undersized or shallow piles are vulnerable to erosion, fracture or overturning.
- Masonry piers prone to water intrusion in humid and wind-driven rain environments.

Columns, also called piers, are made of reinforced concrete and rest on footings.

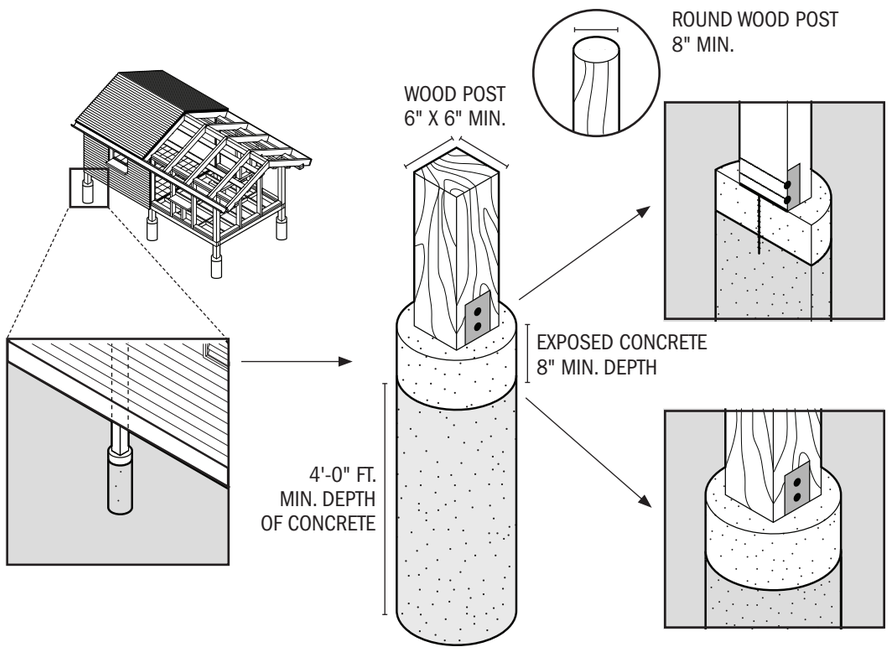
- Typically used in coastal zones further back from the shoreline.
- The embedment depth of the footings depends on the soil capacity.
- Provide at least 3” of concrete cover for the rebar to minimize corrosion risk.
- Properly size and reinforce the footing at the base of each pier.
- Provide a robust connection with continuous rebar between the footing and the pier to prevent separation or failure.
- If you use grade beams to provide additional stability, ensure they comply with floodproofing requirements and are properly connected.
- Use corrosion-resistant and durable fasteners for connections.
- Maintain proper edge distance so fasteners do not fail.
- Ensure that water does not collect bellow beam structures - this can cause subsidence and foundation settlement - similar to sinking through quicksand.

STEP 3 - DESIGN THE FOUNDATION

The type, size and layout of foundation depends on soil’s capacity and the amount of weight or force the building will exert on it.

Consult a professional engineer to determine appropriate soil conditions.

POSTS / PILES – OPEN/DEEP



PROS

- Elevates the house.
- Complies with wet flood-proofing requirements.
- Reduces flood loads on structure.

CONS

- Undersized posts are vulnerable to fracture.
- Improperly braced columns can fail under high loads.

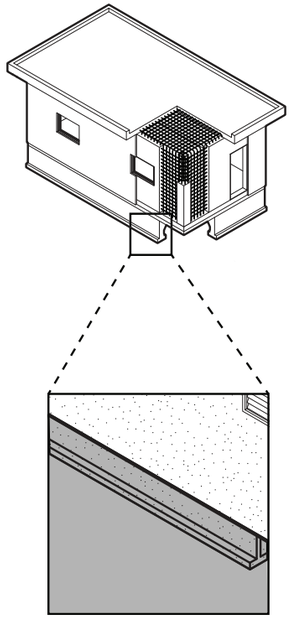
Round or square structures made of concrete or wood embedded in the ground.

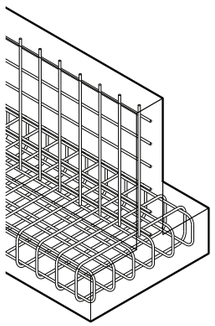
- Typically used in coastal zones, specifically near the shoreline.
- Install bracing, such as knee braces or diagonal bracing, to support the posts.
- Install grade beams or bracing to resist lateral loads.
- Orient bracing parallel to the direction of any potential floating or wind-driven debris to minimize impact.
- Use corrosion-resistant and durable fasteners for connections to the posts.
- Make sure fasteners are not placed too close to the edge as they may fail or pull out under applied loads.
- Treat wood to minimize decay.
- Common post failures include-deterioration of wood, inadequate bracing, undersized piles, and inadequate embedment. Embedment refers to the way the footing - or lowest point of the foundation - anchors to the soil.

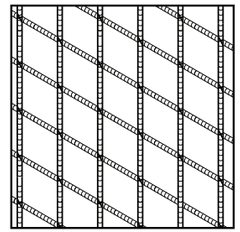
STRATEGY 05

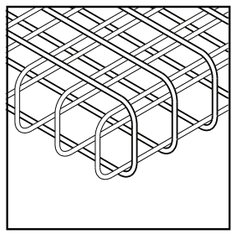
BUILD A STRONG FOUNDATION

WALL – CLOSED/SHALLOW









PROS

- Increases resistance of structure to earthquake.

CONS

- Not recommended in coastal flood zones because walls obstruct flood flow.

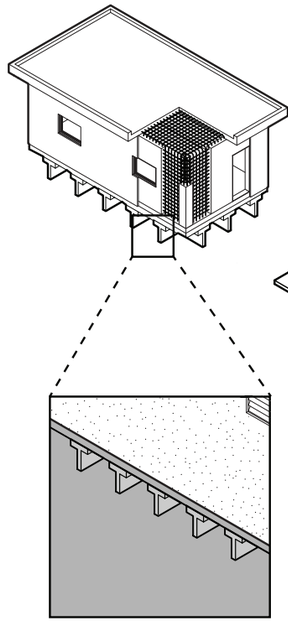
- Use in areas exposed to shallow flooding and low risk of erosion and wave surge.
- Use adequate rebar sizing and spacing.
- Masonry walls should be fully grouted and have rebar.
- Typically used in one-story single family homes.
- Not recommended for coastal areas.
- Continuous walls are made of reinforced concrete or masonry that sit on footings embedded in the ground.
- Provide robust connections between the foundation walls and the floor diaphragm to maintain a lateral load path.
- Structural walls in the first floor should sit directly above foundation walls and have tie-downs and anchor bolts.
- Use continuous and/or lapped rebar in all connections or joints to minimize chance of failure.

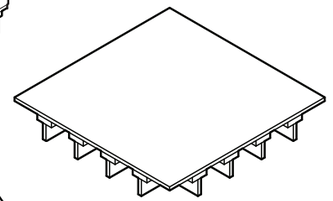
STEP 3 - DESIGN THE FOUNDATION

The type, size and layout of foundation depends on soil's capacity and the amount of weight or force the building will exert on it.

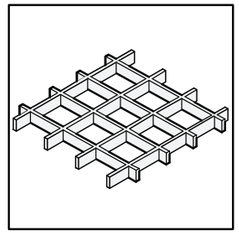
Consult a professional engineer to determine appropriate soil conditions.

GRADE SLABS – CLOSED/SHALLOW





CONCRETE GRID BASE



4 REBARS #3, 6" IN. SPACING, ONE ON TOP OF THE OTHER, SECURED ON THE JOINTS

PROS

- Increases resistance of structure to earthquake
- Increases resistance to uplift and overturning.

CONS

- Not recommended in coastal flood zones because walls obstruct flood flow.

- Mat foundations are continuous slabs of reinforced concrete that sit on grade.
- Typically used in non-coastal areas or terrains with higher scour resistance.
- Can function as a base for the finished floor and should be reinforced with a grid of rebars.
- Provide adequate connections between the structural walls and the slab foundation.

STRATEGY 05

BUILD A STRONG FOUNDATION

WOOD

INSTALL THE FLOOR

FINISH FLOOR

Tiles and polished concrete are most common in Puerto Rico. Do not use vinyl because it is bad fot the environment and occupants due to off-gassing of chemicals.

FLOOR BASE

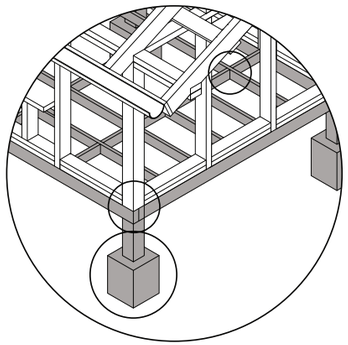
3/4" thick 4' × 8' Plywood Panels. Center on the frame below. Place the panels parallel to the main beams offset them from each other for stronger quality.

WOOD FRAME

Build beforehand so wood panels can be easily fastened. The grid consists of a series of main beams and secondary beams. Use spaces compatible with 4' × 8' nominal wood panels.

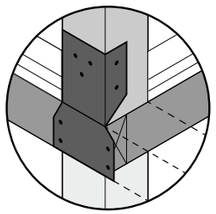
FOUNDATION

Elevated min 18" above the DFE to prevent rotting. See Stragegy 09 Flood Proof Home.

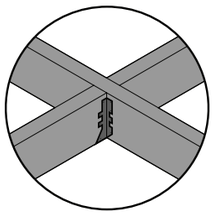


INSTALLATION DETAILS

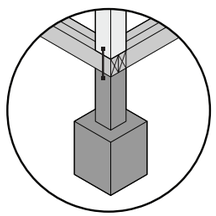
FOUNDATION DETAIL



FOUNDATION FRAME DETAIL



CONNECTION TO FOUNDATION

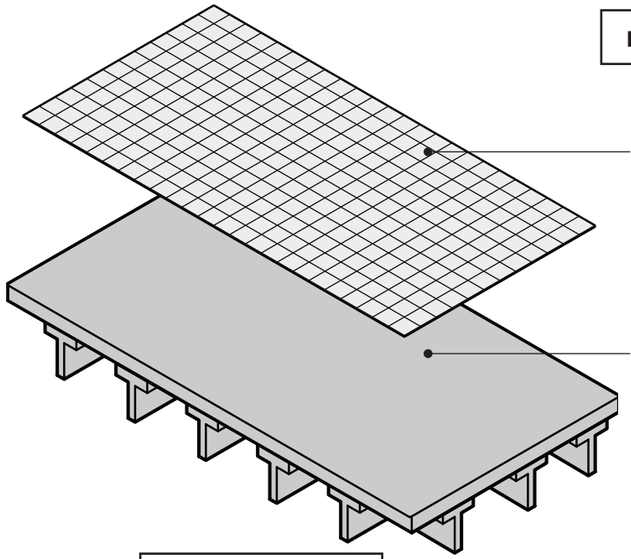


STEP 4 - CHOOSE FLOORING

Consult a structural engineer to determine the appropriate elements size for the flooring.

- A resilient floor system withstands the loads on the building without yielding or losing continuity. Having an interruption in the flooring system can exert unwanted pressure and potentiate the floor falling through.
- The foundation and the floor achieve a continuous load path by using appropriate clips, straps and hold downs whenever a wood member encounters another.
- Complement a strong foundation and flooring system with shear walls and a strong roof to transfer shear loads - the weight of the building and whatever is inside it down - safely.
- Use rated and tested materials.
- The bottom of the lowest structural member supporting the lowest habitable floor should be located above the DFE (Design Flood Elevation). See Strategy 08: Anchor, Seal and Protect Building Openings.

CONCRETE



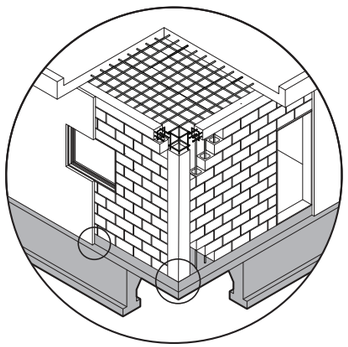
INSTALL THE FLOOR

FINISH FLOOR

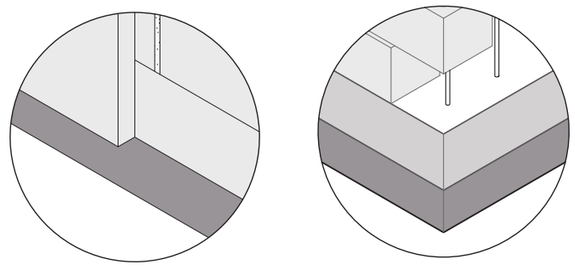
Tiles and polished concrete are most common in Puerto Rico. Do not use vinyl because it is bad fot the environment and occupants due to off-gassing of chemicals.

MAT FOUNDATION

Can serve as concrete floor base or, if treated, can serve as the floor.



INSTALLATION DETAILS



STRATEGY

06 BUILD STRONGER WALLS

$-$$

DISCLAIMER

Consult with licensed building professionals to design and build walls. Stay in touch with the design professionals that designed and constructed your home's walls as an important resource when it is time for maintenance.

Ensure foundation is compliant with 2018 International Code Council codes IBC and IRC (as adopted by the PRBC), and structural provisions, and ASCE 7-16 and ASCE 24-14 (adopted by reference to IBC and IRC).

Strong walls enable the foundation and roof to function together as a resilient structural system. This strategy focuses on how to design strong walls for your home.

Strategy in Action

1. *Wall Design Principles*
2. *Establish the Type of Wall*
3. *Select Wall Materials*
4. *Design the Wall System*

WHAT YOU NEED TO KNOW

A wall is part of the structural system and delineates a home and its interior spaces. It is held by the foundation, it supports the roof, and maintains a continuous load path by allowing the roof loads to reach the foundation.

A wall:

- Supports the roof and transmits vertical (gravity) and lateral (environmental) loads to the foundation.
- Helps air circulate around the home.
- Protects the home from wind, flood, and earthquake loads.

A wall must:

- Be properly anchored to resist wind and seismic loads.
- Have drainage to prevent rainwater ponding, particularly in low-sloped roofs.
- Be leak-free and crack-free, since any holes may compromise its structural integrity.

The components of a strong wall are:

- Framing or the skeleton.
- Strong connections to the structural system or the joints.
- Multiple layers, including insulation, to maintain a regular interior temperature.
- Interior and exterior finishes to shield the structure.
- Openings. (See Strategy 08)

Consider the following when designing the walls:

- Wind.
- Seismic Design Category.
- Flood forces - hydrostatic, hydrodynamic, debris, breaking waves.
- Openings - size and number.
- Strength of the foundation.
- Roof weight.
- Anchoring system for a natural disaster.
- Budget.
- Weight supporting including equipment and people on the roof.

ESTIMATED COST

$	Wood frame with panels $ per sq. ft.
$$	Concrete columns with fill-in walls $ per sq. ft.
$$	Cast-in-place concrete with blocks $ per sq. ft.

SUPPORTING STRATEGIES

05 Build a Strong Foundation

07 Build a Sturdy Roof

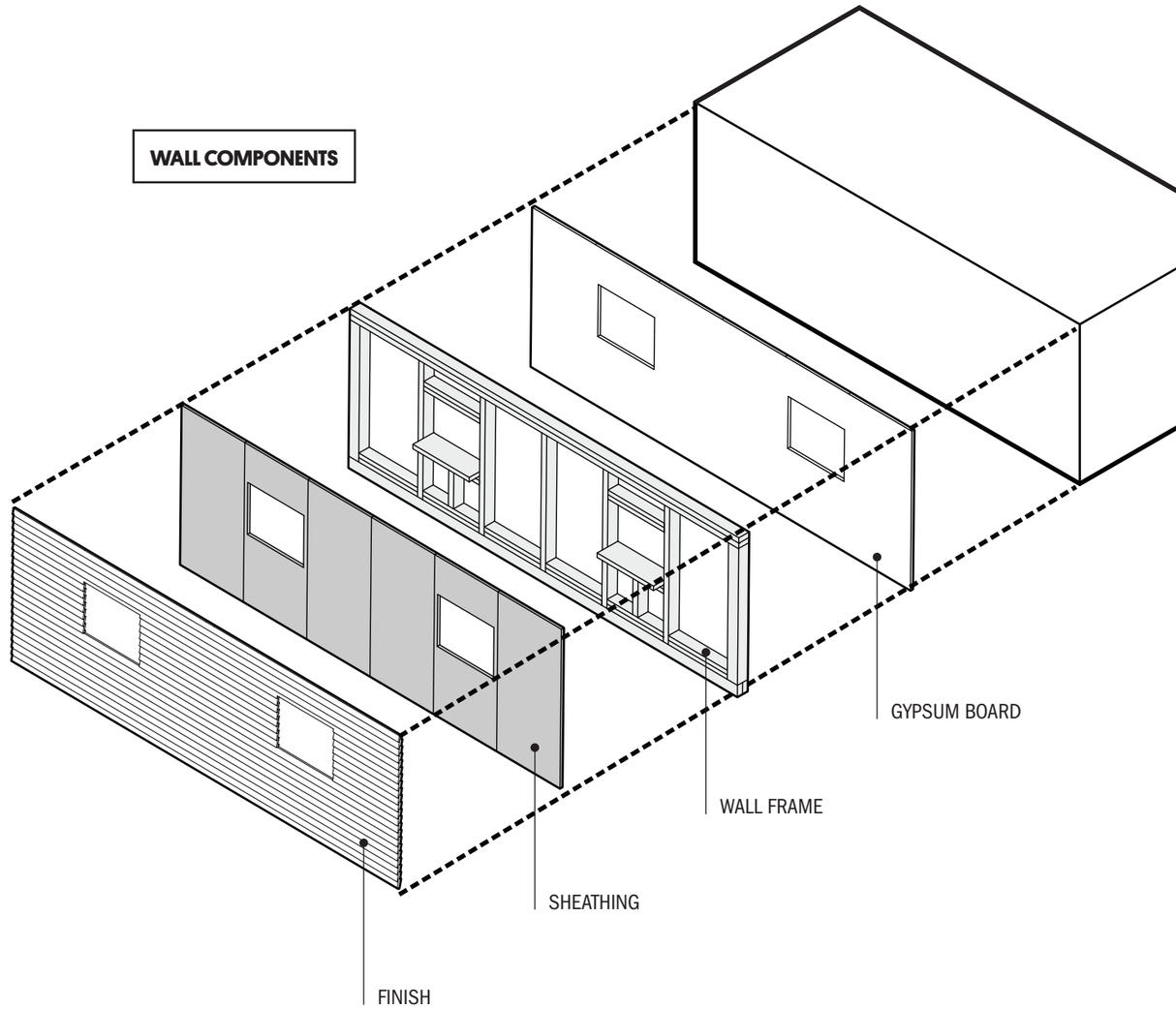
08 Anchor, Seal, and Protect Building Openings

11 Increase Home Ventilation

12 Benefit from Natural Light

23 Develop a Household Emergency Plan

WALL COMPONENTS

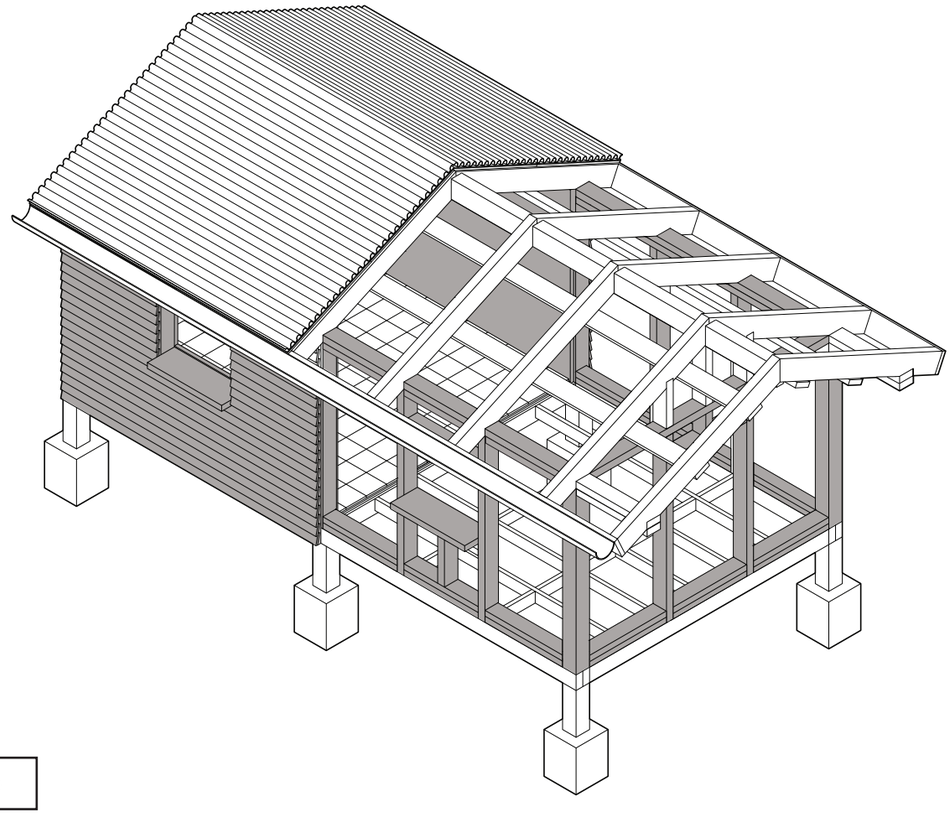


STRATEGY

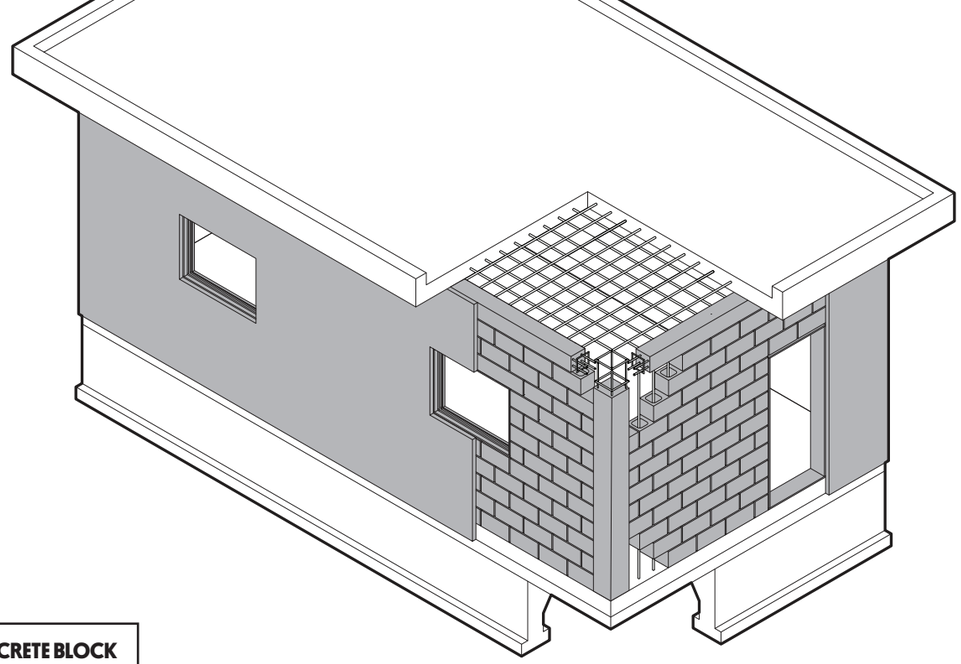
06 BUILD STRONGER WALLS

STEP 1 - WALL DESIGN PRINCIPLES

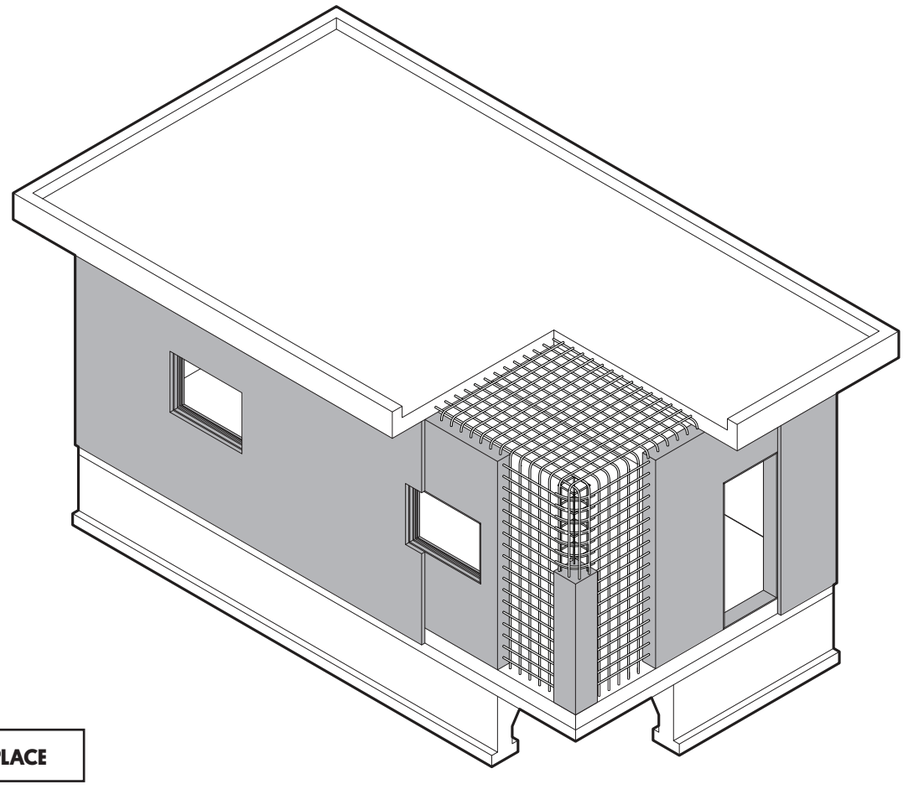
- Maintaining a continuous load path is like a chain that holds a home together from the roof to the foundation. A continuous load path is critical during an earthquake or hurricane because it holds a home together when ground forces or high winds try to pull it apart. Maintain a continuous load path by using vertical reinforcement, from the foundation to the roof, through the structural walls.
- Anchor interior partition walls into the structural frame for stability.



WOOD



CONCRETE BLOCK



CAST IN PLACE

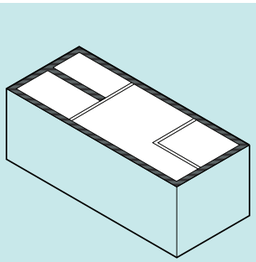
STRATEGY

06 BUILD STRONGER WALLS

STEP 2 - ESTABLISH THE TYPE OF WALL

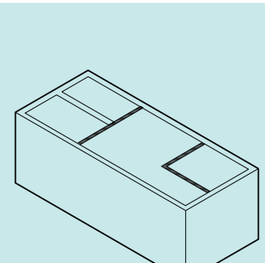
Ask an engineer what is the best type of wall for your home.

STRUCTURAL WALLS



- Mainly exterior walls (interior in some cases).
- Vertically continuous from foundation to roof through all floors.
- Part of the continuous load path.
- Support foundation and roof.
- Support the home under vertical forces, like gravity loads.
- Transfer lateral loads through the house and into the foundation.
- Frame into beams.
- In multi-family buildings, Rear walls and can be placed between units as fire walls.

NON-STRUCTURAL WALLS (PARTITION WALLS)



- Interior walls.
- Not vertically continuous between floors.
- Not part of the continuous load path.
- Do not support any structure.
- Provide insulation and privacy.

STEP 3 - SELECT WALL MATERIALS

Ask an engineer what are the best wall materials for your home.

WOOD FRAME – STRUCTURAL

A structural system of wood rafters, trusses, floor joists, wall studs, columns, and beams that create a structure and framework for applied interior and exterior finished surfaces.

CONCRETE - STRUCTURAL

A mixture of aggregate (usually sand, gravel) along with cement and water. Poured concrete is cast into forms on the building site. Reinforcing steel bars, or rebars, provide concrete with structural strength.

CONCRETE BLOCKS – NON-STRUCTURAL

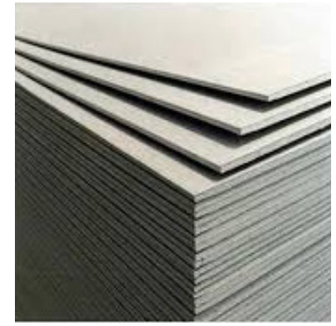
Also called concrete masonry units (CMUs), they are large, hollow units often filled with grout and rebar that create non-structural walls.

PLYWOOD PANELS – NON-STRUCTURAL

Thin sheets of wood layered and glued together to create various standardized thickness and grades used for different applications like formwork for concrete, paneling and finishes. These also serve for boarding up openings in case of a hurricane.

GYPSUM BOARD – NON-STRUCTURAL

Typically made of metal, finished with joint compound sanded between layers until the surface is smooth and ready for paint. Mostly used as interior partitions and dropped ceiling features.



FIBER CEMENT BOARDS (PLYCEM)-NON STRUCTURAL

Thin tiles or sheets made of cement that are reinforced with glass fibers. These come in different sizes, mixtures and consistencies.

STRATEGY

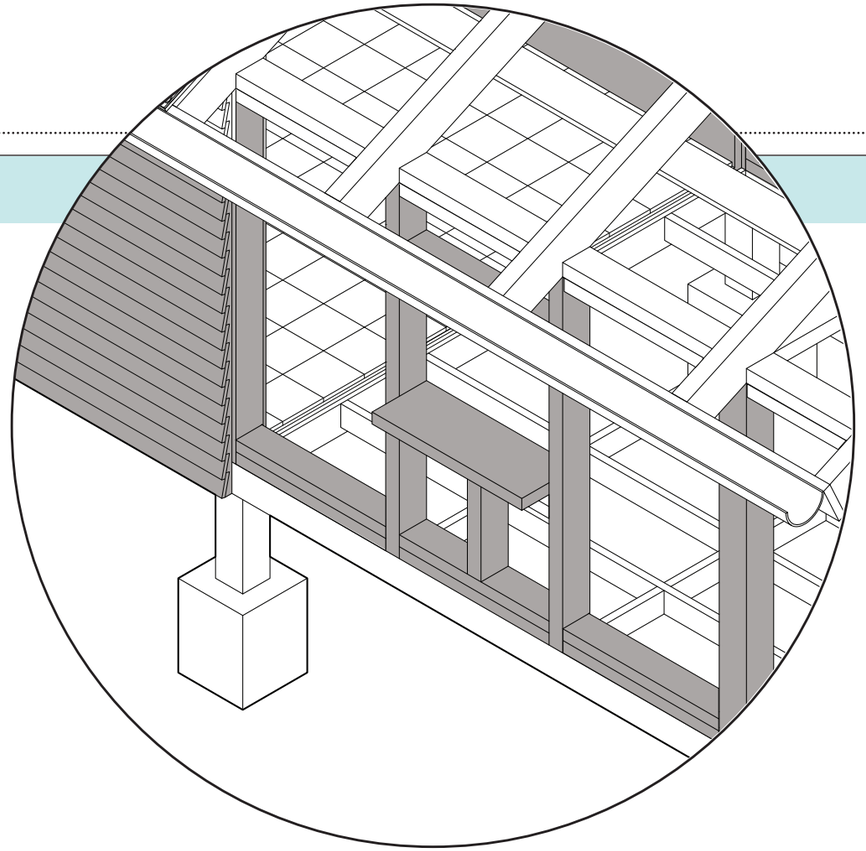
06 BUILD STRONGER WALLS

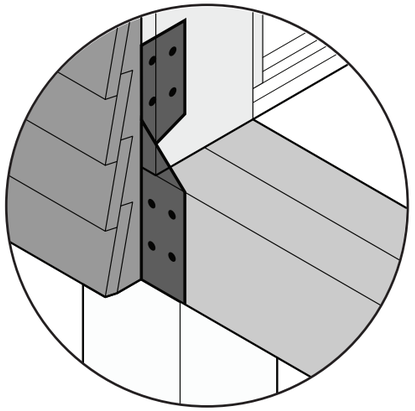
STEP 4 - DESIGN THE WALL SYSTEM

Ask an engineer how to design a resilient and strong wall system.

A. WOOD FRAME

- Wood frame construction consists of a structural frame of beam and columns or stud-frame walls that maintain a direct and continuous load path from the roof down to the foundation.
- Wood frame construction typically uses treated lumber with nominal dimensions or measurements (2 ft. x 4 ft.).
- A double layer of lumber, known as the top plate, sits on top of the wood studs. This piece anchors the roof to the wall construction. See Strategy 07 for more information.
- Space wall studs at 16 in. on center or less sit on an additional double layer of lumber known as the bottom or sill plate.
- Horizontal beams can be added for extra support. Use pressure-treated wood 12 in. above the Base Flood Elevation (BFE). Use moisture resistant panel screws below the beams so they can be easily cleaned and replaced.
- To expand an existing concrete home with wood frame construction, consult a licensed design professional to confirm proper anchorage techniques and ensure a continuous load path.





CONNECTION TO FOUNDATION

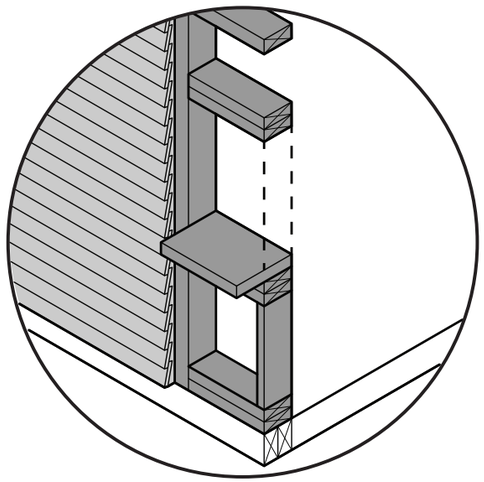
- The sill plate anchors the entire wall system to the foundation using anchors and straps. Nuts and washers are used to tighten the anchor bolts, and holes must be drilled in the lumber before installing the anchors.
- Stud-frame walls and columns rest directly on the sill plate attached to the foundation using anchors and hold down ties.
- Corner columns require (3) 2’x 4’members on each side attatched to bolts and washers. The corner columns are attached to the foundation.

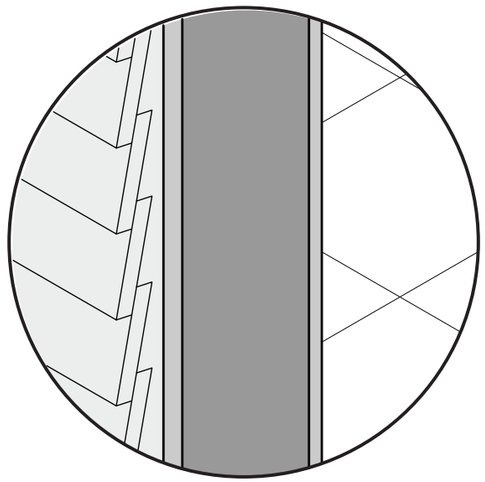
STRATEGY

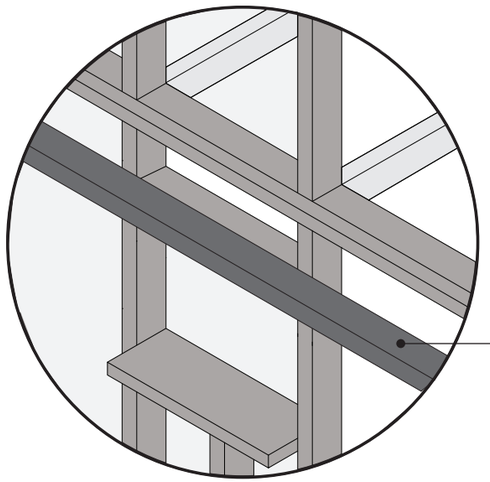
06

BUILD STRONGER WALLS

STEP 4 - DESIGN THE WALL SYSTEM







FRAMING AROUND OPENINGS

- Double vertical “jack trim” and horizontal “header” and “sill” members are recommended on all sides, typically 2 ft. x 4 ft.
- Framing members around the openings are connected using metal plates or angles and fasteners. The fasteners are typically either bolts or lag screws. There is a variety of fasteners in the marketplace. Consult with the manufacturer to determine the appropriate fastener, size, frequency, and fastening pattern for the home.
- Refer to Strategy 08 for anchorage, sealing, and protection methods.
- See Strategy 12 and 11 for placing openings for proper ventilation and natural light.

CONNECTION BETWEEN EXTERIOR AND INTERIOR WALLS

- If interior structural walls are required for heavy lateral loads (i.e. seismic forces), tie them to the structural system correctly. They require special connections to the exterior structural walls and floor diaphragms.

CONNECTION BETWEEN STORIES

- Structural walls should be vertically continuous from the foundation to the roof.
- In multi-story homes, higher floors may have wood framing.
- The roof of a concrete home can be used as a slab-on-grade floor for the wood frame on the second story.
- Anchor wood floors into the structural walls using anchor bolts.
- The second story walls sit directly above the floor joists. They connect to the bottom wall plate and floor joist using nails, fasteners and metal plates/angles, or manufactured connections.
- Exterior and interior structural walls align directly above the first-floor structural walls.
- Use metal straps to reinforce floor-to-foundation connections.
- Ensure vertical members (studs/columns) are properly connected to the horizontal members (top and bottom plates).

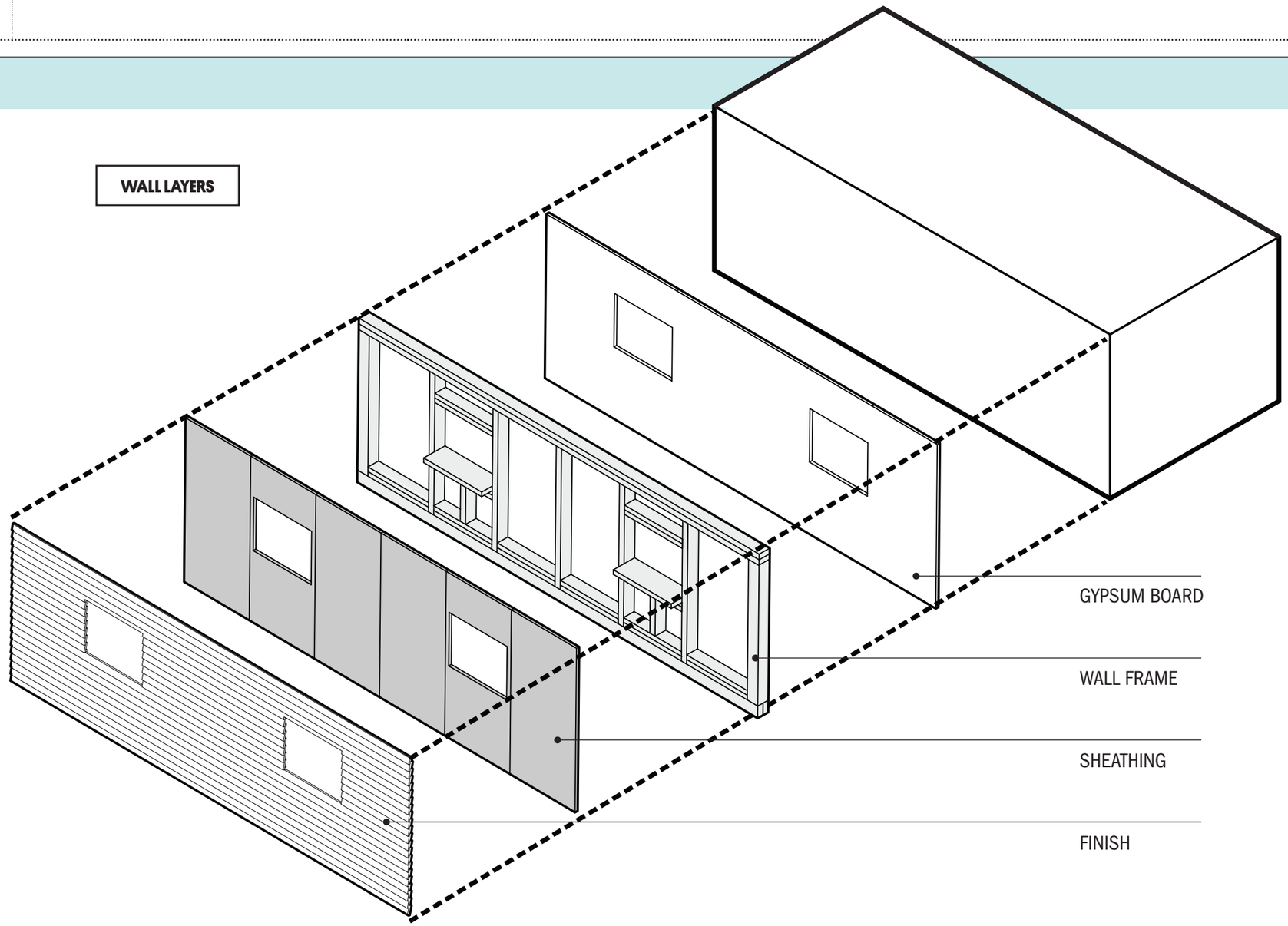
STRATEGY

06 BUILD STRONGER WALLS

STEP 4 - DESIGN THE WALL SYSTEM

FINISHING

- Use flood damage-resistant materials below the anticipated design flood level. Refer to FEMA Technical Building 2 (FEMA TB-2) for requirements in flood zones.
- Place insulation inside the frame between the studs to keep interior temperature stable, despite outside temperature.
- Sheathing, typically plywood, is attached to the wood studs and joists using 6d or 8d common nails.
- Every panel must align with a wood stud, plate, or blocking for proper installation.
- A 4 ft. x 8 ft. panel is recommended to span the wall studs.
- Leave a minimum ½ in. vertical gap between sheathing panels to account for shrinkage of the supporting wood member.
- Exterior wall sheathing, like stucco plastering, can be used as a base for finishes.
- Plywood panels in structural walls should be 5/16 in. thick minimum and CD grade.
- Gypsum board used in structural walls should be ½ in. thick minimum.

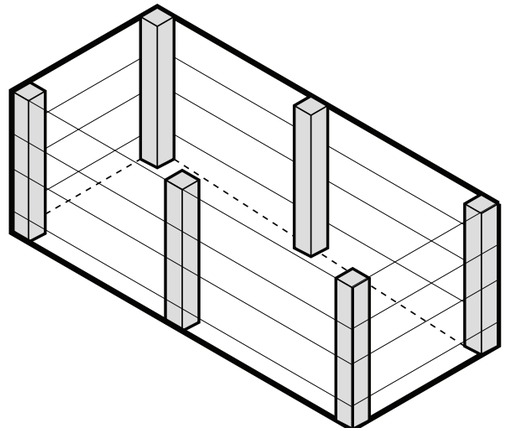


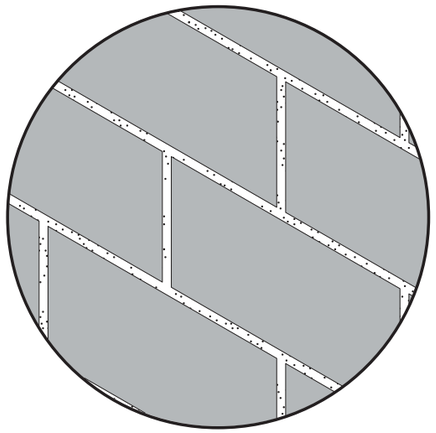
STRATEGY

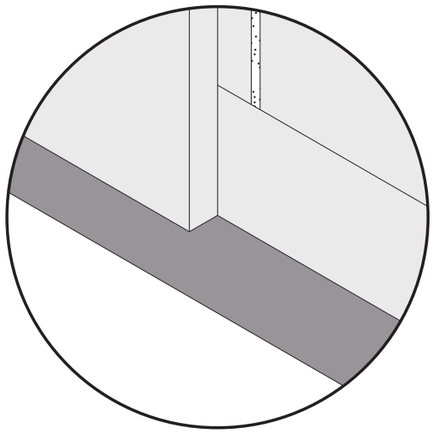
06 BUILD STRONGER WALLS

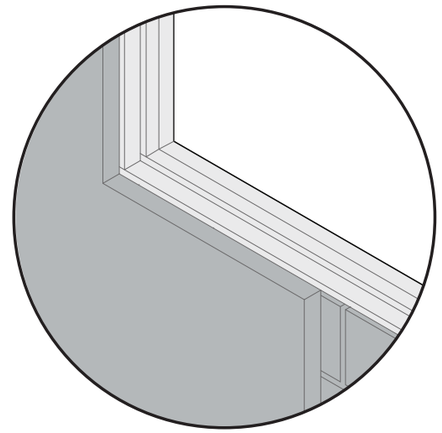
STEP 4 - DESIGN THE WALL SYSTEM

B. CONCRETE









POURED CONCRETE

- Pour concrete directly into engineered formwork with rebar laid into the forms.
- Formwork is a mold, typically made from plywood panels, that frame the wall's final thickness.
- Use ties to maintain the distance while pouring and curing.
- The process consists of: Build the formwork, pour the concrete and sample for testing, wait for the concrete to cure and verify strength test results, dismantle the formwork.
- The process is slower to erect than a wood frame or concrete frame with infill walls.

CONCRETE FRAME WITH INFILL WALLS

- Design a poured concrete frame as outlined above.
- Design a structural grid of rebar that connects columns.
- Columns must be directly above the foundation in order to transfer the load properly.
- Columns and beams have vertical and horizontal rebar to transfer gravity and lateral loads, including wind and seismic loads, into the foundation.
- Use concrete blocks to fill the gaps between the structural grid columns.
- Grout and place rebar in block cell at required spacing.
- Add joint reinforcement and horizontal rebar for lateral loads.
- Tie infill walls to the structural concrete frame.

CONNECTION TO FOUNDATION

- This system can only be anchored to a concrete foundation.
- The foundation should have dowels embedded in the dry mixture extending into the wall, prior to pouring the concrete.
- Reinforcing steel embedded in the foundation, called dowels, are the primary connection between the walls and the foundation. They should match the spacing and size of the wall rebar. See Strategy 05.
- Dowels should extend into the foundation and match the spacing and size of rebar. Typical spacing is 8 in. or 16 in. on center to match the concrete block rebar and size, depending on the structural design. Refer to Strategy 05 for information regarding foundations.
- Ensure there is adequate lap between the dowel and wall rebar to transfer forces into the foundation. The length of lap required depends on the size and type of dowel.
- Provide a minimum of 3 in. of concrete cover on all sides of the dowels.

FRAMING AROUND OPENINGS

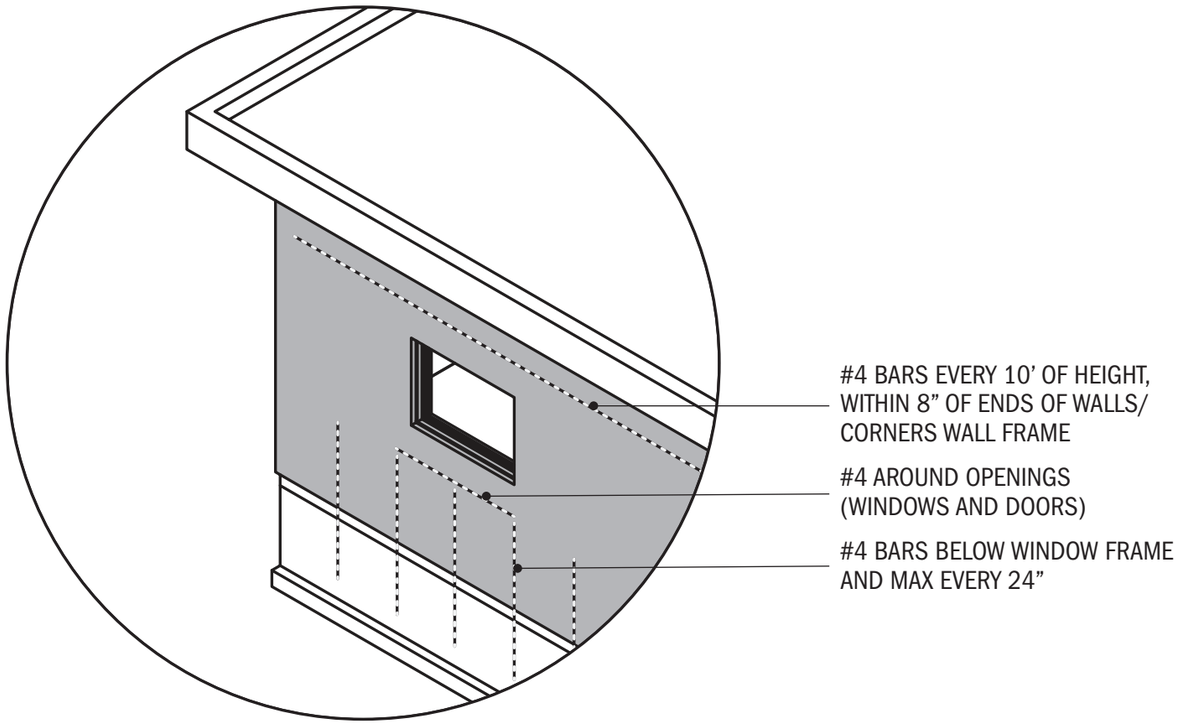
- The building code requires rebar around openings on all sides in structural walls.
- Additional horizontal rebar is required above and below the opening, called a lintel beam. Horizontal rebar should extend beyond the opening in both directions.
- Rebar size and spacing is dependent on the strength required. The building code requires a minimum of No. 4 size rebar (½ in. diameter), spaced at a maximum of 24 in. on center, but this will depend on the structural design.
- For concrete frame with infill walls, a poured concrete frame should be built for wall openings.

STRATEGY

06 BUILD STRONGER WALLS

STEP 4 - DESIGN THE WALL SYSTEM

FRAMING AROUND OPENINGS



CONNECTION BETWEEN EXTERIOR AND INTERIOR WALLS

- Anchor interior partition walls into the frame for stability.
- Maintain a continuous load path by ensuring vertical reinforcement is continuous from the foundation to the roof in structural walls.
- Additional horizontal rebar, called a lintel beam is required and must be continuous on all exterior walls and interior structural walls.
- Ensure there is an adequate lap when transitioning between rebars.

CONNECTION BETWEEN STORIES

- Structural walls should be vertically continuous from the foundation to the roof.
- In multi-story homes, higher floors may have wood framing.
- Anchor wood floors into the structural walls using embedded anchor bolts.

FINISHING

- Latex paint and ceramic tiles are the best type of material to withstand flooding and protect the structure.
- Use manufacturer instructions to prepare the wall before applying.
- Anchor exterior finishes, like tiles, using wall ties.
- In addition to floodproofing requirements, waterproofing is recommended on exterior wall and slab surfaces.

OPERATIONS AND MAINTENANCE

Use the appropriate length of framing members.

Wood expands and contracts under different environmental conditions, such as humidity. Tighten wood fasteners after wood members contract. Anchor bolt nuts should be finger-tight plus a ¼ to ½ turn with a hand wrench. Do not over-torque the anchors.

There are different types of protective coatings for wood fasteners, including screws and nails. Select appropriate protective coatings to prevent rusting of the fasteners.

Corrosion and humidity affect the structural integrity of a house no matter the distance from the coast. Establish a habit of inspecting your walls for signs of humidity and corrosion damage. Pay close attention to the structural walls and its joint connections.

Watch out for deep cracks in the structural walls. If these appear, contact a professional engineer or architect immediately.

Structural walls should not be altered or removed in future remodels without inspection and approval by a registered design professional. Mark structural walls so that they are not altered or removed.

STRATEGY

07 BUILD A STURDY ROOF

$$-$$$$

DISCLAIMER

Consult with licensed building professionals to design and build a strong roof. Stay in touch with the design professionals that designed and constructed your home's roof as an important resource when it is time for maintenance. Ensure openings are compliant with current codes including the2018 IBC and IRC (as adopted by the PRBC) structural provisions and ASCE 7-16 and ASCE 24-14, and certified by the American Society for Testing and Materials (ASTM) as needed for wind-resistance.

A roof shelters you from rain and sunlight throughout the year, and should be strong enough to withstand natural hazard events and disasters. This strategy focuses on how to design a strong roof for your home.

Strategy in Action

1. Roof Design Principles

2. Establish the Type of Roof

3. Design the roof system

WHAT YOU NEED TO KNOW

A roof is part of the Main Wind Force Resisting System (MWFRS). It is held by the walls and the foundation, and maintains a continuous load path by transferring wind loads from wind-facing walls into parallel structural walls on the sides, and down to the foundation.

A roof:

- Protects the home from rain.
- Protects the home from wind loads.

A roof must:

- Be properly anchored to resist wind loads and hold solar panels or other equipment.
- Have drainage to prevent rainwater ponding, particularly in low-sloped roofs.
- Be leak-free and crack-free, as any holes may compromise its structural integrity.

The components of a strong roof are:

- Framing, or the trusses or joists.
- Roof deck, or the envelope.
- Strong connections to the structural system, or the joints.
-

- One or more impermeable layers, including waterproofing membrane, to keep water out of the building and provide insulation.
- Sealed chases to accommodate for future installations of PV panels. Any perforation done to a galvanized material after installation can damage the coating, and result in corrosion and cracking.

Consider the following when designing the roof:

- Wind.
- Seismic design category
- Rain.
- Strength of walls and foundations.
- Anchoring system for a natural disaster.
- Budget.

The most common failures in concrete roof construction are due to:

- inappropriate concrete mix.
- inadequate rebar connections.
- lack of drainage.
- loss of rebar strength due to corrosion.

The most common failures in wood roof construction are due to:

- Inadequate fasteners on roof decking or coverings.
- Inadequate connections between roof and wall frame.
- Lack of continuous load path through structure.
- Strength loss in corroded anchors and ties.

SUPPORTING STRATEGIES

04 Assess the Priorities for Your Home or Building

05 Build a Strong Foundation

06 Build Stronger Walls

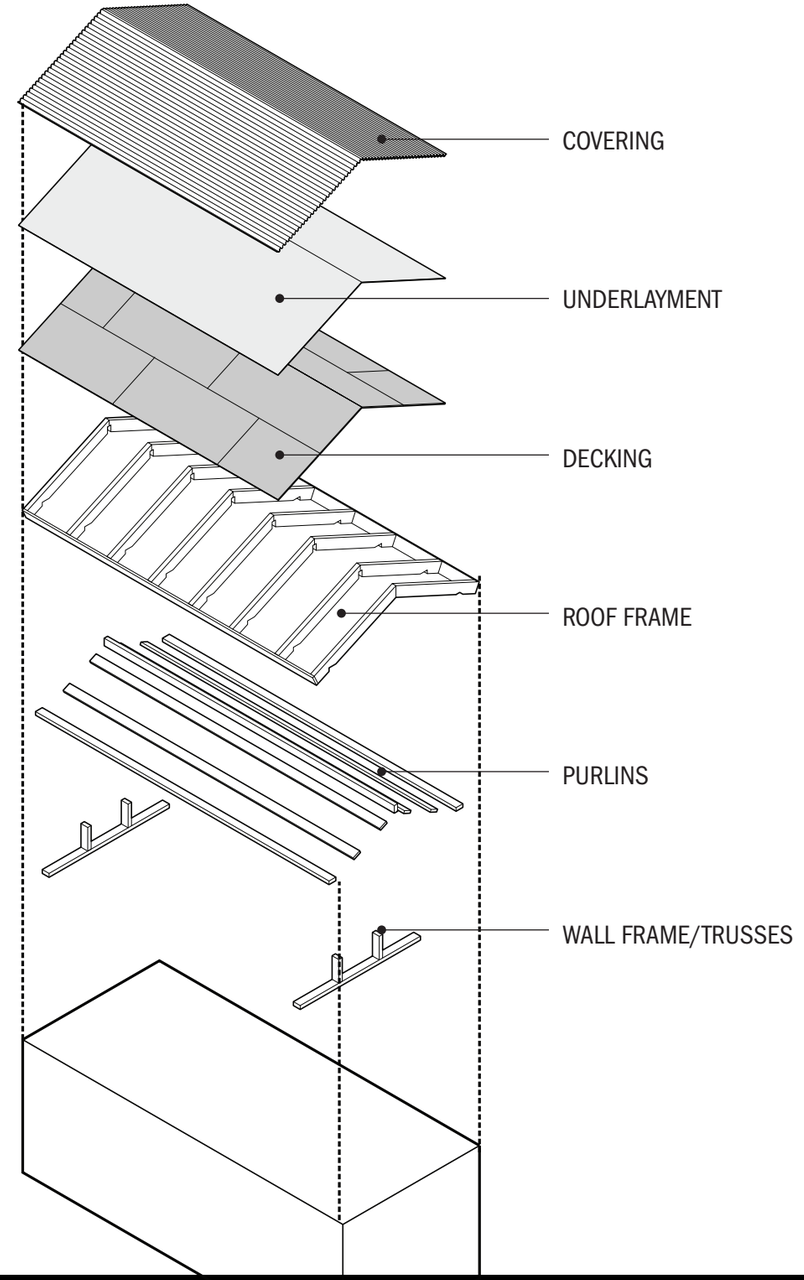
14 Manage Pests

17 Collect + Use Rainwater

19 Prevent Wastewater Backflow in Homes

21 Integrate Solar Energy Systems

25 Develop a Household Emergency Plan



STRATEGY

07

BUILD A STURDY ROOF

CORRECT WOOD ROOF

FAILED WOOD ROOF

CORRECT CONCRETE ROOF

FAILED CONCRETE ROOF

CORRECT WOOD ROOF

FAILED WOOD ROOF

CORRECT CONCRETE ROOF

FAILED CONCRETE ROOF

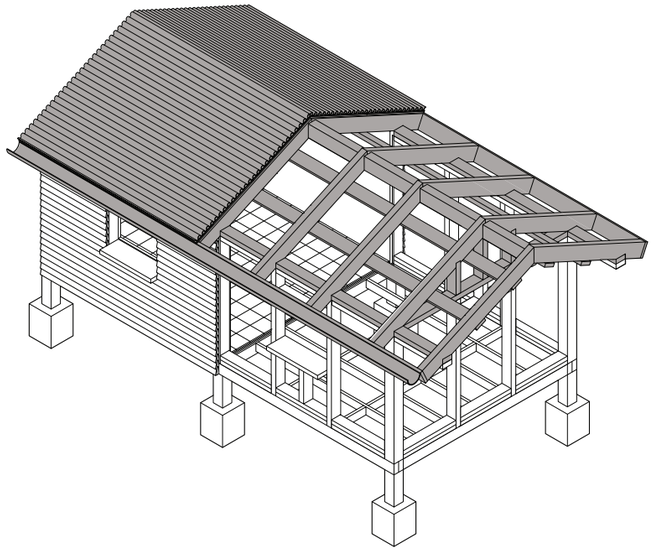
STRATEGY

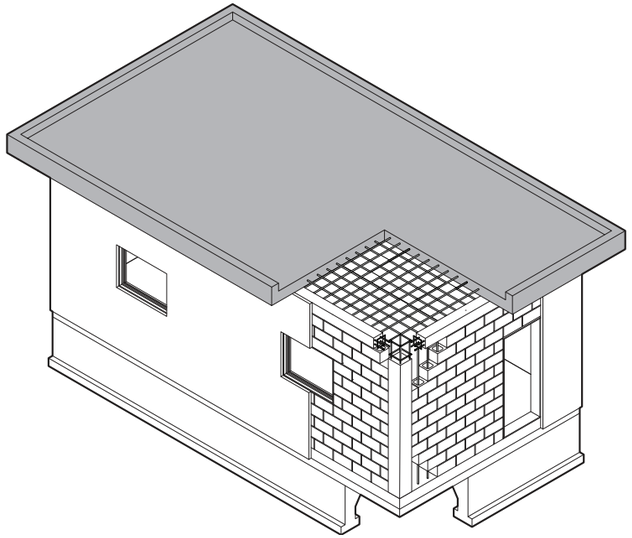
07 BUILD A STURDY ROOF

STEP 1 - ROOF DESIGN PRINCIPLES

Build a drainage system in the roof to prevent rainwater ponding and potential damage during a storm.

- Anchor any equipment mounted on the roof, like solar panels or utilities, to resist wind loads.
- A multi-layer roof (including water barrier or membrane) prevents water leaks, insulates the building, and better protects the building core.
- The roof's slope should be a maximum of 1:2 (1 foot of height for every 2 feet of length).
- Do not add openings on roofs, as this increases the risk of wind damage and leaks. If openings (i.e. skylights) are installed, additional framing members, typical double members, are required on all sides of the opening and they should be designed to resist wind-borne debris impact.
- Antennas, solar hot water heaters, cisterns/ tanks, solar panels or any other equipment should be securely anchored or removed during a natural disaster to prevent damage to the equipment and the roof. See Strategy 25: Develop a Household Emergency Plan.
- Any balcony or garage roof should be designed and constructed apart from the main roof to prevent the main roof to be damaged





STEP 2 - ESTABLISH THE TYPE OF ROOF

- Ask an engineer what is the best type of roof for your home.
- The roof's slope should be a maximum of 1:2 (1 foot of height for every 2 feet of length).

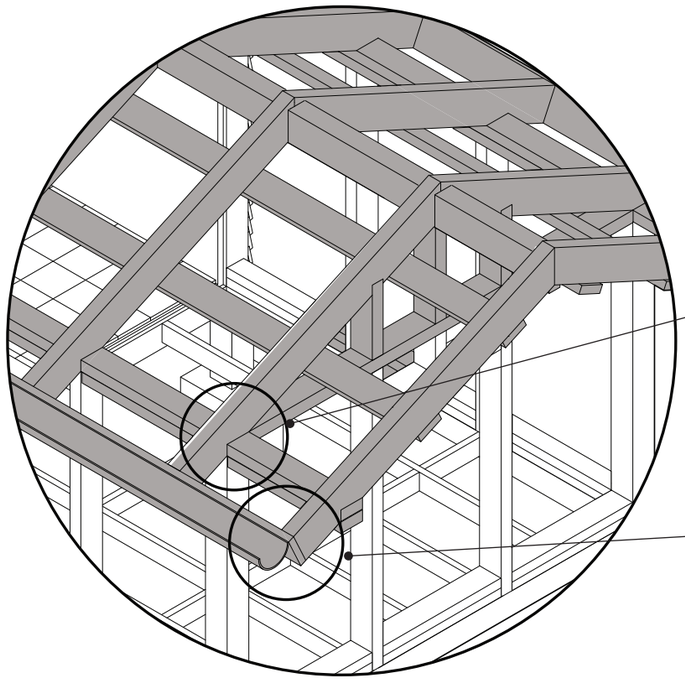
TYPE	HIPPED ROOF	FLAT OR LOW-SLOPED ROOF
DESCRIPTION	A structural system of wood rafters, trusses, floor joists, wall studs, columns, and beams that create a structure and framework for applied interior and exterior finished surfaces.	■ Usually build of concrete ■ Drains prone to be blocked by debris. Drains should b designed properly and checked after a climatological event to prevent pooling sinc could cause roof to collapse. Exercise caution and safety when going to the roof. ■ Prone to punctures from windblown debris or rainwater ponding. ■ Prone to pooling water if not drained appropriately.

STRATEGY

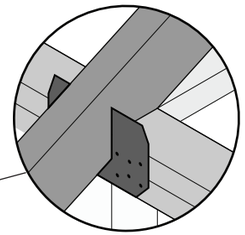
07 BUILD A STURDY ROOF

STEP 2 - ESTABLISH THE TYPE OF ROOF

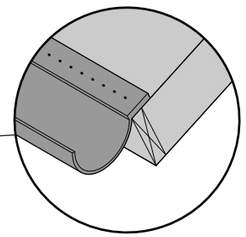
A. WOOD



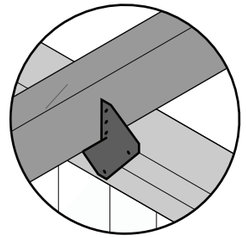
ROOF TO FRAME DETAIL



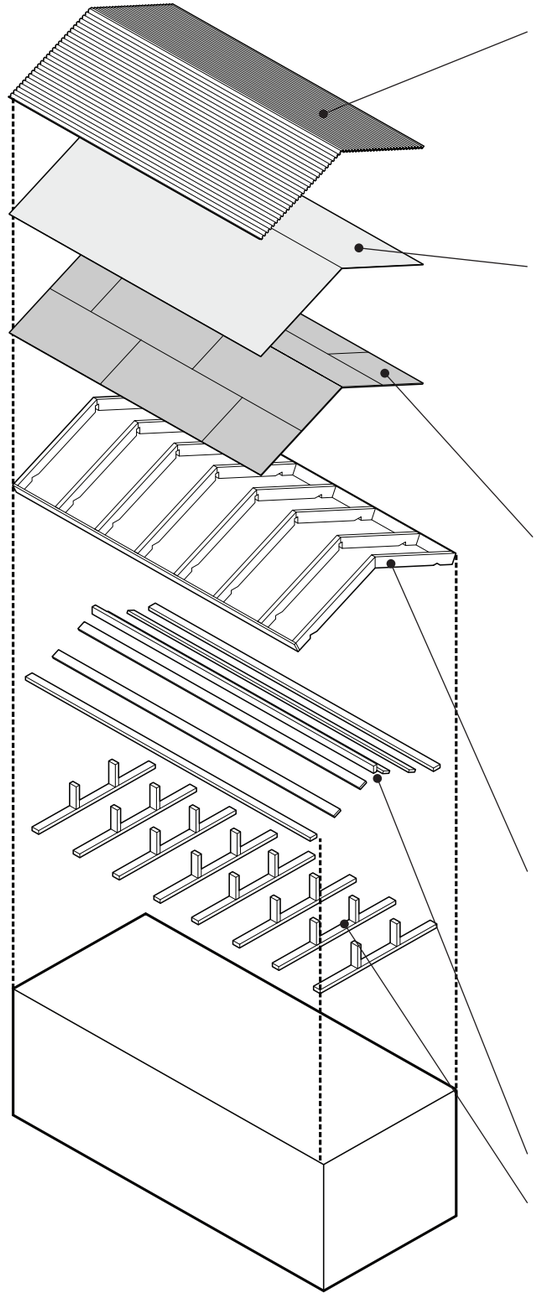
GUTTER DETAIL



FLAT ROOF - ROOF TO FRAME DETAIL



- The roof overhangs (eaves) should not extend more than 18 in. from the exterior wall to reduce risk of roof uplift failure.
- Covered patios and balconies should have their own independent roof structure, in case it gets damaged or is uplifted it does not damage the home roof structure.
- The size and spacing of roof framing members depends on the height and span.
- Roofs with longer spans or larger loads require thicker framing members and stronger trusses.
- Multi-story buildings have higher wind loads and require stronger roofs.



COVERING

Roof's first line of defense against wind,rain, flying debris.

- Zinc is the most common and resilient type of covering.
- Asphalt and concrete/clay tiles are not recommended because the do not protect the roof.
- Anchor zinc panels with #10 or #12 screws of the same material of the metal roof and with rubber washer. Seal screas with rubber seal to prevent water leaks.
- Overlap with 3 channels on each side and anchor with at least 6" extending from the union of the panels.

UNDERLAYMENT

Insulation and waterproofing layers

- Waterproofing layer - prevents leaks.
- Self-adhering polymer modified bitumen membrane, placed on the roof deck.
- Self-adhering polymer modified bitumen flashing tape, placed on all decking panel joints.
- 30 lb. felt tar paper membrane, button cap fastner 9 O.C. edge, 12 in. in O.C. field.
- Insulation layer - keeps moisture from entering the decking.
- Rigid layer, placed on top of the decking.

DECKING

Makes the frame rigid so it can transfer loads to exterior walls

- 4' × 8' 5/8" thick plywood panels.
- Use screws, ring-shack, or screw-shank nails in the corner regions and along the roof perimeter for wind resistance.
- The panels must be longer than 24" anywhere on the roof, and longer than 48" at rake edge (the sloped sides of a gable end).
- A panel "H" clip spaced between framing and member attachments. Spray closed-cell polyurethane foam adhesive on the underside of the decking at all framing and joints attachments to prevent moisture and humidity from damaging the wood.
- Offset plywood panels and screw to the truss beams with 3-3 1/2" wood screws.

ROOF FRAME

Provides structural support for the roof

- Use metal ties to link the structural walls as part of the continuous load path.
- At the top of the roof, rafters frame into a ridge board. Ridge board must be at least 1" thick. Rafters are typically nominal lumber spaced at 16" o.c.
- Collar ties are located below the ridge board and hold rafters together. They mus be at least 1" × 4" and spaced no more than 4" o.c. These are key components to resist uplift forces from wind.
- Provide ridge straps at each connection between the ridge board and rafters before installing decking.

PURLINS

WALL FRAME/TRUSSES

- Use rafter ties at every rafter to connect the walls to the roof to maintain a continuous load path.

STRATEGY

07

BUILD A STURDY ROOF

STEP 2 - ESTABLISH THE TYPE OF ROOF

HURRICANE TIES DETAIL

INSTALLATION DETAILS

INSTALLATION DETAILS

INSTALLATION DETAILS

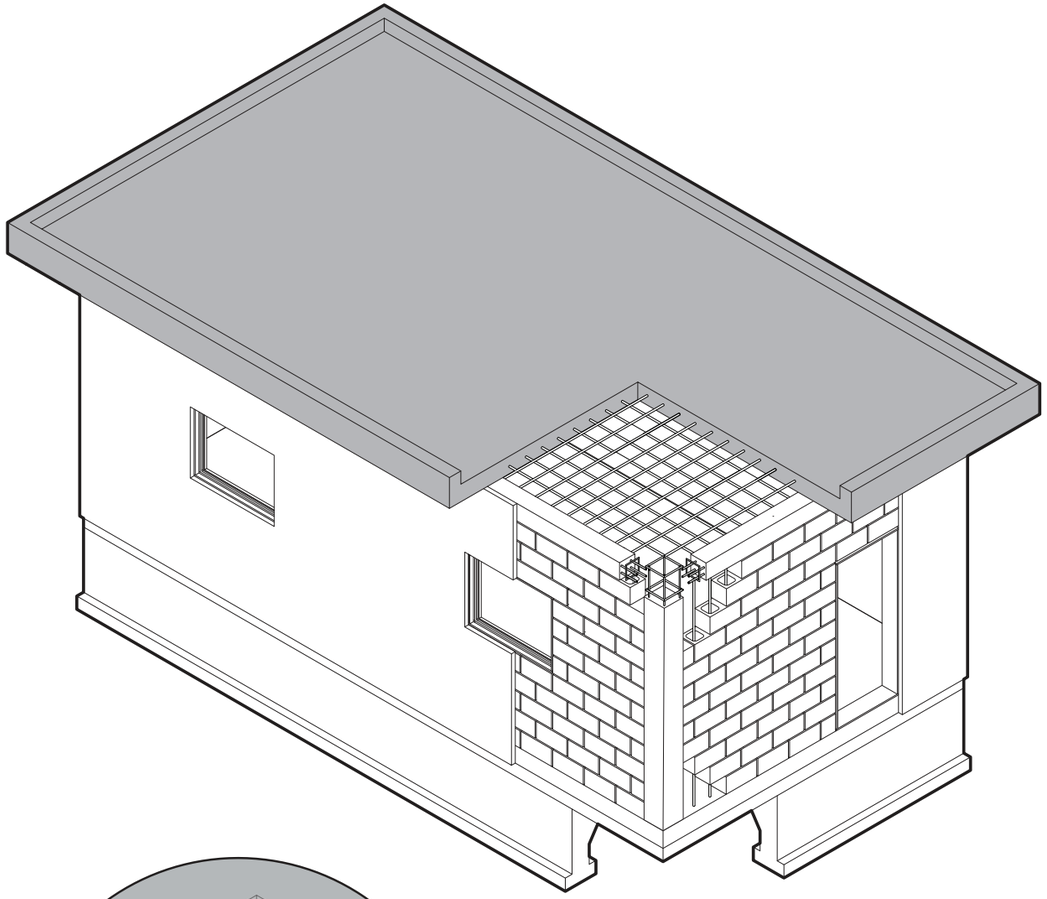
STRATEGY

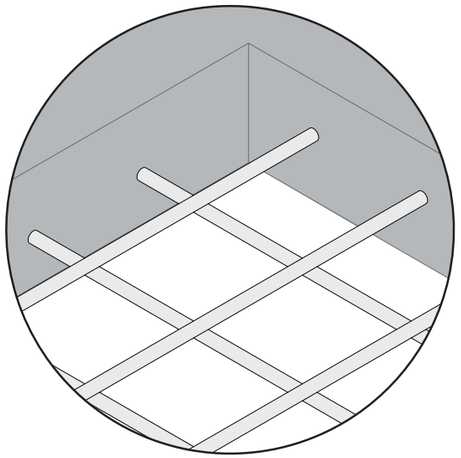
07 BUILD A STURDY ROOF

STEP 2 - ESTABLISH THE TYPE OF ROOF

B. CONCRETE

- With adequate design and construction techniques, concrete roofs perform well structurally during wind and wind-driven rain events, but should specifically be engineered to withstand seismic events or they can contribute to catastrophic failure.
- Consult a professional engineer for all retrofit and design of concrete roofs.
- Beams should have an inch of height for every foot it projects horizontally.
- If you notice any anomalies or that structure does not meet above standard, contact a professional engineer for an evaluation on your building.
- Keep in mind the following considerations when working with a professional engineer.
- Formwork is required to pour the concrete and let it cure. Form ties, secured in place with fasteners, hold formwork together during pour and curing. It's important that concrete cures completely to achieve its full strength and should be tested to ensure strength is achieved.
- Reinforcing steel, or rebar, provides strength to a concrete system. Rebar should be coated to be corrosion-resistant. Provide at least 2-3 in. of concrete cover to ensure rainwater and environmental pollutants don't corrode the rebar.
- Roofs need to be sized appropriately taking into account the rebar, the required concrete depths, electrical conduits and plumbing.
- Concrete strength is dependent on the size and spacing of spacing of rebar. Rebar should be continuous and two-way in slabs and also have temperature rebar.
- Connections between the wood roof system and supporting wall system is critical for the strength of a roof and overall resilience of the house. Embed dowels into structural walls and provide adequate anchors and hurricane ties. Refer to Strategy 6 for additional information about structural walls.
- There are three types of concrete roof systems:
  - Two way flat plate
  - Flat beam and slab
  - Inverted beam





STRATEGY

07 BUILD A STURDY ROOF

STEP 2 - ESTABLISH THE TYPE OF ROOF

OPERATIONS AND MAINTENANCE

If you see cracks, rot or insect damage in the wood roof framing, replace the entire member. DO NOT replace it with a smaller piece of lumber.

Watch for termites. Preserve and treat your wood to prevent it from rotting.

If you see any cracks, splits, tears, punctures in the waterproofing membrane or other exterior roof components, patch or replace component in accordance with above best practices.

Periodically inspect drains and downspouts, especially before and after a storm, to ensure they are clear of debris and are free flowing.

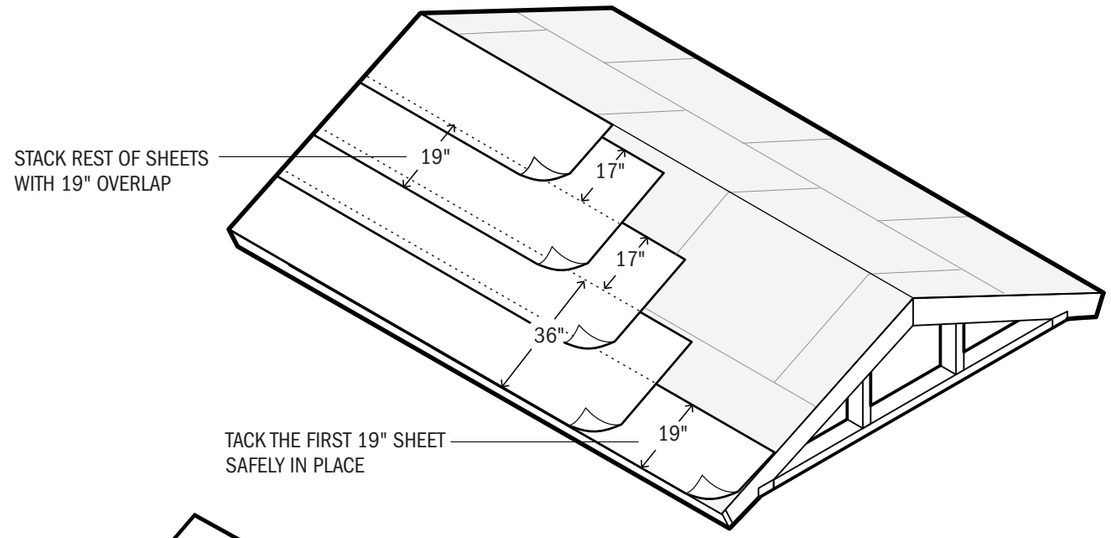
Corrosion and humidity affect the structure and fasteners of a roof no matter the distance from the coast, use stainless steel fasteners wherever possible (especially at roof edges and corners).

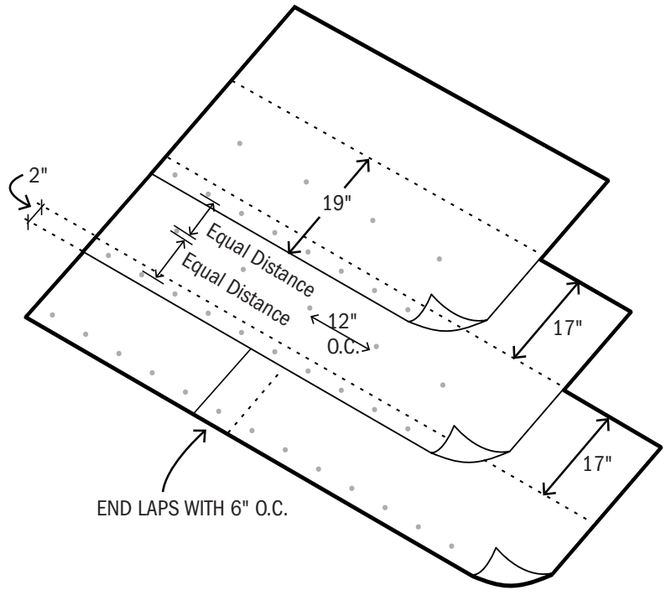
Inspect rooftop equipment (including water tanks) and mechanical components to ensure tie downs and other fasteners are maintained.

Make sure the roof can withstand the weight of the equipment or water tank, which make cause the roof to collapse and cause fatalities.

WATERPROOFING

- Waterproof the roof to ensure that water does not damage the concrete roof structure and/or leak into the structure.
- Integrate waterproofing concepts into the concrete mix. Using the wrong proportions of a mix, particularly high percentage of aggregate, can result in an excessively porous surface that leads to waterlogging.
- Use a sealant or continuous membrane on the exterior of the roof.
- Terminate waterproofing at all edges and transitions to guard against wind uplift. Gaps in waterproofing or excess material might catch in high winds and lead to progressive roof system failures.
- Apply the protection layers following a 2% slope in direction to roof drainage (see Strategy 20: Collect and use Rainwater) to ensure rainwater doesn't pool. Rainwater pooling is a serious hazard: not only does it lead to leaks, but pooling water can increase the weight on the roof, potentially compromising its structural integrity.





STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

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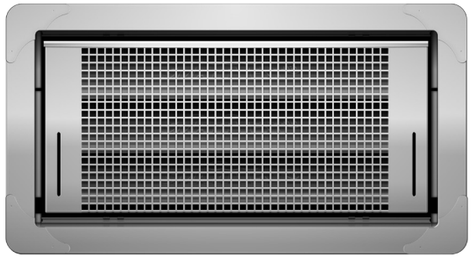
DISCLAIMER

Consult with licensed building professionals to design and build openings. Stay in touch with the design professionals that designed and constructed your home's openings as an important resource when it is time for maintenance. Ensure openings are compliant with current codes including the2018 IBC and IRC (as adopted by the PRBC) structural provisions and ASCE 7-16 and ASCE 24-14, and certified by the American Society for Testing and Materials (ASTM) as needed for wind-resistance.

A house has many openings, including entry doors, windows, skylights, and garages as well as vents. Properly anchored and sealed openings protect a home from natural disasters. This strategy focuses on protecting your home by appropriately selecting and securing openings.



Smart Vent

DESCRIPTION AND FUNCTION

An **opening** is a door, window, skylight, vent, or other aperture in the house's exterior envelope that provides controlled access/egress or regulates the flow of air and protects the home's occupants from weather, pests and/or pollutants. Openings also help maintain the temperature and humidity levels within the home.

Openings must meet the following design requirements:

- Be protected against breaching.
- Comply with floodproofing requirements for openings in flood zones. See Strategy 09.
- New glazed doors, windows and skylights in newly-constructed homes must be manufactured to resist wind pressures and wind-borne debris.

Consider the following when choosing and placing the openings:

- Risks exposure from wind and wind-driven rain.
- Balancing comfort and aesthetics with risk tolerance.
- Life cycle costs – includes initial installation costs and long-term maintenance.

Why openings fail

- incorrect anchorage can make even strongest doors/windows/skylight fly off.
- cracks or improper sealing through which water can seep.
- not protected against projectiles at high-wind scenarios.

SUPPORTING STRATEGIES

- 06 Build Stronger Walls
- 10 Control Thermal Heat Transfer
- 11 Increase Ventilation
- 12 Benefit from Natural Light
- 13 Control Moisture and Mold
- 14 Manage Pests
- 25 Respond + Begin Household Recovery

CORRECT OPENING

Smart Vent

CORRECT OPENING

FAILED OPENING = INAPPROPRIATE ANCHORAGE

FAILED OPENING = OPEN OPENING

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 1 - TYPES AND EFFECTIVENESS OF OPENINGS

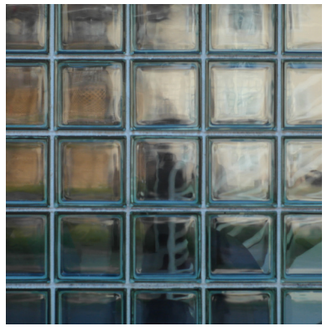
See Strategy 11 to understand how to select windows to maximize ventilation.

- Fixed assemblies are generally more resistant to wind and rain than operable assemblies. However, they provide limited ventilation and are vulnerable to pressure failure.

A. WINDOWS

IN-PLACE PROTECTION

IN PLACE PROTECTION WINDOWS



	FIXED, IMPACT-RESISTANT GLAZING	ALUMINUM JALOUSIE WINDOW	GLASS BLOCKS
PROS	■ Code Compliant and can withstand wind load. ■ May reduce a home's energy consumption. ■ No manual deployment required (passive).	■ Common in Puerto Rico. ■ Allows daylight and ventilation, maintains privacy. ■ Flood damage-resistant material	■ Inexpensive ■ Allows daylight and maintains privacy. ■ Flood damage-resistant material. ■ No manual deployment required (passive).
CONS	■ Expensive	■ Allowed by code, but is vulnerable to wind-borne debris so it must be protected by wind resistant panel. ■ Does not comply with the energy code. ■ Vulnerable to wind-driven rain entry.	■ Sealed element - Cannot be opened.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 1 - TYPES AND EFFECTIVENESS OF OPENINGS

A. WINDOWS

NO PROTECTION

GLASS JALOUSIE

PROS

- Very common in Puerto Rico.
- Allows daylight and ventilation.
- Flood damage-resistant material .

CONS

- Vulnerable to wind-borne debris damage and wind-driven rain entry.

CASEMENT

- Very common in Puerto Rico.
- Allows daylight and ventilation.

- Vulnerable to wind-borne debris damage and potential wind-driven rain entry.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 1 - TYPES AND EFFECTIVENESS OF OPENINGS

B. DOORS

IN-PLACE PROTECTION

FIXED, IMPACT-RESISTANT

PROS

Flood doors and barriers must comply with floodproofing requirements. See Strategy 09.

CONS

Are vulnerable to rain water entering the inside with the wind action.

Are costlier compared to non-impact resistant doors.

GLASS PANEL SLIDING DOORS

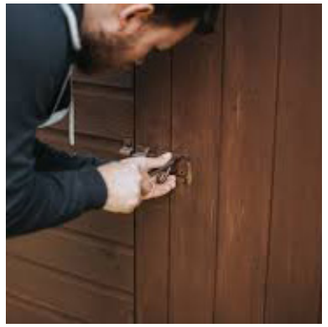
PROS

- Offer views to the outside, and natural lighting.

CONS

- When used, the inside may need additional protection from the sun's rays
- If not impact resistant, these are vulnerable and may have to be protected with shutters or other in the event of a hurricane and may be vulnerable to burglary.

NO BUILT-IN PROTECTION



SINGLE-LEAF WOOD

PROS

- Can be made impact resistant.
- Have aesthetic attributes.

CONS

- If not treated properly, are vulnerable to the sun and humidity.

DOUBLE LEAF WOOD

PROS

- Can be made impact resistant.
- They take less space when opening.

CONS

- More expensive than single leaf.
- Need to be secure between the two leaves compared to the single leaf that are secure to the wall Vulnerable to wind pressure and wind-borne debris failure as well as wind-driven rain entry in gaps between the door and door framing.
- Requires glazing protection.

BIFOLD

PROS

- Can open up a space to the outside to the exterior.
- They are usually not recommended since they might lose its balance or form by the action of gravity and use.

CONS

- Vulnerable to wind pressure and wind-borne debris failure as well as wind-driven rain entry in gaps between the door and door framing.
- Requires glazing protection.

PIVOTING

PROS

- The use of pivot doors is usually motivated by aesthetics
- Can be made of different materials

CONS

- Expensive
- Vulnerable to wind pressure and wind-borne debris failure as well as wind-driven rain entry in gaps between the door and door framing.
- Requires glazing protection.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 1 - TYPES AND EFFECTIVENESS OF OPENINGS

C. GARAGE DOORS

PROS

- Can be found in a variety of sizes and materials.

CONS

- Ensure doors and openings in garage doors are wind-resistant and have been tested for positive and negative pressures.
- Single two-car garage doors are more vulnerable to wind failure than one-car garage doors unless they are braced prior to the storm (active).

D. SKYLIGHTS

PROS

- Allow daylights in spaces that are far from exterior walls.
- Some skylights can open to allow for additional ventilation.

CONS

- Rooftop skylights can increase vulnerability of wind and wind-driven rain entry into the home, leading to potential structure and contents damage.

E. VENTS

Smart Vent

PROS

- No manual deployment required.
- HIghly effective at protecting structure.
- Can lower insurance as a wet flood proofing technique.
- Must be designed and installed to prevent water damage or leakage.

CONS

- Flood doors and barriers must comply with floodproofing requirements. See Strategy 09.

OPERATIONS AND MAINTENANCE

- Inspect seals and framing of windows, vents and doors annually for signs of wear or separation.
- Watch out for corrosion, clean immediately and replace corroded elements if necessary. The use of corrosion-resistant connectors, fasteners and surface materials will reduce this risk.
- Timber openings must be inspected annually for signs of rot or insect damage. If damage cannot be repaired using painting or sealing, replace damaged timber with new timber or decay-resistant materials.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 2 - ANCHOR OPENINGS

- Even hurricane-rated openings can fail if they are not properly anchored to the structural framing (not just the surrounding exterior sheathing).
- Use corrosion-resistant hardware and fasteners.
- If the openings contains glass, ensure the system complies with the appropriate ASTM requirements and specified design thickness.

WOOD FRAMING

DO'S

- Galvanized wood screws

DONT'S

- Nails or Staples

CONCRETE

DO'S

- Galvanized Concrete or Lag screws

DONT'S

- Nails

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 3 - SEAL OPENINGS

▷ Fill any cracks, crevices or penetrations around its perimeter and at interfaces between the opening and the supporting wall to prevent intrusion of water and leaks from wind-driven rain.

A. SEALANTS

SEALANT JOINTS

- Prevents water entering between frame and wall.
- Removable stop, sealant, and backer rod.
- Sealants should be waterproof/ marine rated

WEATHERSTRIPPING

- Prevents water from entering through the opening.
- Examples include door drips,neoprene seals.

B. DOORS AND FLASHING

VESTIBULE

- Provide additional surface for weather-stripping and to trap water before it enters the main structure.

OUT-SWINGING DOORS

- Place weatherstripping on the interior side of the door to minimize decay.

PAN FLASHING

- Prevents water from seeping underneath the door.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 4 - PROTECT EXTERIOR OPENINGS

IN PLACE AUTOMATIC METAL ROLL SHUTTER

COST

$$

SPECIFICATIONS

- Look for label that indicates it is compliant with ASTM standards (ASTM E1996m 2017)
- Anchor to the wall, not to the opening frame.

PROS

- Permanent solution.
- Resistant to wind and debris impact.
- Easily open and close from inside the home.

CONS

- Active mitigation
- Requires mechanical maintenance.
- Must be properly secured. Misalignment on tracks can lead to structural damage.
- No obstructions (i.e. window air conditioning units).
- Ensure it can be raised manually, in case of a power outage.

TEMPORARY PLYWOOD PANELS

COST

$

SPECIFICATIONS

- Must be at least 7/16 in. thick and preservative-treated.
- Anchor to the wall, not to the opening frame.

PROS

- Quick assembly.
- Can be anchored to window frame or bracket frame mounted on the wall.

CONS

- Active mitigation.
- Temporary solution.
- Not permitted on structures with roofs more than 33 ft or with wind speeds greater than 130 mph.
- Properly anchor to wall to prevent blow-off.

ALUMINUM OR POLYCARBONATE PANELS

COST

$-$$

SPECIFICATIONS

- Panels must overlap and be fastened together
- Anchor to the wall, not to the opening frame.

PROS

- Best value for cost and durability.
- Easy to store.

CONS

- Active mitigation.
- Temporary solution.
- Difficult to install on upper levels.
- Need two rails permanently installed on the opening perimeter.

MANUAL ACCORDION

COST

$-$$

SPECIFICATIONS

- System similar to metal roll shutters, except they are opened and closed on the sides of the opening.
- -Anchor to the wall, not to the opening frame.

PROS

- In place, ready to close.

CONS

- Active mitigation.
- Must be closed manually from the outside.
- Difficult to access on higher levels.

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

STEP 5 - OPENING FAILURE

CRACKS OR INAPPROPRIATE SEALING

Allows wind and wind-driven rain to enter a house, damaging the building envelope and creating potential wind pressure failure.

OPENING COVER FAILURE

If air comes in but cannot escape, it exerts additional pressure on the interior of the structure that can lead to structural damage and failure of openings.

PAN FLASHING

Failure to close openings or implement opening protection systems allow significant wind and wind-driven rain to enter and damage the structure. Unsecured objects and materials (furniture, wall finishes, electrical equipment) may also be at risk of being damaged by wind pressures or pulled out through the opening.

INAPPROPRIATE ANCHORAGE

Full detachment of openings from the supporting wall can lead to wind and wind-driven rain damage and associated damages and losses.

FAILED OPENING

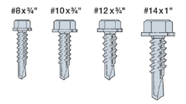
TIGHT OPENING

STRATEGY

08 ANCHOR, SEAL & PROTECT OPENINGS

ANCHORAGE SYSTEMS

NAME	IMAGE	FUNCTION	USES
WEDGE ANCHOR		Fastening structural steel, handrails, signs, racks, equipment and formwork bracing	Solar water heater and other equipmen
SLEEVE ANCHOR		Fastening in solid concrete and masonry	Solar water heater and other equipment
DROP-IN ANCHOR		Internally threaded drop-in expansion anchors for use in flush-mount applications. Requires a setting tool.	Solar water heater and other equipment
STRIKE ANCHOR		Inserted into pre-drilled hole, the strike center pin to expands.	Solar water heater and other equipment
LAG SHIELD		Lag screw is inserted to expand shield.	Solar water heater and other equipment
CHEMICAL ANCHORING		Pre-drilled hole is filled with concrete adhesive.	Solar water heater
ANCHOR FASTENERS		Anchor wood to concrete	Connect wood sill plates to concrete foundation
CONCRETE AND MASONRY SCREW		Anchor opening elements (i.e. windows)	Fastening windows Permanent metal shutters

NAME	IMAGE	FUNCTION	USES
HURRICANE TIE		Tie roof truss to wood wall frame	Wood roof truss
TRUSS CONNECTOR PLATES		Tie roof truss components together	Wood roof truss
STUD PLATE TIES		Tie from foundation to wood columns	Wood columns
STRAP TIES		Tie from foundation to wood columns	Wood columns
FASTENERS		Fasteners for metal ties	Metal ties
COMMON STAINLESS STEEL NAIL		Nails for metal ties when indicated	Metal ties
WOOD SCREWS		Wood to wood screw	Wood panel shutters

STRATEGY

09 FLOODPROOF YOUR HOME

$-$$$

If your home or building is located in designated floodplain as noted by FEMA along the coast which experience storm surge with breaking waves during or along a river that may overflow during heavy rains, you should understand how flood water can affect your structure so that you can mitigate the risks, damages and costs associated with flooding. This strategy focuses on ways to floodproof a home to minimize water damage. See the Resources section below to check your home's vulnerability to coastal flooding.

DISCLAIMER

Consult licensed building professionals to determine the best floodproofing strategy for your home. Stay in touch with the design professionals that designed and constructed your system as an important resource when it is time for maintenance.

FEMA does NOT recognize dry floodproofing as an acceptable strategy for residential structures. The building code requires buildings with residential occupancy to be wet floodproofed.

Ensure floodproofing is compliant with code: IBC (as adopted by the PRBC) structural provisions and ASCE 7, with materials certified by the American Society for Testing and Materials (ASTM) against high winds and flooding.

WHAT YOU NEED TO KNOW

Floodproofing prevents water from entering and damaging the home and critical mechanical, electrical and plumbing systems. There are two types of floodproofing:

Wet floodproofing – Mitigates water damage to the home by allowing water to freely flow up to the DFE and allows unoccupied portions of a building to be flooded that are modified using flood damage-resistant materials and relocating key equipment and contents, reducing damages and losses.

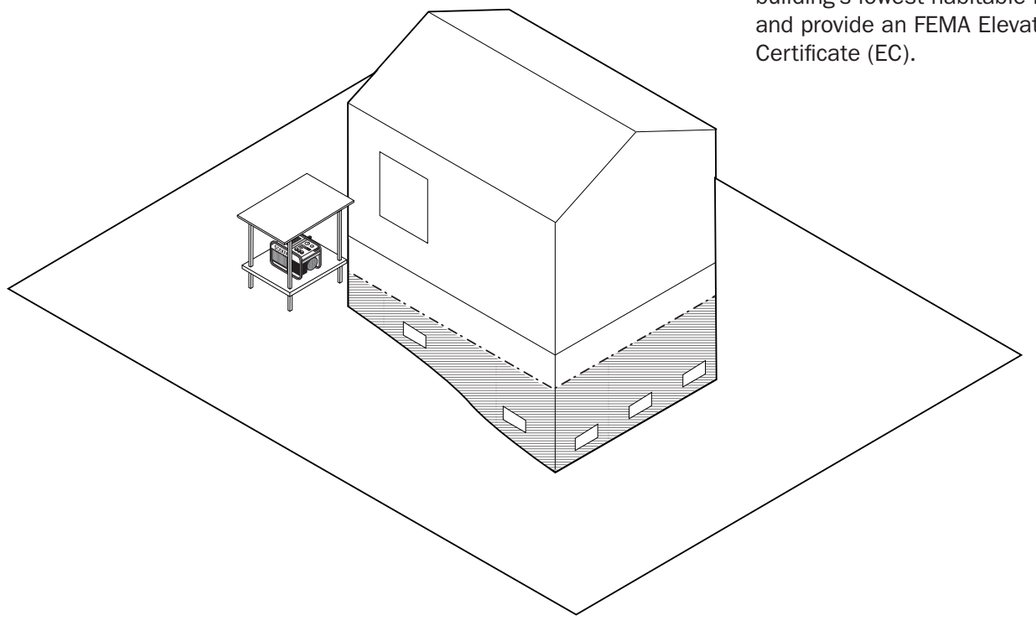
Dry floodproofing – Mitigates water from entering the home through its watertight structure. Use only in non-habitable commercial spaces of concrete multi-family buildings. Remember that dry floodproofing is active mitigation and subject to failure. It is an expensive option.

- **Active** – Requires human intervention for removable elements to be deployed before a natural disaster.
- **Passive** – Fixtures and systems are automatically integrated into the structure, so they do not need to be deployed before a natural disaster.

Design Flood Elevation (DFE) is the level at which a building should be floodproofed. A building's DFE is calculated based on FEMA's Base Flood Elevation (BFE) plus an additional amount as a safety buffer which is called "freeboard" and is indicated in the 2018 building code (2' or more)

The BFE is provided in the FEMA Flood Insurance Rate Maps (FIRMs), which includes wave effects. These maps do not take into account future sea-level rise from climate change. See "Resources."

Hire a surveyor who will identify the building's lowest habitable level and provide an FEMA Elevation Certificate (EC).



OPERATIONS AND MAINTENANCE

Clearly label breakaway walls and critical components.

Regularly inspect outdoor fixtures for signs of rust and corrosion, and areas below the DFE for leaks, seepage and cracks.

Prior to an expected flood, items used or stored in flood-prone basements or ground-floor spaces should be moved out of the building or to higher floors in advance of a flood. These include vehicles, mechanical equipment, furniture, area rugs, personal belongings, cleaning supplies and toxic chemicals.

After a flood, it's important to clean areas where the floodwaters, debris, and scour have occurred, as these could pose serious safety and health risks to occupants. *If wastewater has flooded home its important to take special precautions when cleanup and consider hiring a professional with safety equipment to protect against disease.

In coastal and tidal riverine areas, corrosion of metals caused by salt water inundation may be a problem. Periodic maintenance of key components and fasteners is important for the overall health of the building.

ESTIMATING COSTS

Costs are dependent on variables including location, materials, type of construction, and risk exposure, that all contribute to real cost estimating valve.

SUPPORTING STRATEGIES

01 Reinforce Site

02 Reinforce Site with Vegetation

03 Plant an Edible Garden

05 Build a Strong Foundation

13 Control Moisture and Mold

22 Prevent Wastewater Backflow in Homes

25 Establish Household Emergency Plan

STRATEGY

09 FLOODPROOF YOUR HOME

WET FLOODPROOF HOME

Design with the understanding that the portion of the building below the DFE will flood.

1. REPURPOSE ALL FLOORS BELOW THE DFE

DESCRIPTION

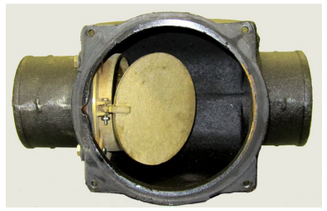
- Floors located below the DFE can be used for storage, vehicle access or parking.
- Walls prone to contact with floodwater must be designed with flood openings or to break away under flood loads.
- Refer to FEMA technical bulletin TB-9 for information regarding breakaway walls.
- Note that walls must be certified as breakaway walls.

2. ELEVATE CRITICAL SYSTEMS

- Elevate interior and exterior systems like mechanical air handling, electrical, and plumbing at least 1 foot above the DFE to ensure their function during and immediately after a flood.
- Prevent direct contact with flood water and minimize/avoid damage.
- If relocating systems is not possible, they must:
  - be designed and installed to prevent water from entering or accumulating within the components.
  - resist hydrostatic, hydrodynamic and debris impact loads.

3. INSTALL FLOOD VENTS AND/ OR FLOOD OPENINGS IN WALLS

- This will allow water to pass through perimeter walls and throughout the wet floodproofed areas.
- Locate openings below the BFE
- Bottom of openings are 1 ft or less above the ground level.
- Locate at least 2 openings on different walls of each enclosed area. If there are multiple enclosed areas, each area should have flood openings.
- 1 sq. inch of flood openings are needed for every 1 sq. foot of enclosed area.
- Openings should have a width and a length of at least 3 inches.
- Any louvers, screens, or covers on flood openings must allow automatic flow of floodwater in and out of the area.
- Doors and windows without installed openings do not count.



4. PROVIDE BACKWATER VALVES FOR WATER, SANITARY AND STORMWATER SYSTEMS

DESCRIPTION

- Backwater valves prevent wastewater from entering into the home's plumbing system and flooding the house. Refer to Strategy 19 for more information.
- Harden pipes up to DFE to reduce pressure on pipes if there backlow occurs.

5. ELEVATE, SECURE, OR TIE DOWN TANKS

- Includes fuel and water tanks
- If they cannot be elevated above the DFE, secure and properly tie down.
- Ensure they are empty to avoid leaks and contamination.

6. USE FLOOD DAMAGE-RESISTANT MATERIALS UP TO THE DFE

- Use stainless steel connectors and fastening systems.
- Materials must withstand direct and prolonged contact with water with flood water for 72 hours.
- The FEMA Technical Bulletin 2 (TB 2) of Flood Damage-Resistant Materials Requirements of 2008, approves only class 5 (highly resistant that can withstand exposure to water in movement) and class 4 (resistant but less durable under water in movement).
- Some class 5 materials include: concrete block, marine grade plywood, glass blocks, polyurethane formed in place and steel with waterproof adhesives.

- Install detachable mold- and moisture-resistant cladding at the bottom four feet using corrosion resistant screws.
- Design and build interior walls to vent/breath so cladding does not need to be removed for wall to dry
- Build cabinets off the floor above the flood line

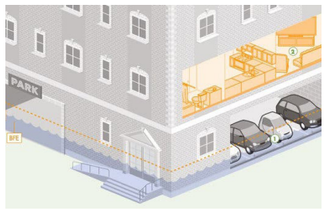
- Other acceptable materials per TB2 include:
  - Cement Board,
  - Concrete,
  - Non paper faced GWB,
  - Marine grade plywood,
  - Preservative treated lumber,
  - Plastic lumber,
  - Fiberglass,
  - Stone
  - Steel (painted/coated), closed cell insulation,

STRATEGY

09 FLOODPROOF YOUR HOME

DRY FLOODPROOF HOME

In a residential building, **dry floodproofing can only be used in non-habitable spaces**, e.g. lobbies, building manager office, utility rooms, retail, storage, etc. and is only permissible when the facility has a lowest floor commercial use.

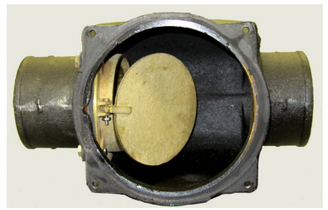


DESCRIPTION

1. Design the structure to withstand hydrostatic, hydrodynamic and debris impact loads associated with the DFE and determined by a structural engineer.

2. Seal all cracks and openings (except for flood vents or openings) below the DFE.

3. Install backwater control plugs in floor drains.



DESCRIPTION

4. Use waterproof covers for vents, louvers located under the DFE and install them before a natural disaster.

5. Permanently seal floor drains

5. Install sewer backwater valves.

6. Cap house trap to prevent water from flowing into the home if main sewer is backed up.

6. Install a sump pump at the lowest point of the home.

DESCRIPTION

7. Protect electrical equipment that cannot be relocated with waterproof enclosures.

8. Permanently replace first floor doors with flood doors and install removable flood gates over entryways.

9. Install waterproof hatch doors on sidewalk hatches.

DESCRIPTION

10. All power sockets must be at least 18 in above the floor or projected flood level. Prevent damage to the circuits from flood water.

10. Use a trench drain at the base of the stairs to reduce seepage from a non-protected hatch.

Bailey House

WILLIAM KEEGAN FOUNDER, PRESIDENT HEART 9/11

Description: The Healing Emergency Aid Response Team 9/11 (HEART 9/11) is a team of first responders including the FDNY, NYPD, and NYC Building Trades. The group came together in the aftermath of September 11, 2001 in New York City. The mission of HEART 9/11 is to immediately respond to natural and man-made disasters, rebuild community centers in hard-hit areas to meet community needs, and help communities recover by building resiliency for families and individuals. In Puerto Rico, HEART 9/11 worked on an initiative launched by New York Governor Andrew Cuomo, called NY Stands with Puerto Rico. The initiative, launched in April 2018, helped repair and rebuild approximately 90 homes in Orocovis.

A highly decorated Lieutenant and a 20-year veteran of the Port Authority Police Department, Bill Keegan was Night Operations Commander of the NYC World Trade Center Rescue/Recovery Teams, and awarded the highest medal for the WTC 9/11 response effort. In 2007, William Keegan founded HEART 9/11 (Healing Emergency Aid Response Team) – a non-profit disaster response organization comprised of police, fire, union construction workers, 9/11 surviving families and those who share our belief that we can help ourselves by helping others.

INTERVIEW

What led you to come to Puerto Rico? What challenges did you face? What happened?

We knew the pain that we had been through on 9/11. You wake up one morning and there is bright sunshine and within hours your world is turned upside down. We thought that, with our skills and expertise, we could make a difference for the people of Puerto Rico. We responded to Texas and Hurricane Harvey and had been in the Keys because of Hurricane Irma, so we thought we would be up to the task because other organizations had been stretched so thin prior to the hurricane the week before. We knew our level of expertise would go a long way in helping to organize recovery response in Puerto Rico. Many of the people that work in the trades, from the police officers to the firefighters, come from Puerto Rican descent, and they were anxious to get back to their homeland and families and bring them comfort and supplies. In the end, they wanted to bring them a sense of home by transferring their skills and knowledge to the people of Puerto Rico, so they can help rebuild themselves.

What challenges did you face?

The first one was a combination of obvious difficulties like lack of fuel, water, and medical supplies proved greater as you moved away from the island's coast lines. There were logistical challenges of ships and other planes bringing in supplies. There wasn't any power, so we had to have generators in place in our own supply chain of food and water.

The second challenge was entering communities that were unable or had no experience with networking and organizing themselves to respond to the magnitude of the disaster. First, what we needed to do was help them organize. Then, we had to demonstrate that if they partnered with the community boards, neighborhoods, pastors, and churches, they could get something done quickly. The level of our expertise with real union carpenters that know how to frame and put sheet metal in showed the community repeatedly that we were able to get the work done—and provide real tangible results—not just being people promising someday. Literally, men and women with toolbelts on, putting people's homes back together, and putting roofs back on. The community was going around the streets and collecting the sheet metal that was blown off their roofs and bringing it to HEART 9/11 members to install and at least have a roof over their heads.

Working with communities is critical to help you prioritize the most vulnerable households. Our teams were able to provide medical support and enable people to obtain medical attention. We became a holistic response group that gave people advice on how to make homes safe, helping take down trees, and clearing roads.