Earthquake & Hurricane Home Safety

August 2020 – Earthquake Training Resource for Design / Construction Professionals & Homeowners

Content Development Team

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Enterprise: Who We Are

Create opportunity for low- and moderate-income people through fit, affordable housing in diverse, thriving communities.

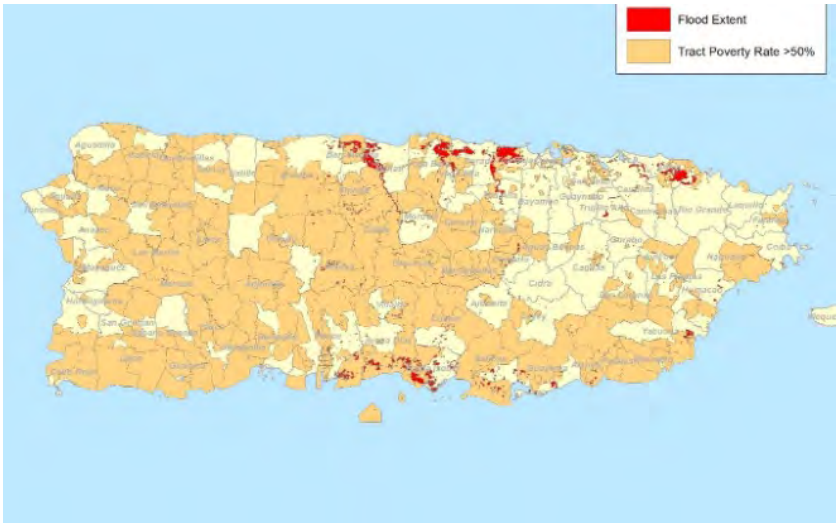
15 Years of Work in Housing Resilience, Recovery, Rebuilding

Disasters Impact Housing Security

Hurricane Katrina	Super Storm Sandy	Hurricane Harvey-Houston	Hurricane Maria-Puerto Rico/USVI	Fires, California
August 23, 2005	October 22, 2012	August 17, 2017	September 20, 2017	October 2017, 2018, 2019
800K Homes	650K Homes	135K Homes	370K Homes	60K Plus

Housing Affordability Crisis

- Homeowners in Puerto Rico have a median income of only $25,200, and renters, with a median income of $11,300.



Natural Hazards Aggravate Affordable Housing Shortage

KEEP SAFE

A GUIDE FOR RESILIENT HOUSING DESIGN IN ISLAND COMMUNITIES

Enterprise

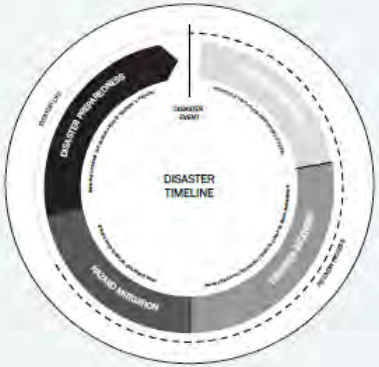
ASOCIACIÓN DE CONSTRUCTORES DE PUERTO RICO

MANTÉNGASE SEGURO

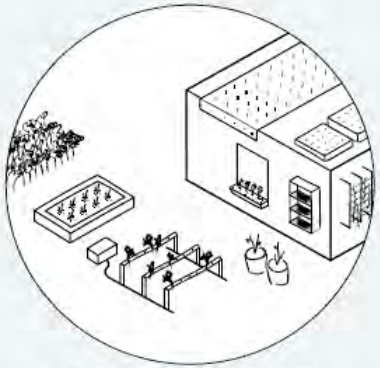
UNA GUÍA PARA EL DISEÑO DE VIVIENDAS RESILIENTES EN COMUNIDADES ISLEÑAS

Enterprise

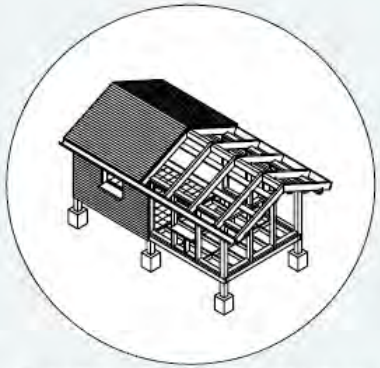
ASOCIACIÓN DE CONSTRUCTORES DE PUERTO RICO



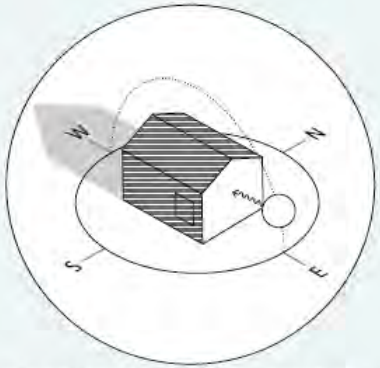
Introduction



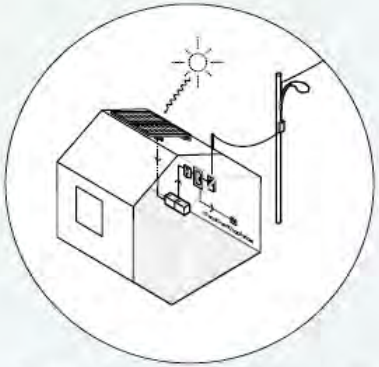
Chapter 1: A Safer Site



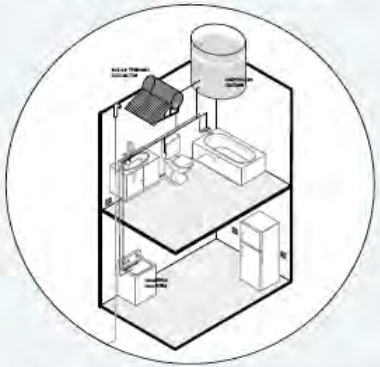
Chapter 2: Building Protection



Chapter 3: Passive Habitability

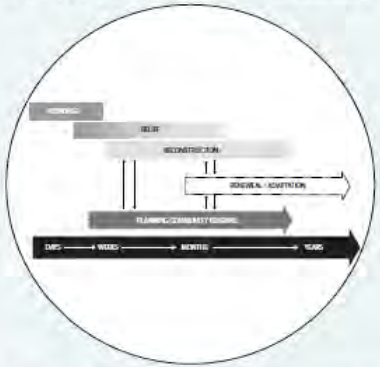


Chapter 4: Energy Generation



Chapter 5: Water Management

Chapter 6: Household Preparedness



Chapter 7: Community Engagement

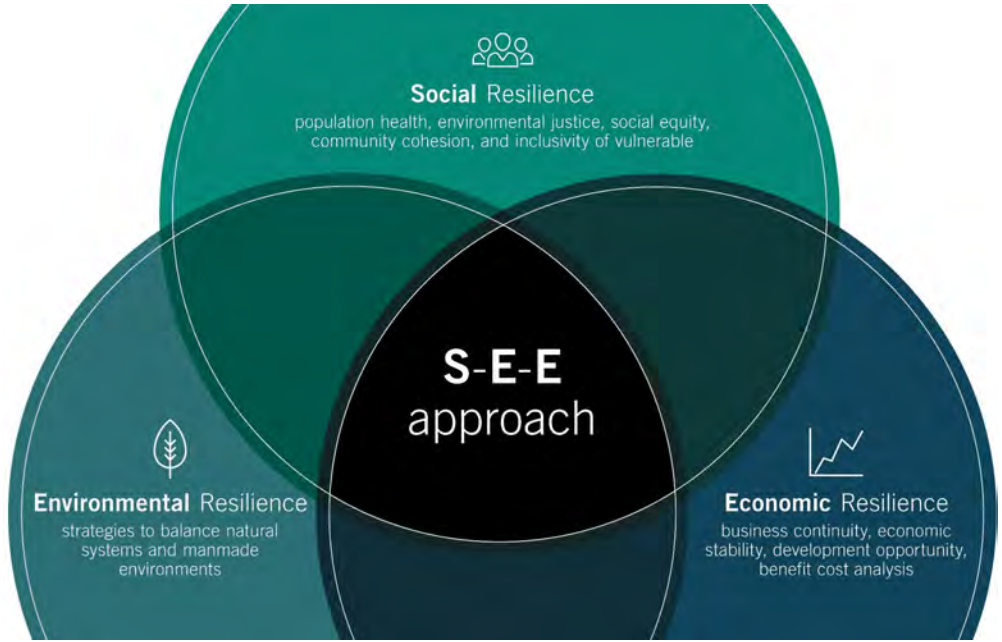
Rapido Temp to Perm Housing Houston, Texas

ResilientSEE-PR

We're a global alliance committed to designing and rebuilding a resilient, sustainable Puerto Rico.

We provide pro bono resilient design, planning and educational resources to communities in Puerto Rico.

To learn more about our projects, please visit **resilientSEE-PR.com**



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resilientSEE-PR.com is an initiative of AreaRESEARCH.org

Presentation Credits

Content Development Team

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Content development meeting at Perkins and Will Boston Studio

Introduction

Puerto Rico Trench and Falla Montalva, types of earthquake movements and effects.

Part 1

Assessment of Home for Reentry: Protecting Life / Protecting Property

Part 2

Who can assess my home?

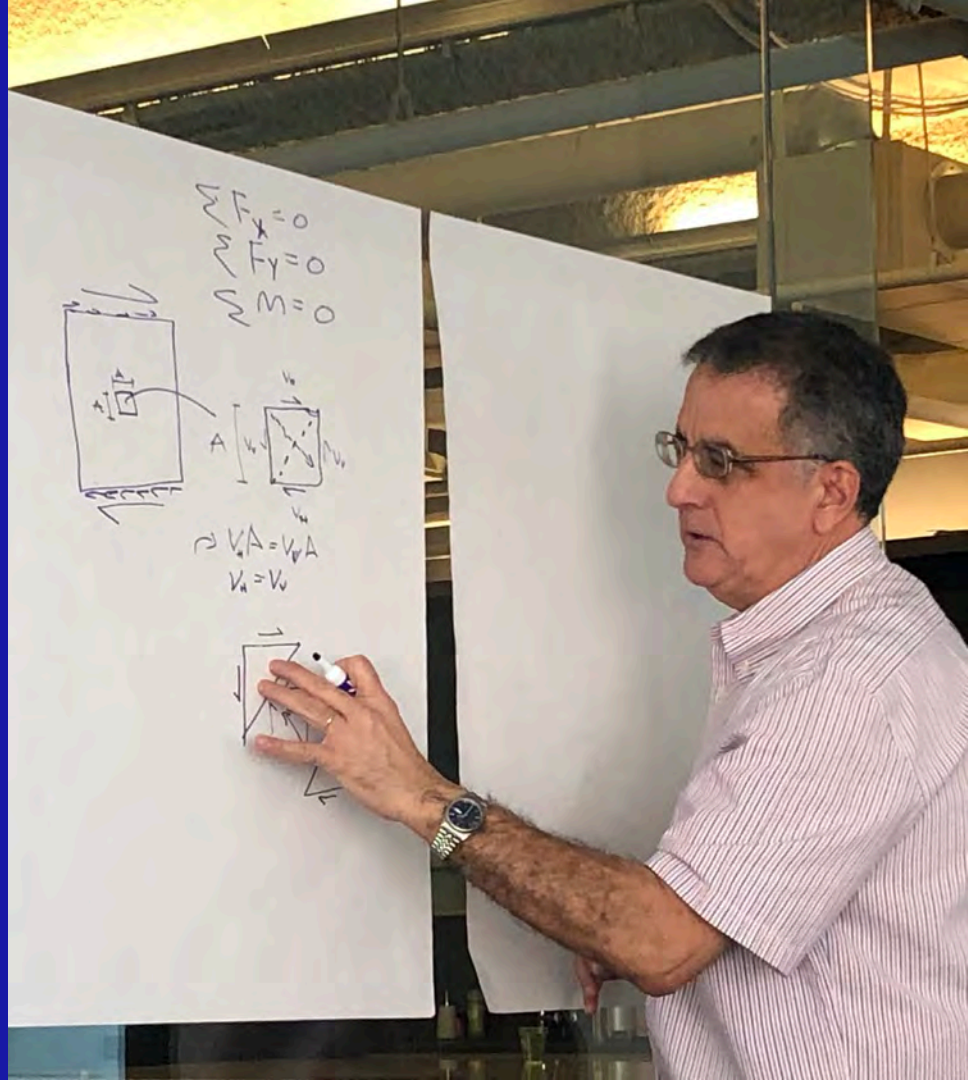
Part 3

Most common structural failures in Puerto Rico, their causes and methods of repair

Part 4

Techniques for Homes to Withstand Seismic and Wind Events

Part 5 / Hurricane Season Tips



Structural engineer, Pedro Sifre, explaining how the typical “X” masonry failure occurs.

Introduction

Puerto Rico Trench and Falla Montalva, types of earthquake movements and effects.

Awareness is defined as knowledge or perception of a situation or fact.

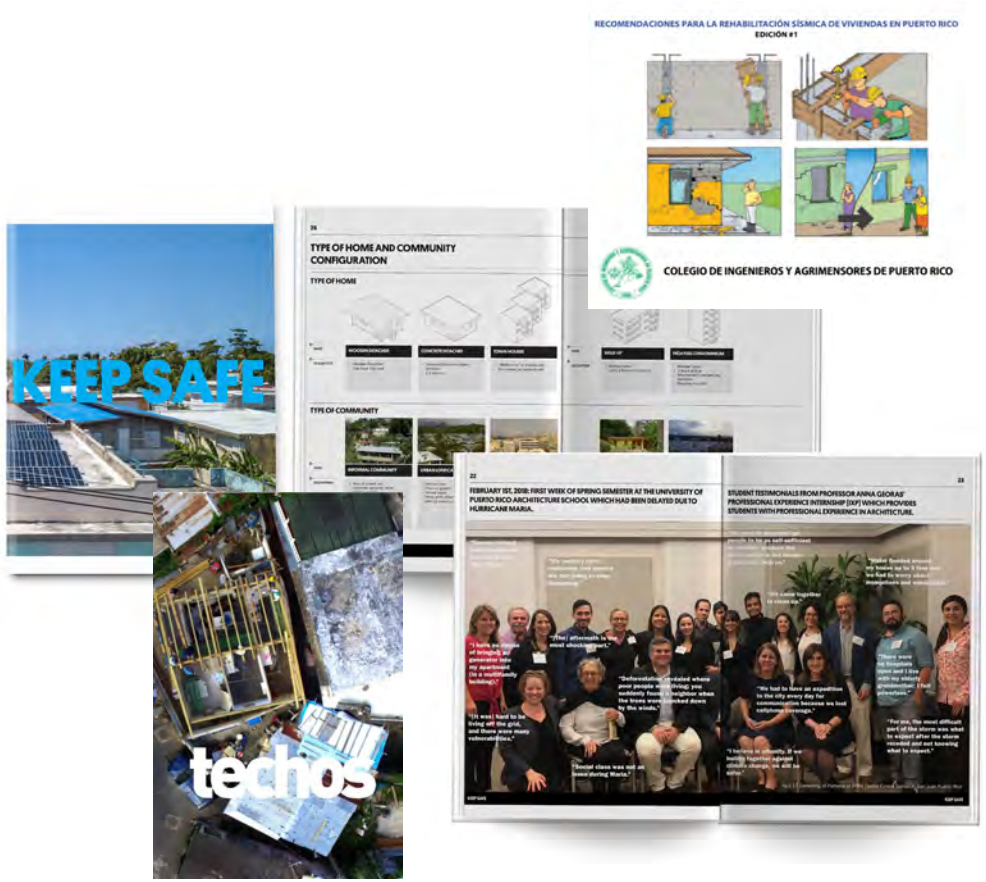
Key Training Resources

During this training we suggest consulting the following resources, hyperlinks provided:

[Keep Safe: A Guide for Resilient Housing in Island Communities, 2019, led by Enterprise Community Partners with many partners and collaborators]

[Recomendaciones para la Rehabilitación Sísmica de Viviendas en Puerto Rico, Edición #1, Colegio de Ingenieros y Agrimensores de Puerto Rico, 2011]

[Techos: Prototyping Resilience Design Guide, 2019, MIT School of Architecture and Planning, Case Study led by Danniely Staback with many partners and collaborators]



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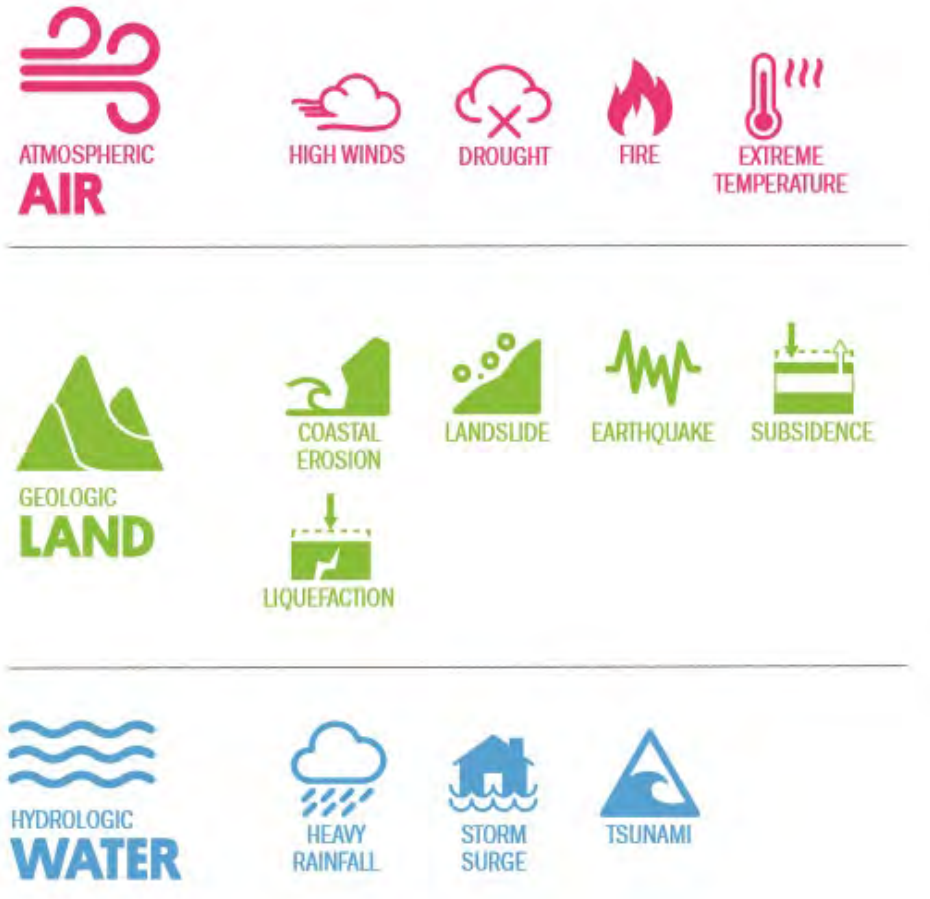
Keep Safe: A Guide for Resilient Housing in Island Communities.

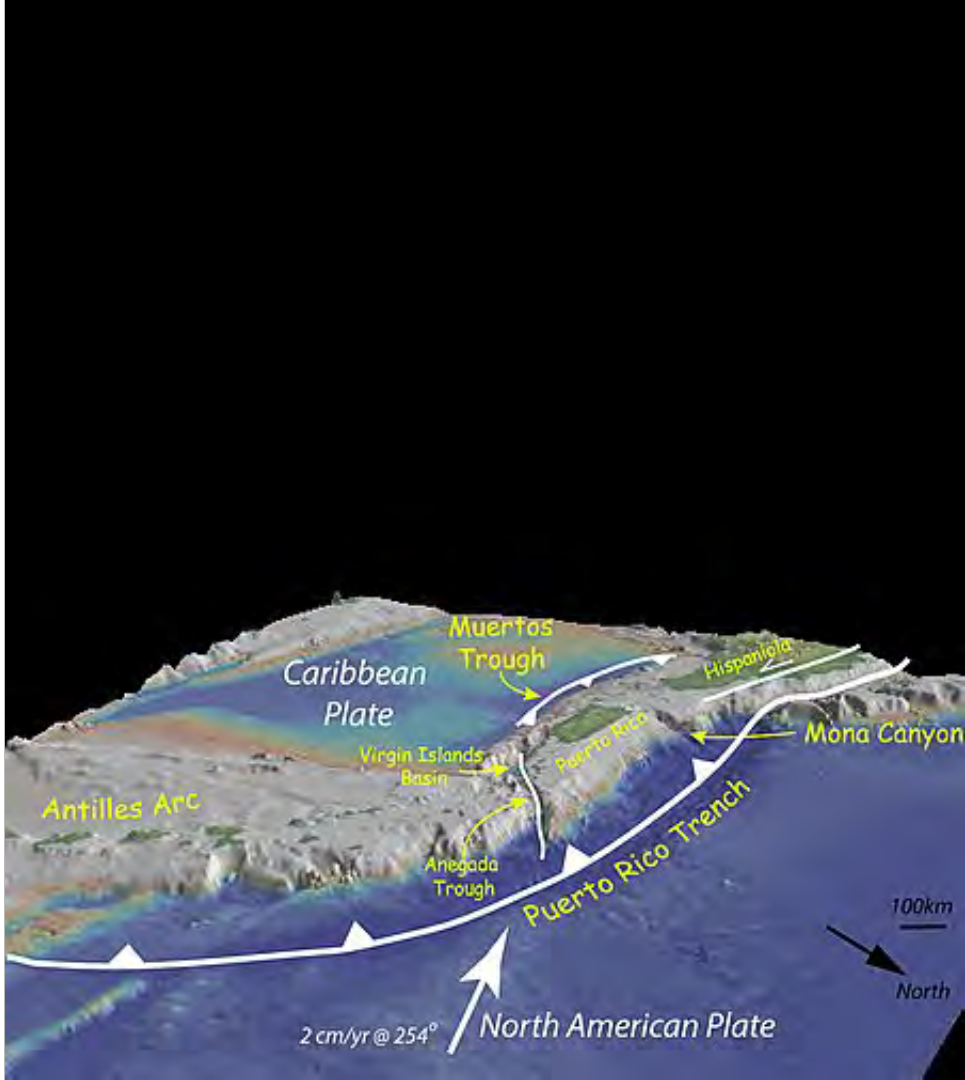
https://keepsafeguide.enterprisecommunity.org/

Puerto Rico Hazards



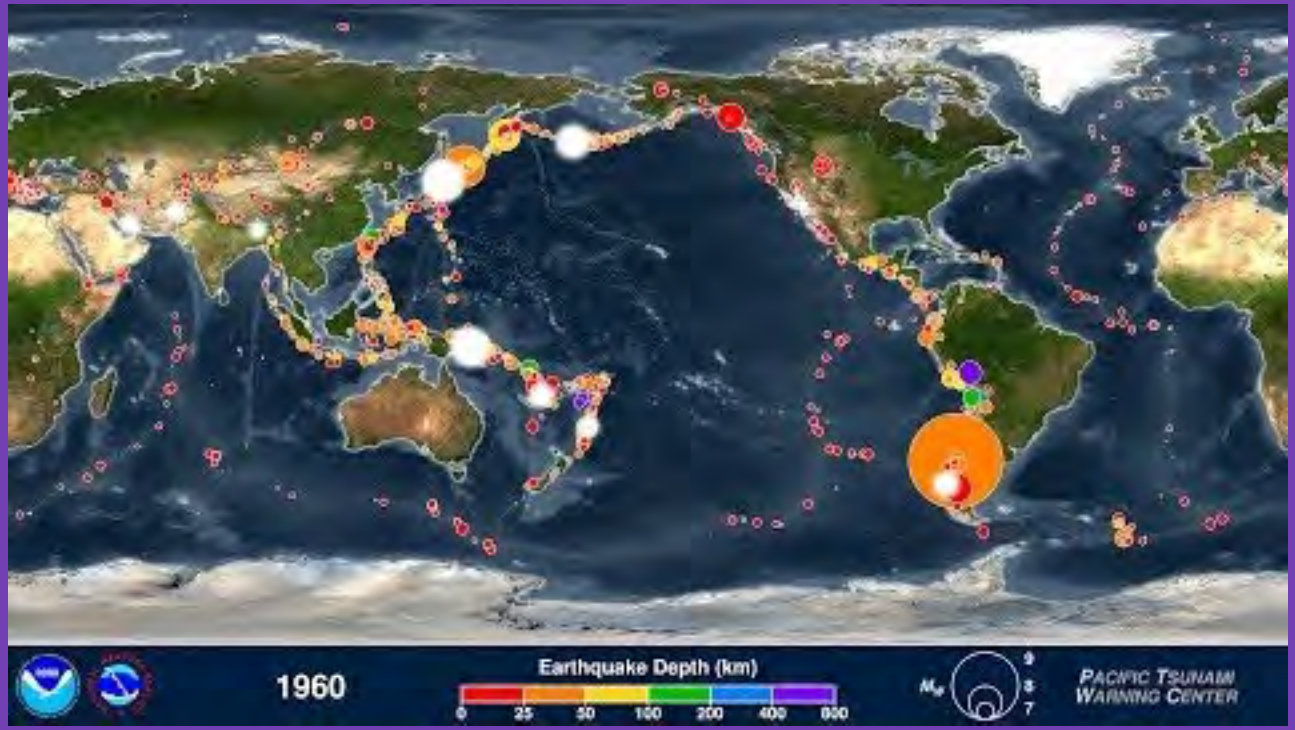
→ **See Keep Sage guide, Introduction.**

Most earthquakes happen at the contact between great tectonic plates. Puerto Rico is located in the limit between the plates of North America and the Caribbean.



Caribbean and North American plates, major faults and plate boundaries. Image credit: Wikipedia.

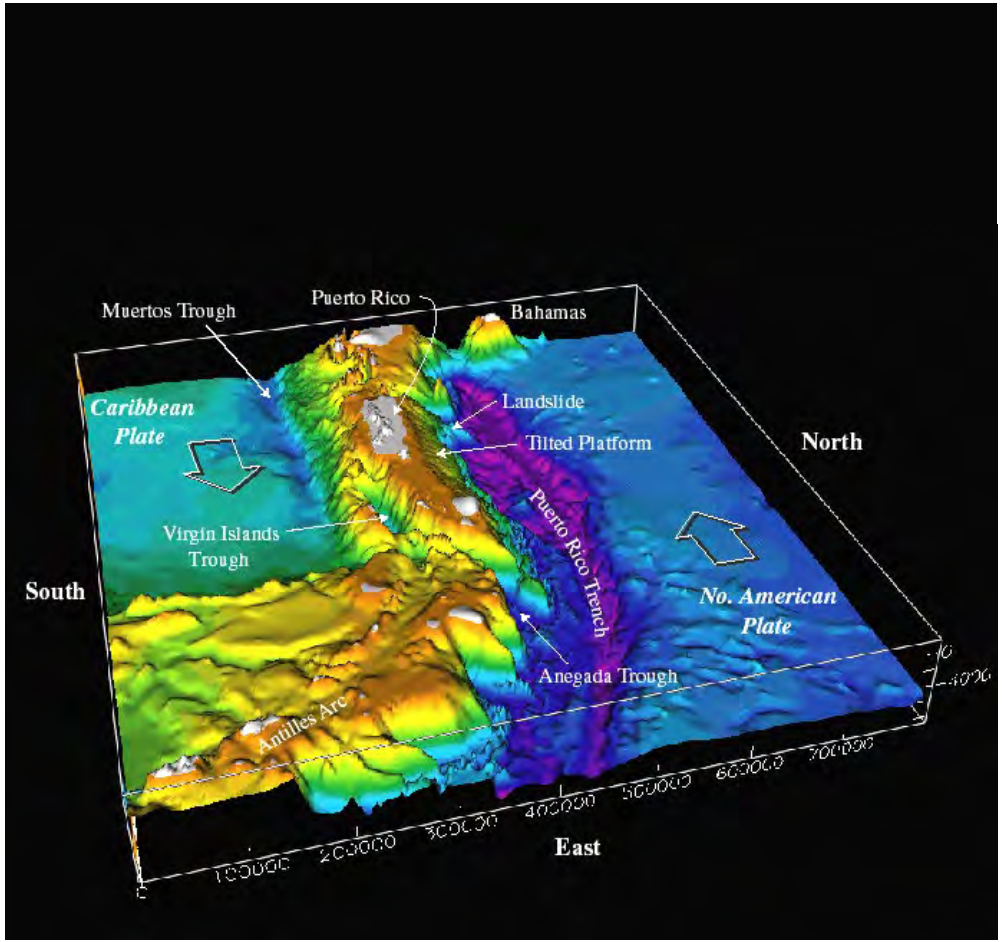
Global Earthquake Animation The 20th Century



NOAA/NWS/Pacific Tsunami Warning Center

Puerto Rico Trench and Falla Montalva - Seismic activity is concentrated in 8 zones

1. Puerto Rico trench
2. Slope faults in the North and South of PR
3. Northeast of 'Zona Sombrero'
4. To the west, at the Mona Canyon
5. Mona Passage
6. To the east, in the depression of Virgin Islands and Anegada
7. Muertos Depression to the South
8. Southeast of PR



Bathymetry of the northeast corner of the Caribbean plate. Image courtesy of the U.S. Geological Survey.

Puerto Rico Trench and Falla Montalva - Seismic activity is concentrated in 8 zones

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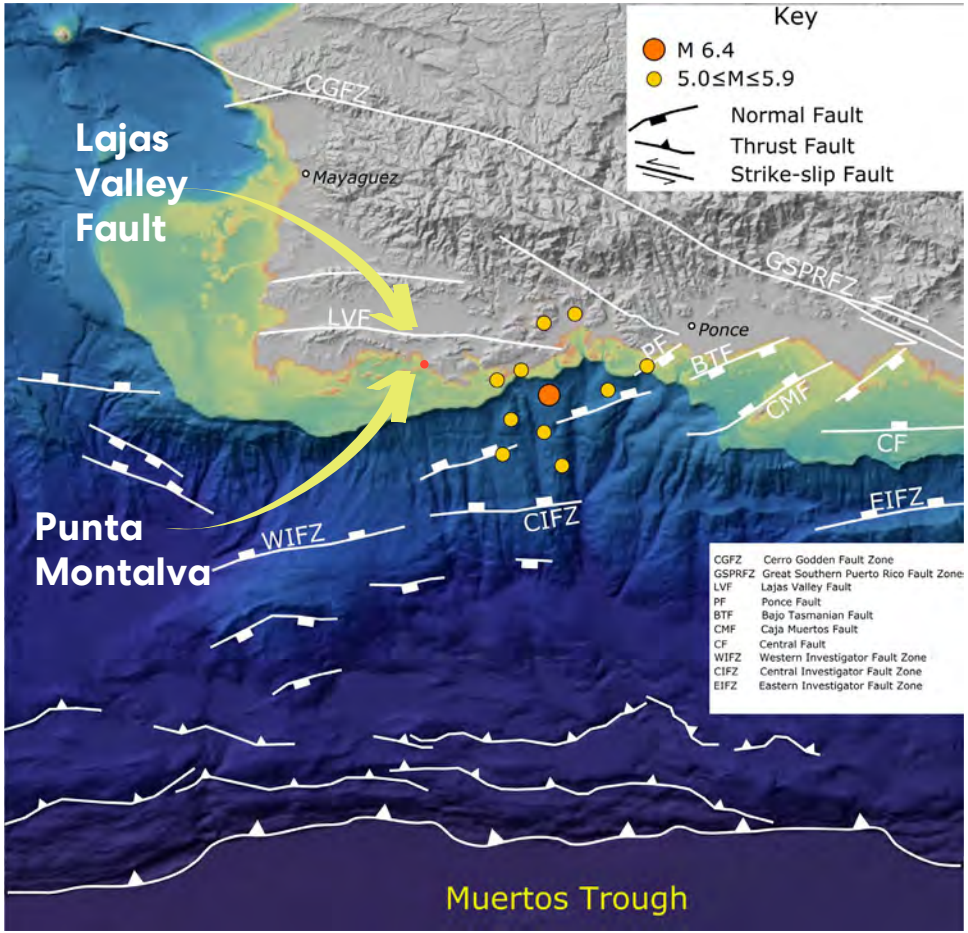

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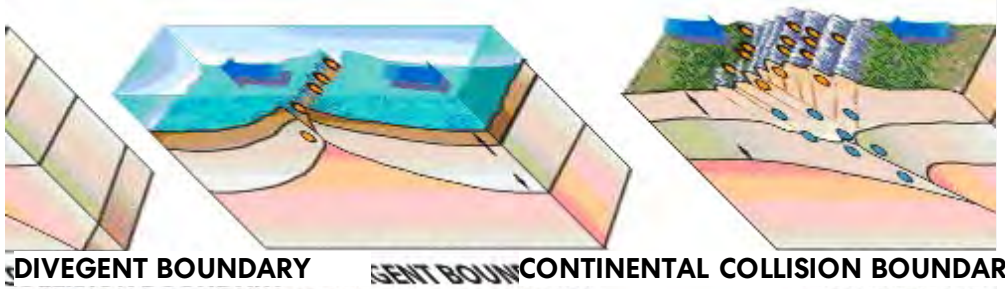
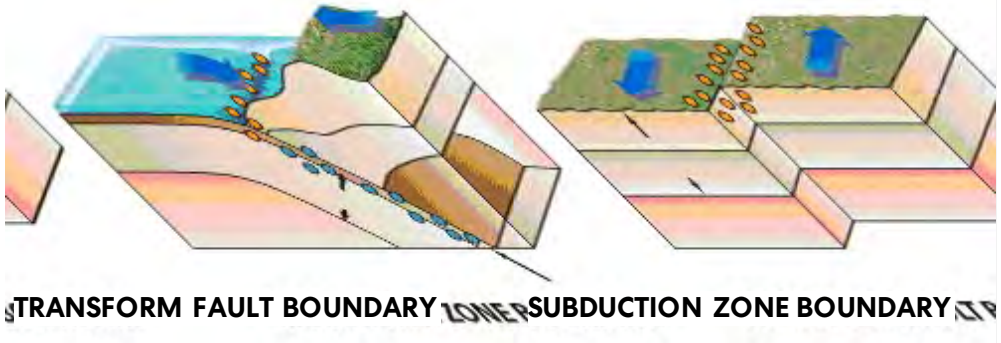
Map showing location of largest earthquakes in the 2019-2020 Puerto-Rico sequence with topography and faults.
Credit: Mikenorton

Types of Earthquake Movement

- Shaking in one horizontal direction
- Shaking in multiple horizontal directions
- Shaking up and down



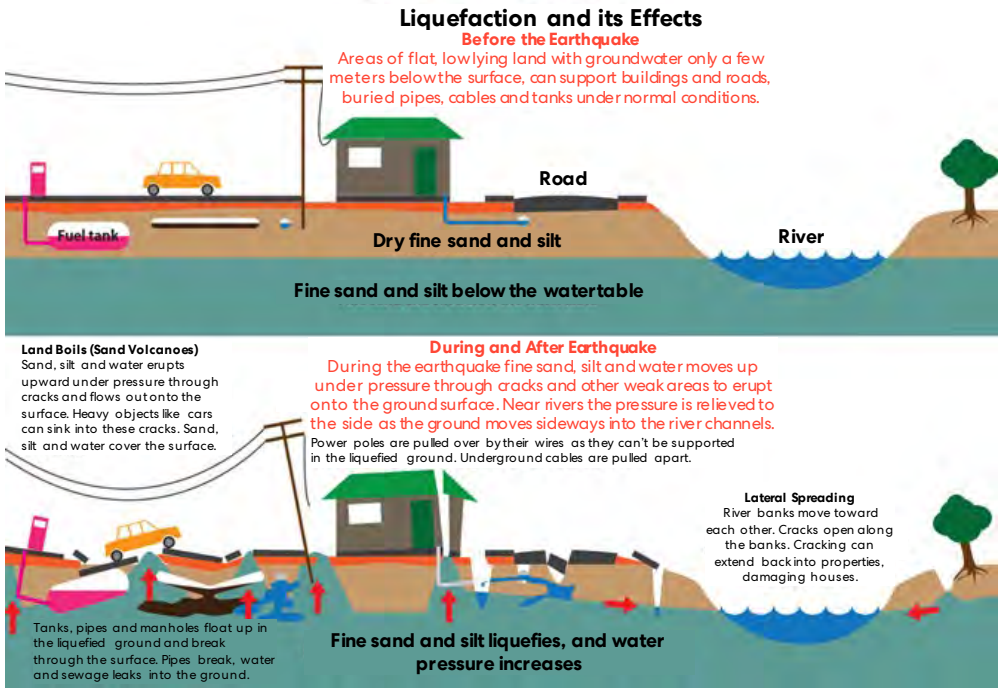
Lajas Valley Fault Moves like this!



Types of Earthquake faults.

Other Effects of Earthquakes

- Liquefaction
- Landslide
- Ground rupture
- Tsunami
- Fire / Gas escape



Liquefaction and its effects. Credit: IPENZ (now Engineering New Zealand) (2011).

Earthquake Effects

- **Liquefaction**
- **Landslide**
- **Ground rupture**
- **Tsunami**
- **Fire / Gas escape**

Landsliding, amplification, and liquefaction are all potential hazards from earthquake ground shaking, particularly in soft wet soils.

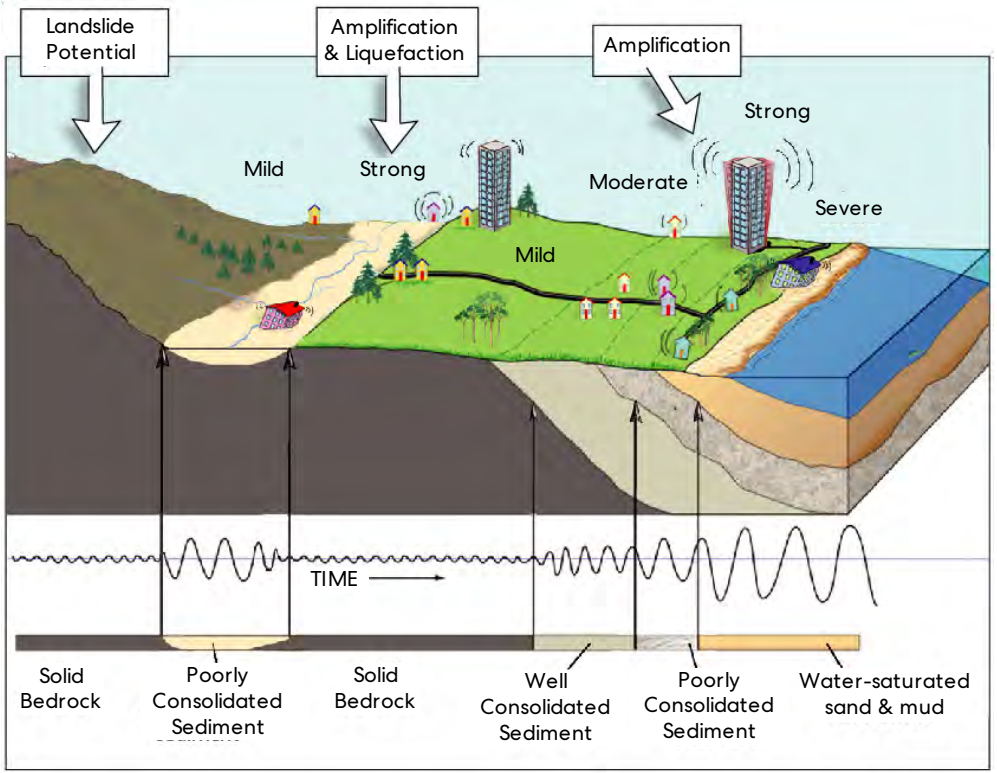
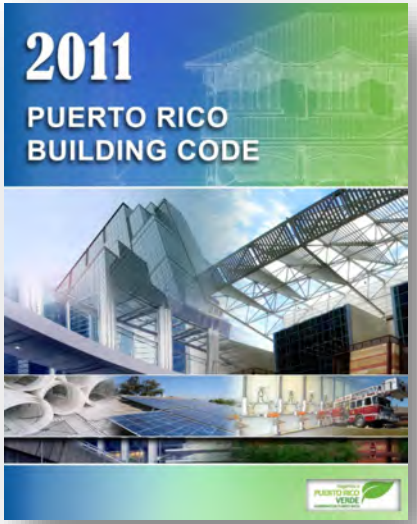


Image credit: SERC

Part 1

Assessment of Home for Reentry: Protecting Life / Protecting Property

Protecting Life



Building codes play an important role in maintaining safety for communities with emphasis in health, safety and welfare of building occupants. Building codes give direction to architects, engineers, contractors, and property owners to build safe buildings.

The priority of a building code is to protect life. In the case of an earthquake, the building might deform but not collapse to give occupants time for evacuation.

Code Compliance

Construction in Puerto Rico must comply with the International Building Code and local building codes for Seismic Design Category D.

D_0 Light Brown	Could experience very strong shaking (the darker the color, the stronger the shaking).	Very strong shaking – Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures.
D_1 Darker Brown		
D_0 Darkest Brown		

Types of Building Failure

Total Collapse

Bad design and construction, loss of life.

Partial Collapse of Framed Buildings

First floor collapse and those in that floor could die.

The fact that a building has reinforcement does not mean that it is secured.

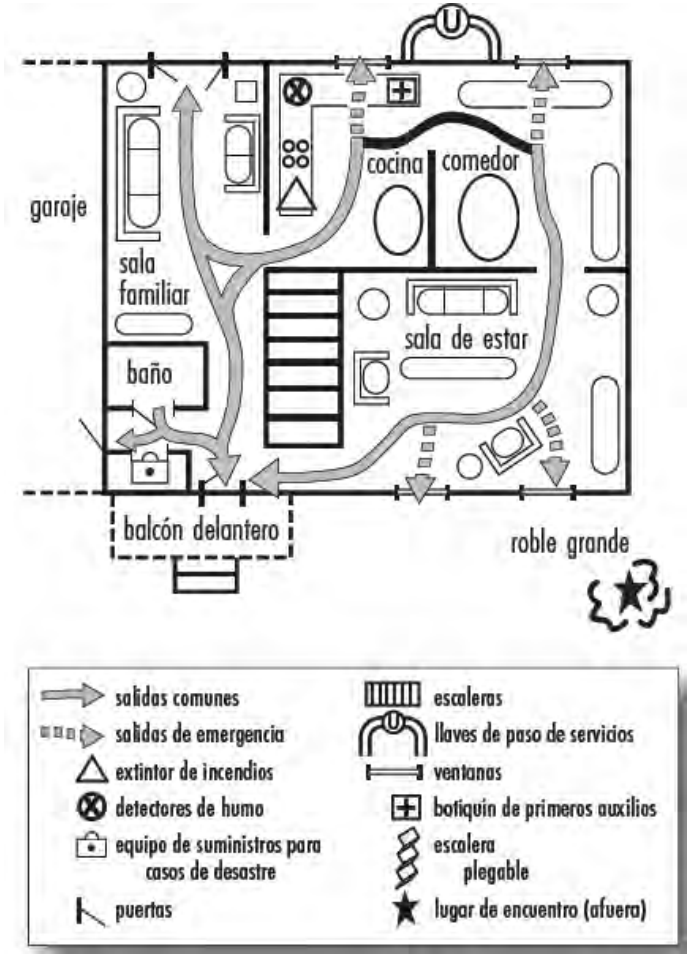
SDC map of Puerto Rico, the United States Virgin Islands and Tortola for low-rise Occupancy Category I and II structures located on sites with average alluvial soil conditions.

Protecting Property

Structures with ductile detailing, redundancy and regularity are favored for seismic force resistance.

We can design and build in a way that minor damages can be repaired without having to demolish the entire structure, saving time, money, and trauma to each family.

Before



http://redsismica.uprm.edu/

Consult a professional structural engineer about the structural safety of your home. Produce a plan of how to retrofit or reinforce any inadequate elements.

Hold family drills, keep a household emergency supply kit.

Anchor tall and heavy furniture or ceiling objects with flexible fasteners to walls.

Do not store heavy objects on high shelves. These objects could fall on people.

Visualize your path of travel out and make sure there are no objects that might fall, obstructing you egress.

If you can easily get out of your home, do it.

If you are in a high rise, you may seek immediate shelter under a table (drop, cover and hold on). After tremors, go to nearest egress stair and evacuate the building.

Emergency Items at Hand and Backpack

Keep at your night table!

Earthquake kit to keep at hand	shoes, flashlight, whistle, glasses, medicine, driver's license	
Emergency Backpack	**Important Personal Items**	money, credit cards, passport
	Miscellaneous	radio, canned food, water, batteries, cellphone, charger
	Clothes	clothes, towels, gloves
	First Aid	first aid kit, gauze, toilet paper, tissues / moist towels

Icons in this chart come from https://thenounproject.com/

Illustration from INDECI

Practice an emergency plan.

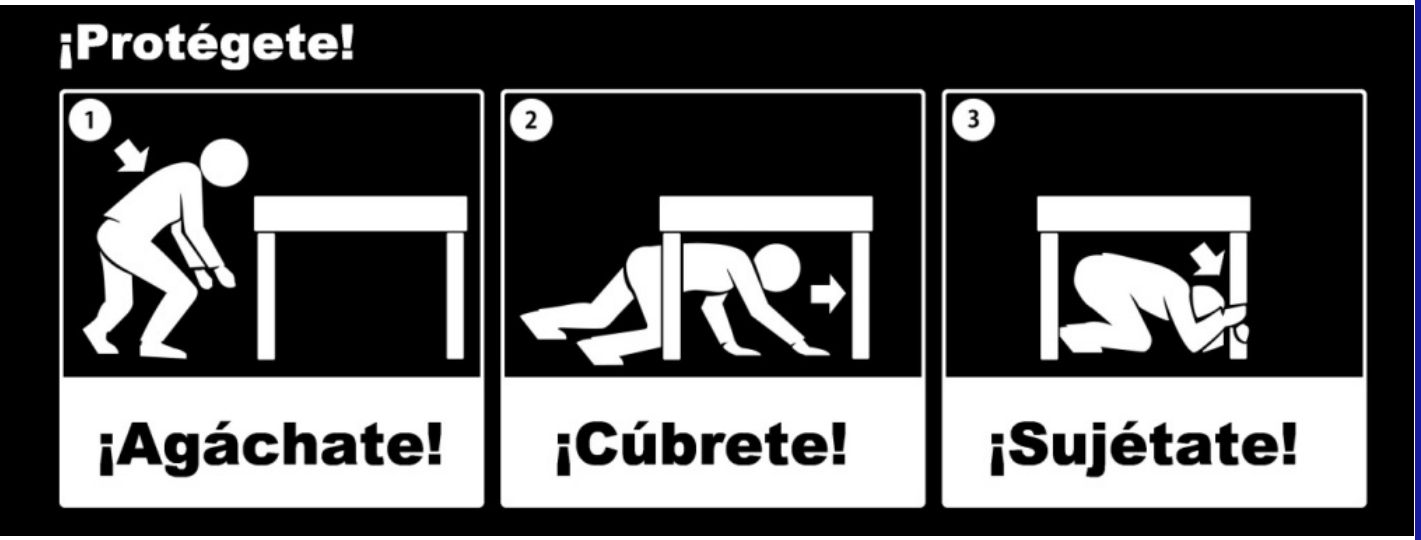
Practice how to protect yourself.

Examine and use your environment.

Prepare and maintain your provisions.

http://redsismica.uprm.edu/

During



http://redsismica.uprm.edu/

If you are in a vehicle, pull over and stop. Set your parking brake.

If you are in bed, turn face down and cover your head and neck with a pillow.

If you are outdoors, stay outdoors away from buildings.

Do not obstruct egress paths or doorways.

Do not run outside.

After

https://www.earthquakecountry.org/step6/

Assess your family, friends and neighbors.

Extinguish any fires or sparks or call 911 if fire is a blaze.

Shut off water and gas supply.

Check your home for damage. Assess if safe to stay or seek shelter elsewhere.

Prepare for a possible aftershock.

Part 2

Who can assess my home?

A trained professional can let you know if your house is strong and safe to be inhabited.

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

CIAPR
Colegio de Ingenieros y Agrimensores

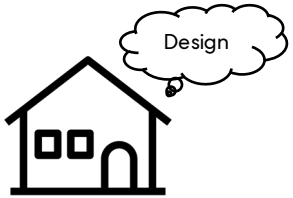
COLEGIO DE
ARQUITECTOS Y
ARQUITECTOS PAISAJISTAS
DE PUERTO RICO

Photo Courtesy of José Sanchez and Eddie Guerra

Responsibility by Discipline

Architect

Plans, designs and oversees multidisciplinary team and construction of a project

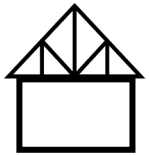


Geotechnical Engineer

Understands soil/rock mechanics, interprets behaviors of earth materials

Structural Engineer

Analyzes, designs, plans and researches structural components and systems



Contractor

Oversees a construction site, and manages vendors and trades that build project

Voluntariado de Ingenieros y Profesionales de Puerto Rico

The Voluntariado engages **volunteer** engineers and professionals to **facilitate prevention, response, mitigation and recovery** of natural disasters that **impact housing in Puerto Rico.** After the January earthquakes, the Voluntariado received over 10,000 requests for inspections (tagging). Today, supported by ConPRmetidos, The Voluntariado evolved to also provide **case management services helping families through the process of inspection, certification and restoration of their home**. The efforts also include lawyers and psycologists to assist families with any additional need.

↑ Voluntariado de Ingenieros Civiles, Info@ingenierospr.org, (786)292-2388

https://www.ingenierospr.org/

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

Colegio de Ingenieros y Agrimensores de Puerto Rico

Educational Guides and Manuals are available for download. There is a list of professionals searchable by discipline and expertise.

Visit: https://www.ciapr.org/guias-y-manuales-de-orientacion/

CIAPR
Colegio de Ingenieros y Agrimensores

→

CIAPR, G-8 y United for Puerto Rico begin construction of Mi Casa Resistente.

Colegio de Arquitectos y Arquitectos Paisajistas de Puerto Rico

CAAPPR hosts educational conferences for professionals and the community. These are posted in the website's calendar. There is a Professional Directory online.

COLEGIO DE ARQUITECTOS Y ARQUITECTOS PAISAJISTAS DE PUERTO RICO

→ https://www.caappr.org/

American Institute of Architects, Puerto Rico

AIA Puerto Rico has deployed trained professionals to tag houses in the southern neighborhoods of the Island. This allows families to understand what homes are safe, need repairs or have major structural damages. Why is this important as a short-term action? It removes the uncertainty that many families face about the safety of their homes.

AIA's Disaster Assistance Program equips architects with the knowledge and skills to mitigate, prepare for, respond to, and recover from a disaster.
https://www.aia.org/resources/69766-disaster-assistance-program

Eugenio Ramírez, AIA Puerto Rico President with a team tagging houses.

https://www.aiapr.com/home

SAP Training

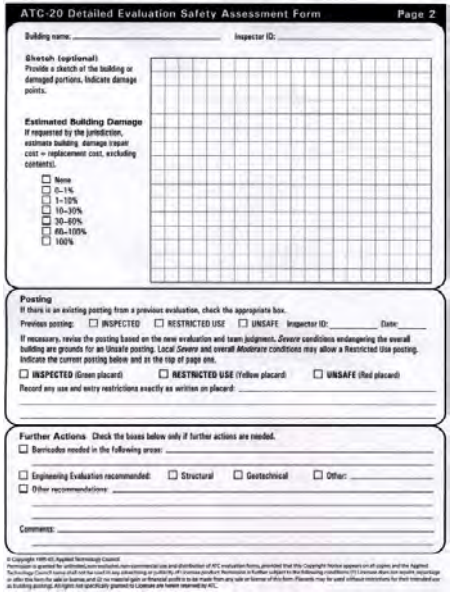
The **Safety Assessment Program** (SAP) utilizes volunteers and mutual aid resources to provide professional engineers, architects, and certified building inspectors to assist local governments in safety evaluation of their built environment in the aftermath of a disaster. The program is managed by Cal OES, in cooperation with professional organizations. Cal OES issues registration ID cards to all SAP Evaluators that have successfully completed the program requirements.


ATC-20 Detailed Evaluation Safety Assessment Form

Inspection

Building Description

Evaluation


ATC-20 Detailed Evaluation Safety Assessment Form Page 2

Posting

Further Actions

SAP trained licensed architects and engineers can assess your home.

Cal OES GOVERNOR'S OFFICE OF EMERGENCY SERVICES

ATC-20 Detailed Evaluation Safety Assessment Form. Identification card example.

SAP Tagging

ATC-20 ***Post-earthquake*** *Safety Evaluation of Buildings (Second Edition)*

ATC-45 *Safety Evaluation of Buildings* ***after Windstorms and Floods***

Cal OES
GOVERNOR'S OFFICE OF EMERGENCY SERVICES

→

Tagging is a way of communicating hazard level after inspection.

PRoTECHOS

Mission

To provide roof reconstruction and related vocational training to residents of underserved communities throughout Puerto Rico.

Visit protechos.org or globalgiving.org to learn more and donate to this effort that changes lives!

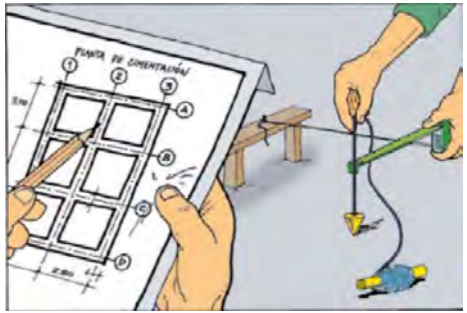
Ramona's roof was destroyed by hurricane Maria, and PRoTECHOS rebuilt it.

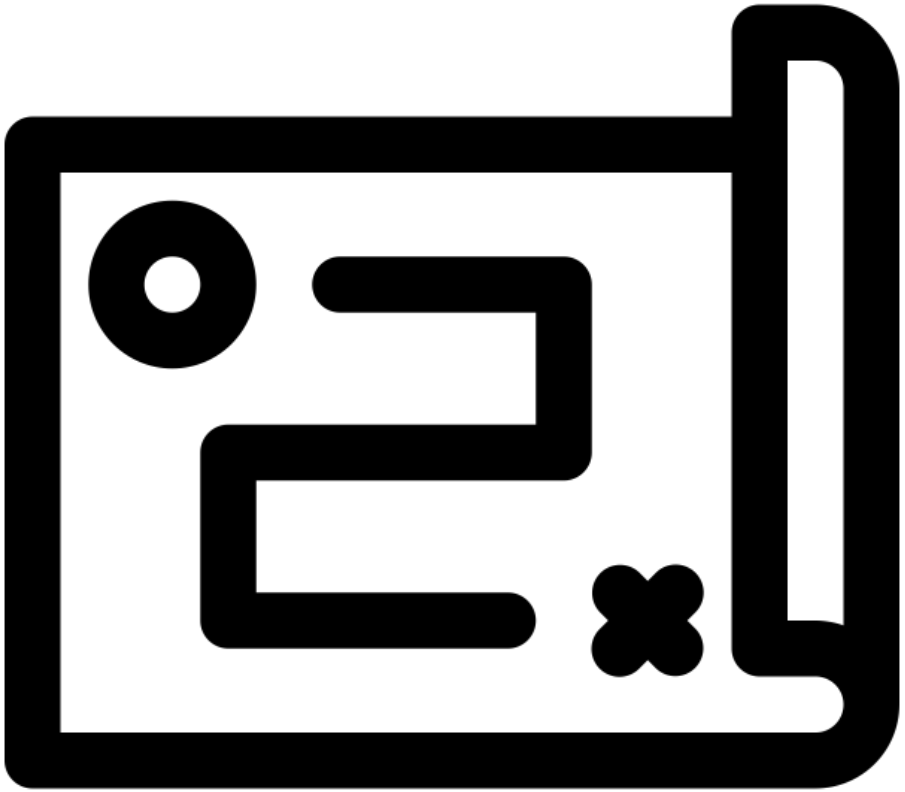
PRoTECHOS

Securing the roof frame to the wall through mechanically fasten anchors.

PRoTECHOS working during the COVID-19 emergency.

Start Roadmap





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Process and documentation are critical to planning.

Left image from *Recomendaciones para la rehabilitación sísmica de viviendas en PR*

Part 3

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

Most common structural failures in Puerto Rico, their causes and methods of repair


VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO
CONPRMETIDOS
IDEAS+ACCIÓN

Our Core Team

17,933 +
HOURS DONATED

The VIP-PR team is made up of a variety of dedicated professionals who provide their own unique perspective to the table - but all with one thing in common: we are willing to give whatever it takes to see Puerto Rican families in safe and healthy homes.

Jesabel Rivera, MPH
co-Founder &
Executive Director

José Sanchez, P.E.
co-Founder
Structural Engineer
Chairman

Eddie Guerra, P.E.
co-Founder
Structural Engineer
Volunteer Team Lead

Lucero Andújar-Iglesias
Case Manager &
Program Specialist

Victoria Mendez
Relationship & Fund
Development Specialist

Yanel De Angel, FAIA
Architect
Volunteer

Jesús Nuñez, P.E.
Structural Engineer
Volunteer

Edgar Marmolejo, P.E.
Structural Engineer
Volunteer

Ruben Velez, P.E.
Structural Engineer
Volunteer

Nannette Jover, P.E.
Structural Engineer
Volunteer

Luiber Lugo
Contractor
Volunteer

Ariel Irizarry, P.E.
Structural Engineer
Volunteer

Danielly Staback
Architect
Volunteer

Identified Vulnerabilities

Limited Access to Structural Experts

Limited access to structural or seismic engineers in the island. The access is even less for low income families.

Spread of Informal Constructions

Lack of access to affordable professional assistance has left homes vulnerable to disasters.

Inadequate Reporting for Federal Agencies

A significant number of federal aid applications were denied because of inconsistent reporting and complex application process.

Recurring Earthquakes

Thousands of aftershocks has led homeowners to feel uncertain of the safety of their home and how to respond.

Lack of Guidance and Information on Safe Home Rebuilds

Homeowners face challenges in accessing educational resources and material to support their home rebuild journey.

Vulnerable Demographic

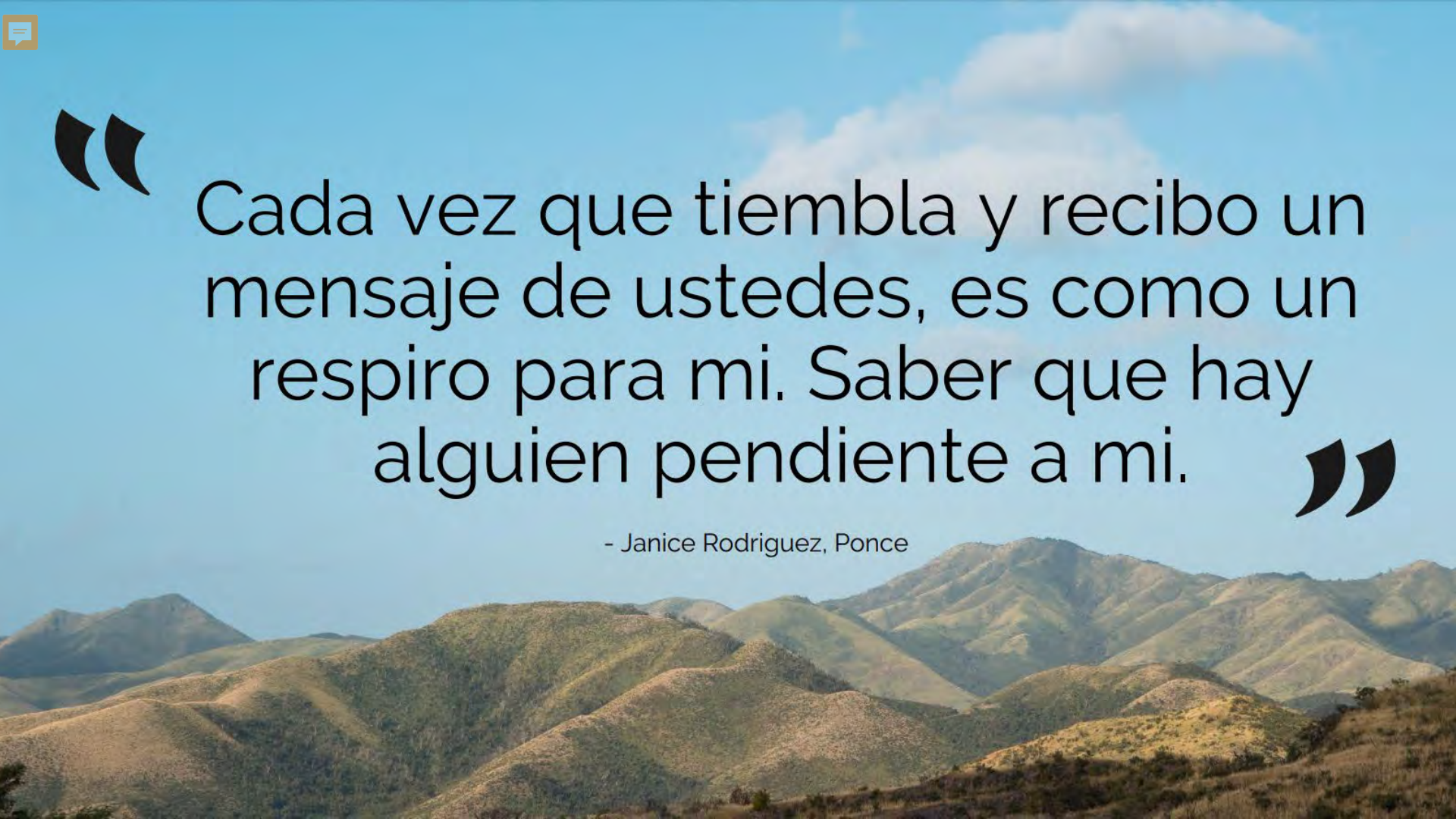
Elderly and special needs demographics are disproportionately affected with system barriers and targeted by scammers.

COVID-19

COVID-19 "Safer at home orders" forces families to stay in homes that may compromise their safety.

Trauma and Its Impact on Health

Recurring disasters and overwhelming recovery process deteriorates social determinants of health.


“Cada vez que tiembla y recibo un mensaje de ustedes, es como un respiro para mi. Saber que hay alguien pendiente a mi.”
- Janice Rodriguez, Ponce

Our Mission

Engaging **volunteer** engineers and professionals to facilitate **preparedness, response, mitigation and recovery** of natural disasters that impacts housing in Puerto Rico

COVID - 19 Impact on Operations

Trauma and Its Impact on Health

COVID-19

The home should be a space of safety for Puerto Ricans...
for thousands that is not the case.

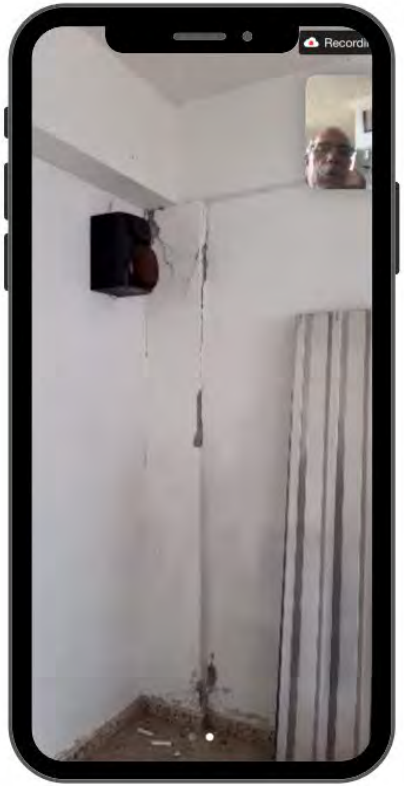
Due to safer at home orders, our dedicated team has been **conducting online home inspections** with the purpose of determining the safety and habitability of these homes.

Why:

- Aftershocks continue to tremble the island and the number of inspection requests increases each day.

- COVID-19 "Safer at home orders" forces families to stay in homes that may compromise their safety.

- Recurring disasters and overwhelming recovery process deteriorates social determinants of health.



Our Strategy

TRANSFORM

Activate our network of construction professionals and partners to reconstruct safer homes, Mentoring colleagues and homeowners on disaster resilient design and enforcement

Lack of Guidance & Information on Safe Home Rebuilds

Limited Access to Resilient Rebuild Experts

Lack of Code and Regulations and Enforcement

CONNECT

Create crucial reports, leverage our network of disaster recovery experts, and partner organizations to address the unique needs of each case

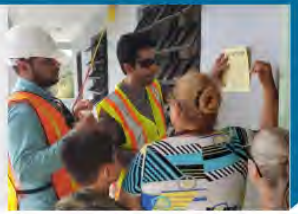
Trauma and Its Impact on Health

Vulnerable Demographic

Recurring Earthquakes

ASSESS

Participant begins our Ruta a Una Casa Segura program. We begin by providing reliable home inspections, one-on-one meetings with experts, detailed structural engineering reports, all while creating a relationship of trust to better assess social determinants of health.



COVID-19

Limited Access to Resilient Rebuild Experts

Inadequate Reporting

Informal housing dangers and limitations

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

RUTA A UNA CASA SEGURA (RUCS) PROGRAM

CASE MANAGEMENT

Disaster recovery professionals manage each participant's case and FEMA application process.

Participants are connected to VIP-PR's team of pro bono lawyers, emotional support, and construction experts throughout the entirety of the RUCS program.

INSPECTION

Trained professionals assess the vulnerability of each home by conducting complimentary virtual ATC-20 home inspections and damage reporting.

Assesment report: Free

DETAILED REPORTING

Structural engineers and construction professionals provide detailed reports that comply with federal and private standards.

Structural Engineering Report (S.E.R): $500*

FEMA provides survivors with $500 for S.E.R*

RECONSTRUCTION

Participants are paired with licensed engineers, contractors, and architects who utilize locally-appropriate sustainable building materials and disaster resilient designs.

CONPRMETIDOS
IDEAS+ACCIÓN

Impact by the numbers

15,793

FAMILIES HAVE REQUESTED ASSISTANCE

AS OF AUGUST 26, 2020

3,288

HOMES INSPECTED

1,972
INSPECTED

1,150
RESTRICTED USE

166
UNSAFE

APPROVED

AS OF AUGUST 26, 2020

95%

CASES APPROVED

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

"If you have a chance to accomplish something that will make things better for people coming behind you, and you don't do that, you are wasting your time on this earth."

ROBERTO CLEMENTE

VOLUNTARIADO
DE INGENIEROS Y PROFESIONALES DE PUERTO RICO

JOIN OUR TEAM

Become part of an innovative team of professionals who are making an impact in the community. Join us today!

SCAN ME

Benefits

- **Make an impact to those who need it the most**
- Continued education
- Weekly technical forums
- Training relevant to disaster response and recovery
- Peer-to-peer mentoring

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@ingenieros_pr

www.IngenierosPR.org

Info@IngenierosPR.org

Recent Experience of Inspections in Puerto Rico*

* Based on the experience of more than 500 inspections made by the Volunteer group

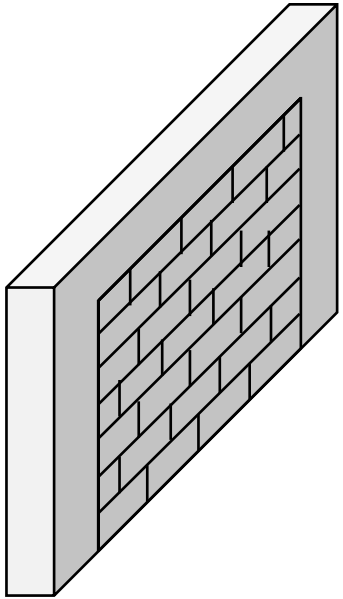
In general, residences inspected in Puerto Rico present one of the following three (3) designs:

1-story house made of concrete blocks / porches

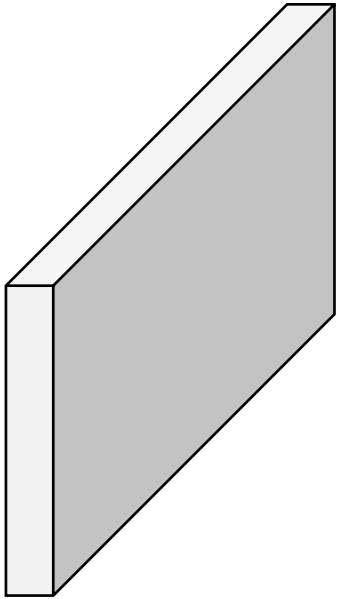
2-story house made of blocks and concrete

House made of wood with concrete foundation

Two systems that resist typical lateral load in residences in Puerto Rico



Block wall not reinforced in concrete frame



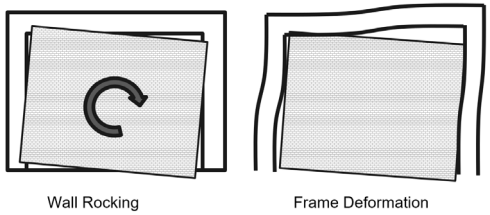
Reinforced concrete wall

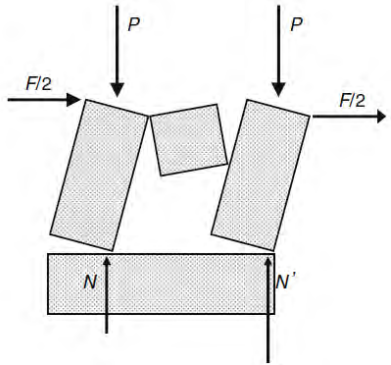
Typical Failures Observed in Residences in Puerto Rico, Causes and How to Repair

Failure #1
Wall-Frame Interface Separation

A. What do I see?

B. Why does it happen?



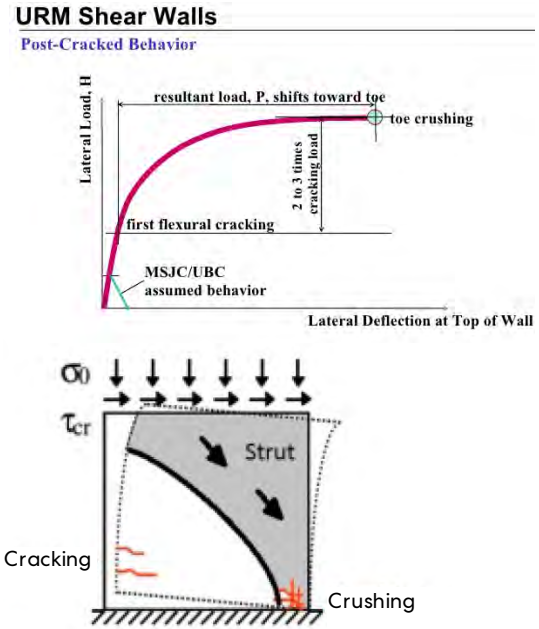


C. Typical repair methods

Failure #2
Wall in Compression Failure

A. What do I see?

B. Why does it happen?

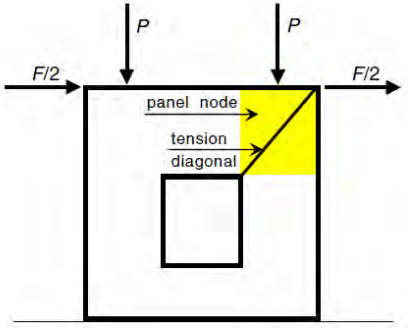


C. Typical repair methods

Failure #3
Diagonal Cracks in Corners

A. What do I see?

B. Why does it happen?



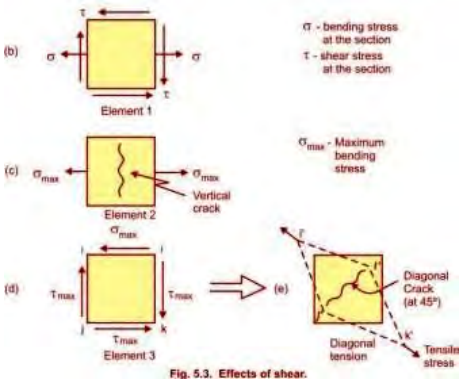
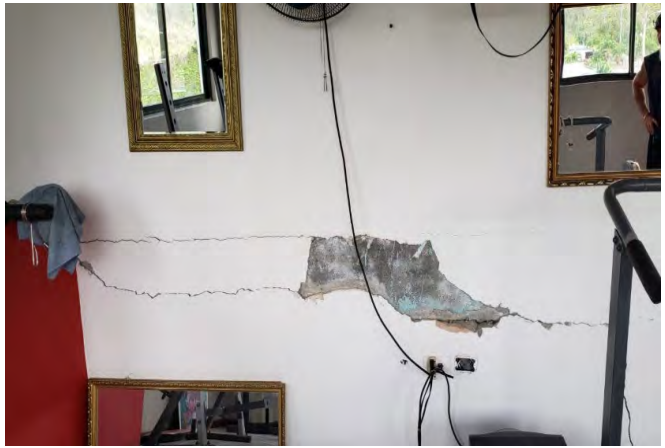


Fig. 5.3. Effects of shear.

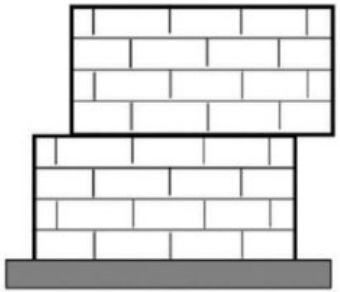
C. Typical repair methods

Failure #4
Horizontal Cracks along the Wall

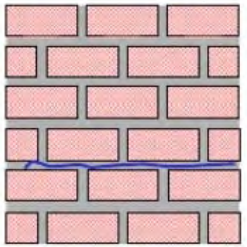
A. What do I see?



B. Why does it happen?



Low vertical compressive stress



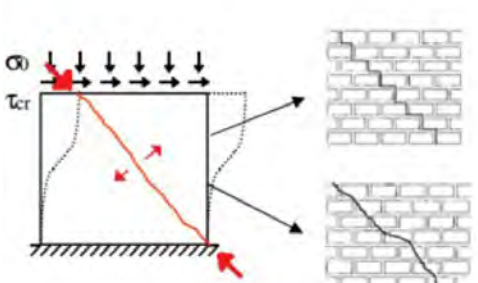
Sliding along bed joints

C. Typical repair methods

Failure #5
Diagonals Cracks in the Middle of the Wall

A. What do I see?

B. Why does it happen?



Stair wise crack, poor mortar joints

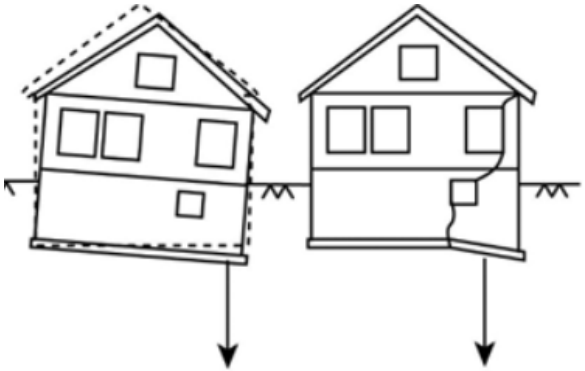
Diagonal crack, good mortar joints

C. Typical repair methods

Failure #6
Floor Failures

A. What do I see?

B. Why does it happen?

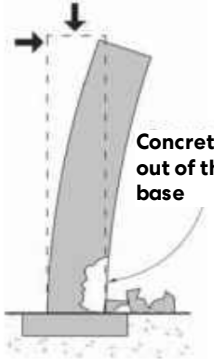


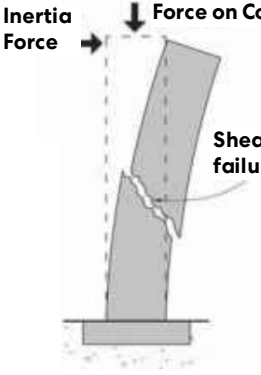
C. Typical repair methods

Failure #7
Column Failures

A. What do I see?

B. Why does it happen?



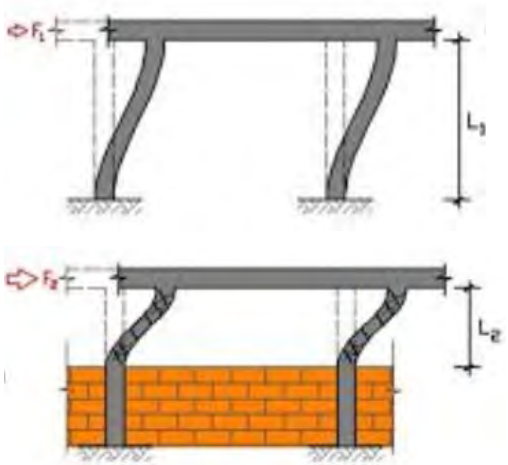


C. Typical repair methods

Failure #8
Short Column Failure

A. What do I see?

B. Why does it happen?



C. Typical repair methods

Part 4

Understanding Techniques for Homes to Withstand Seismic Events

Safe Construction

The following considerations are essential to seismic safety, and they require professional assessment:

1. **Site selection evaluation**: soil quality, flood plain, slope and soil stability, natural features
2. **Structural continuity**: crucial to decrease the risk of common failures
3. **Load path redundancy and continuity**: from roof to joists, to beams, to walls, to floors, to foundations, to soil

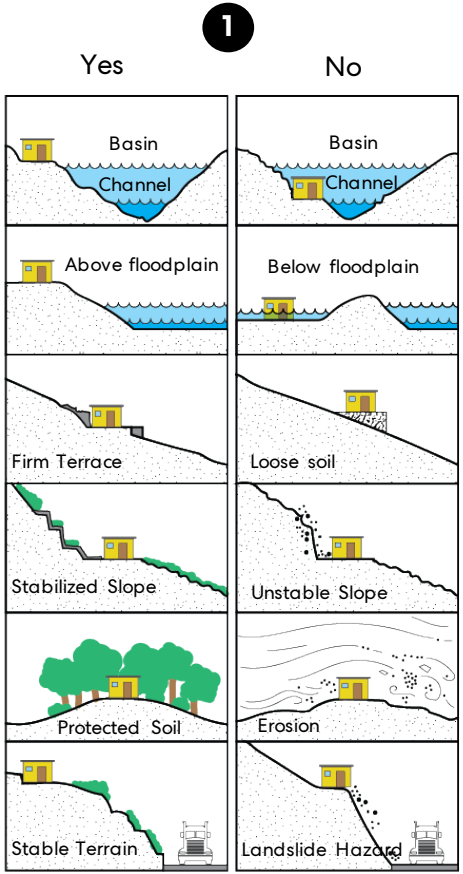
Resources

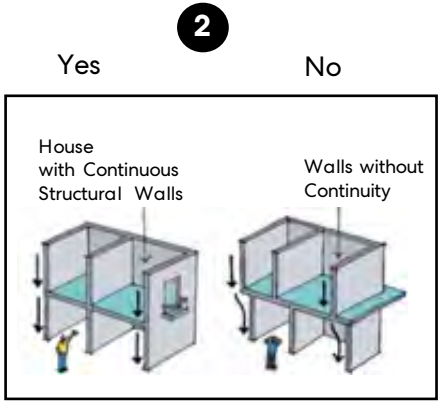
Recomendaciones para la Rehabilitación Sísmica de Viviendas en Puerto Rico
https://www.yumpu.com/es/document/read/63060487/18vivienda-small

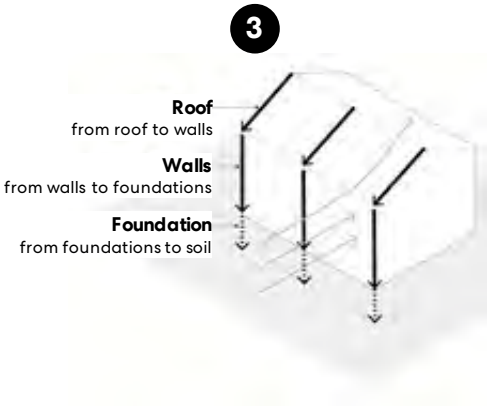
Keep Safe: Resilient Housing Design for Island Communities
https://www.enterprisecommunity.org/solutions-and-innovation/disaster-recovery-and-rebuilding/mantengaseseguro

→

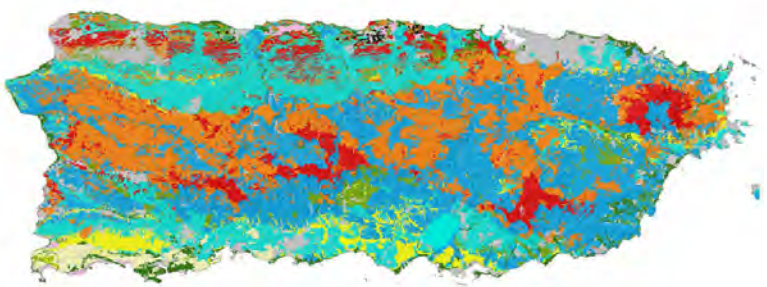
Safe site location and structural redundancy and load path continuity.





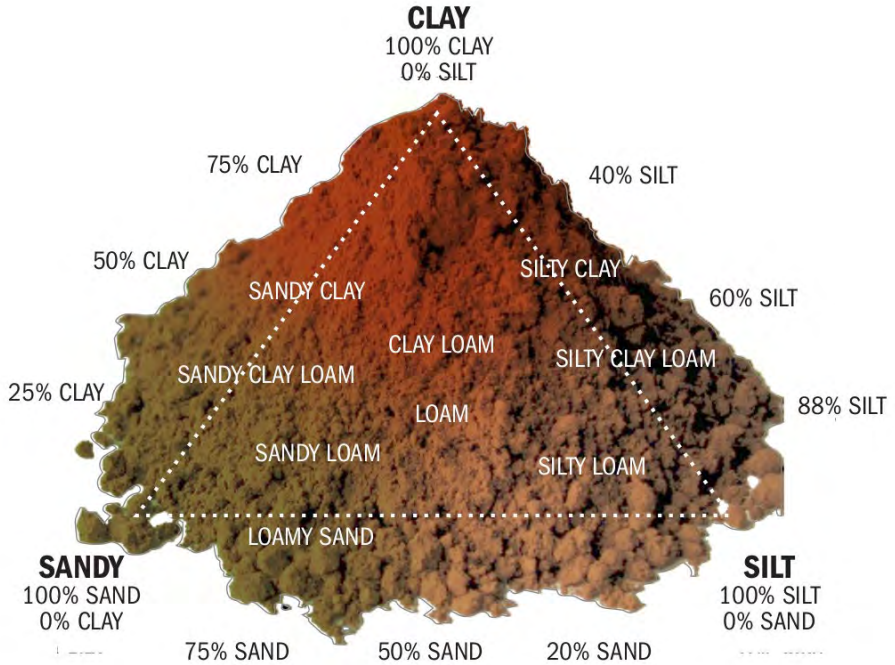


Soil Types Properties



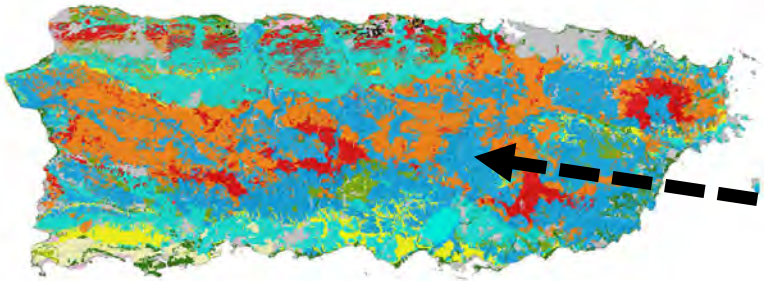
LEGEND

- **Alfisols**: semi-arid to humid areas
- **Aridisols**: arid or semi-arid climate
- **Entisols**: unconsolidated sediment or rock
- **Histosol**: organic materials
- **Inceptisols**: more developed unconsolidated sediment or rock
- **Miscellaneous**: Areas of human altered soil and non-soil areas
- **Mollisol**: semi-arid to semi-humid areas, typically under a grassland cover.
- **Oxisols**: tropical rain forest
- **Spodosols**: typical soils of coniferous or boreal forests
- **Ultisols**: product of continuous weathering of minerals in a humid, temperate climate
- **Vertisol**: high content of expansive clay minerals



→ See Keep Safe guide, chapter 1.

Soil Types Properties



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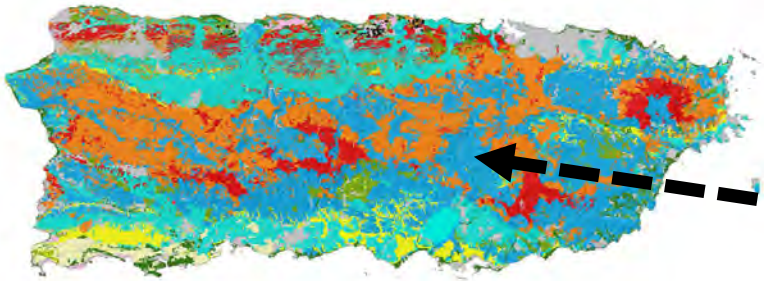

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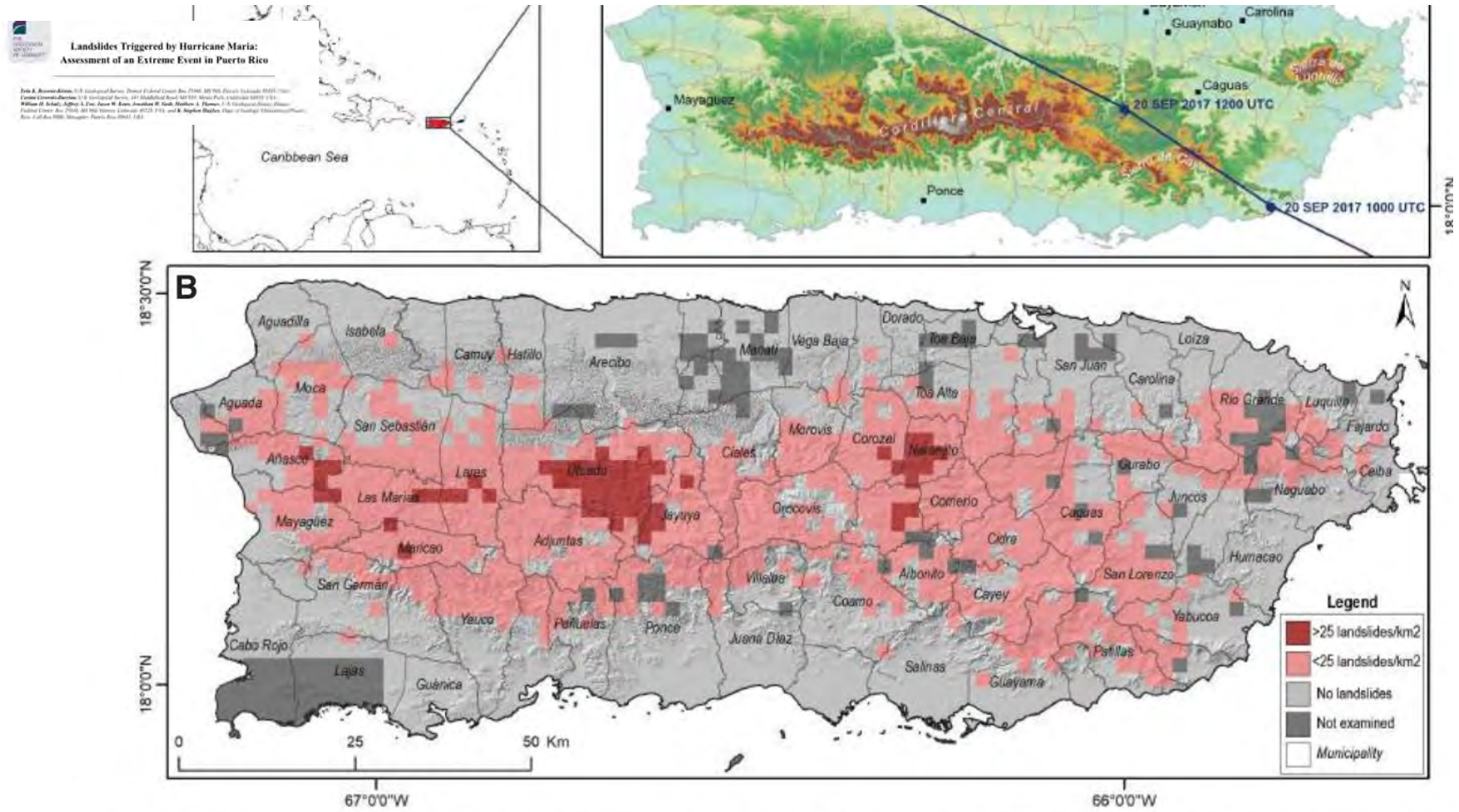
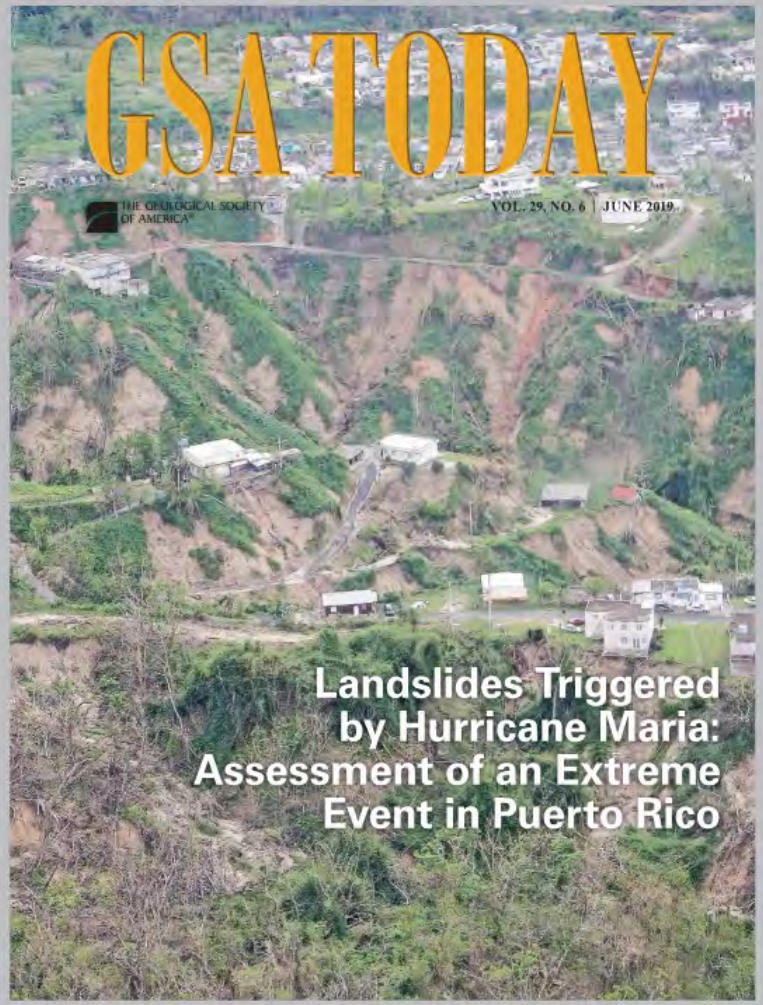
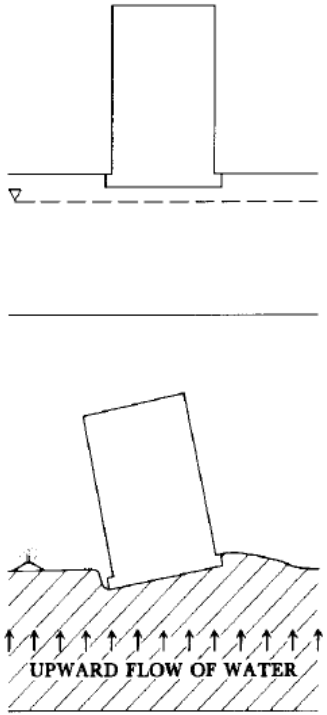


Figure 1. (A) Topographic map of Puerto Rico showing the storm track of Hurricane Maria. (B) Relative density of landslides mapped the rapid classification of satellite and aerial imagery and site visits following Hurricane Maria (updated from Bessette-Kirton et al., 2

22–25 Sept. GSA 2019 Annual Meeting & Exposition



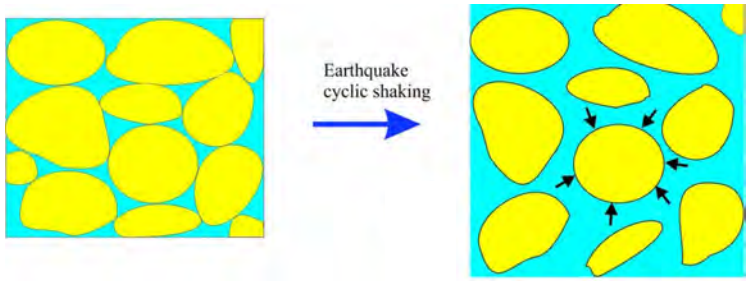
Liquefaction Potential



Activated Ground Water Illustration

Earthquake Engineering research Institute, Earthquake Basics Brief No. 1 – Liquefaction

Liquefaction Potential



Ball Pit Analogy

Liquefaction Potential

Dry Sand

In Still Water

Agitated Water – Waves Breaking

Liquefaction Potential

Loss of Soil Bearing

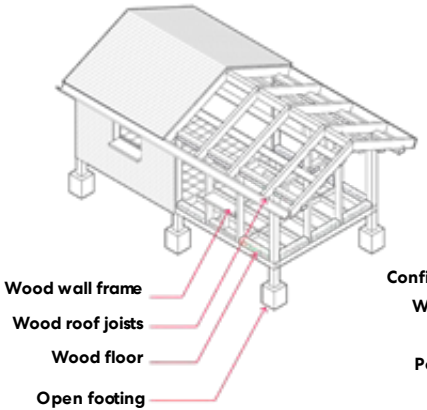
- **At Epicenter**
- **1999 Izmit EQ, Turkey**
- **Mag. 7.4**
- ***Earthquake Engineering research Institute, Earthquake Basics Brief No. 1 – Liquefaction***

→

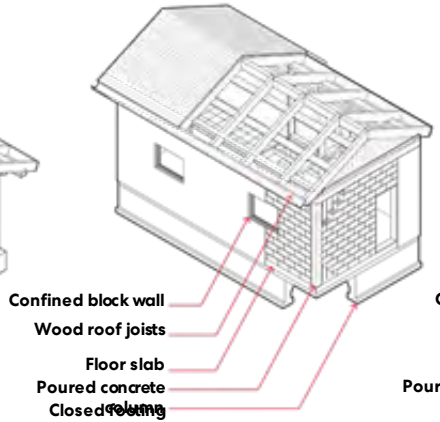
Collapse due to liquefaction.

Construction Types

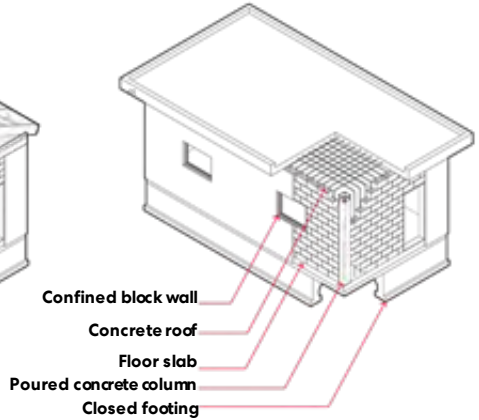
Wood



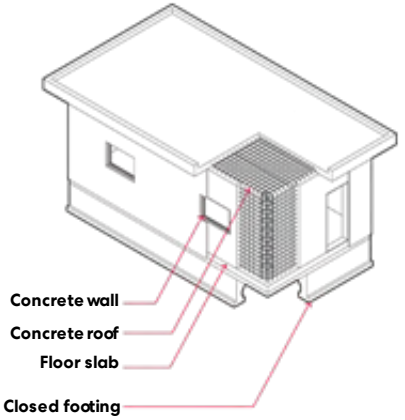
Concrete Block + Wood



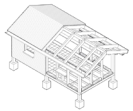
Concrete Block + Concrete



Concrete



Construction Types Pro's

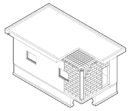


Wood

- **Inherently flexible**: strong but elastic
- **Ductile connections**: ability to yield and displace without fracturing (mechanical connections are critical)
- **Lightweight**: reduces inertial seismic forces which are proportionate to weight, is more ductile and less dangerous in the event of an earthquake
- **Can be very strong and stiff**: depending on the thickness of mass timber, panels, number fasteners, and bracing of shear walls to resist lateral distortion
- **Less costly** and requires less specialized labor
- **Naturally sequesters carbon** and can be outsourced from sustainably run forests

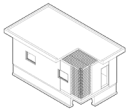
Concrete Block + Wood

- **A lightweight wooden roof on a concrete block wall** is appropriate, specially if the foundations and walls were not designed for a heavier roof
- **Concrete block can be reinforced** to offer more strength and rigidity
- **Concrete block walls can withstand winds due to their weight,** but only if properly built.
- **Concrete blocks are inherently fire resistant**
- **A wood roof can be adequately tied to concrete blocks**



Concrete Block + Concrete

- **Concrete reinforced roof must be adequately tied to concrete block walls** to keep elements from slipping away from each other
- Reinforced concrete blocks and concrete roofs can withstand winds due to the **added weight,** but only if properly built. Else, they may crumble in an earthquake.
- It performs specially well during hurricanes due to its weight and ability to **shield from projectiles**
- **The reinforced concrete mix could be designed to contain recycled content**



Concrete

- **An all reinforced concrete building, allows more design flexibility**
- **It can be very durable and withstand major hazards** such as hurricanes and earthquakes
- It performs especially well during hurricanes due to its weight and ability to **shield from projectiles**
- **Allows for multi-story construction**
- **Great option for strong foundations**
- Concrete is **inherently fire resistant, does not decay** like wood and provides **better sound control** compared to simple wood construction

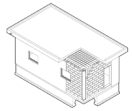
Construction Types Con's

Wood

- Can be **especially susceptible** to **hurricanes** if not built correctly
- **Requires many mechanical fasteners and anchors** to be code-compliant and secured
- **Foundation may be wooden piles on concrete footings**, but wooden piles are susceptible to decay
- In traditional construction in Puerto Rico, the envelope is more prone to air and water infiltration.
- In humid tropical climates, wood is prone to **rot** and to wood boring insects. **Pressure treating and painting wood** for both may be costly.

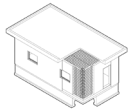
Concrete Block + Wood

- If concrete block walls are not designed correctly, they **will not hold a concrete roof.** Wood should be considered instead.
- Not aesthetically pleasing if left **un-plastered**, matter of opinion
- Foundation must be **concrete**
- **Wind driven** rain can be a problem if joints are not sealed and maintained.
- **Reinforcement** that is **not properly** protected by mortar or grout cover is susceptible to corrosion.



Concrete Block + Concrete

- **Concrete reinforced roof must be adequately tied to concrete block walls** to keep elements from slipping away from each other
- When built **incorrectly**, a concrete house can be **especially susceptible to collapse** in the event of an earthquake
- **In coastal areas,** protecting reinforcement from corrosion over time may require **galvanizing**, using **thicker walls** than is structurally required, which adds cost.
- Improperly **detailed reinforcement** is vulnerable to **corrosion**, which can crack the concrete, letting in more water and chlorides, weakening it even more.



Concrete

- **Requires more skilled labor and attention to detail** (rebar connection mistakes might be hidden)
- **Requires water** in the mixing and curing process
- Concrete placement must be **monolithic** and well **coordinated**
- When built incorrectly, a concrete house can be especially susceptible to collapse in the event of an earthquake
- **Illegal mining of sand for concrete mix causes environmental damage** (erosion in Puerto Rican beaches can lead to a vulnerable coastline). This illegally mined sand may also be high in **chloride content**, which accelerates the corrosion of the concrete reinforcement.

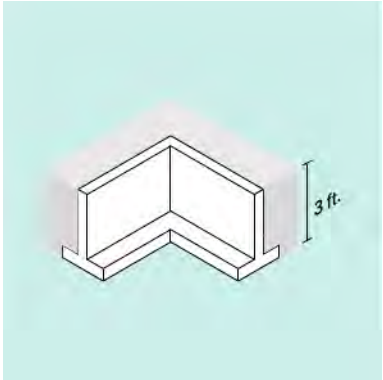
Concrete Construction

Foundations must take the “load” of the wall system, roof, and anticipated interior elements.

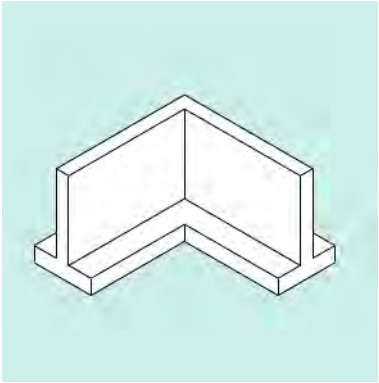
Important Considerations

- ✓ **Design wind speed**
- ✓ **Seismic design category**
- ✓ **Flood zone**
- ✓ **Soil type**
- ✓ **Water table**
- ✓ **Budget**

→ **Variety of foundations, see Keep Safe guide, chapter 2, strategy 5.**

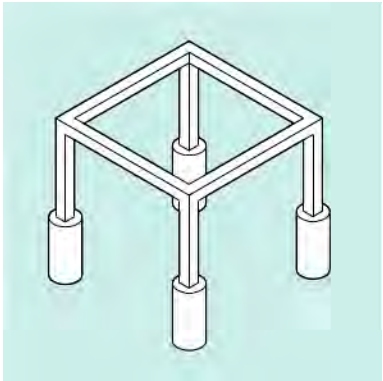


Closed - Shallow

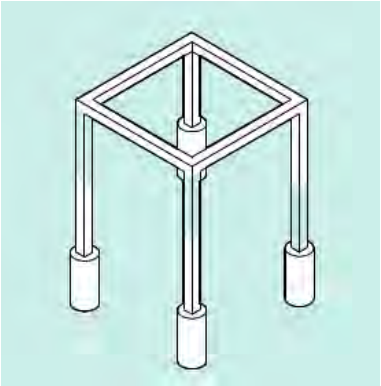


Closed - Deep

Open - Shallow



Open - Deep



Why do foundations fail?

Weak structural connections to wall or floors

Improper concrete mixture, inadequate and/or exposed rebar in concrete foundations

Corrosion of rebar that then expands to crack and shed the concrete cover; exposes more of the concrete to water ingress, which further worsens the corrosion, in a cycle that eventually severely weakens the structure.

Decay and incorrect footing connections in timber foundations

Soils that is not appropriately prepared or compacted, and improper sizing of footings for structural support

→ Foundation failure, house in Yabucoa.

Adequate Concrete Mix

The following are rules of thumb for concrete mix proportions. A properly designed house will have the mixes specified by a professional. Commercially supplied Ready Mix will have more consistency and quality.

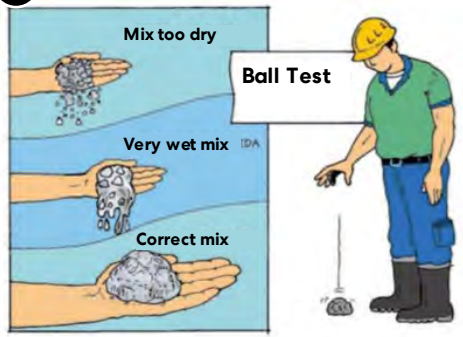
1. Achieving a **proper concrete mix** is critical and must be carefully done. The **proportions of cement, sand, and crushed stone vary for each element** (footings, columns, beams, floors, and lintels).
2. For consistency**, ingredients should be measured using the same container**. **Clean** water should be added carefully, as to **not over-water the mix**.
3. Once the concrete is poured, it must be **vibrated to eliminate air bubbles or voids between the reinforcement**, which may weaken the stiffness and continuity of any of the elements.
4. **Concrete needs time to cure and set**. The curing time can be generally of one week. During this time, it must be protected from wind and sun, and it must be kept as moist as possible, specially during the first three days.

1

Concrete dosage by volume

Elements	Cement	Clean Sand	Piedra
Foundations	1 part	2 parts	2 1/2 parts
Columns and Beams	1 part	2 parts	2 parts
Floors	1 part	2 parts	3 parts
Lintels	1 part	2 parts	3 parts

2



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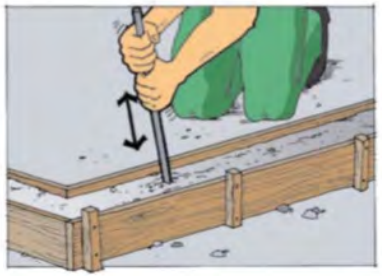

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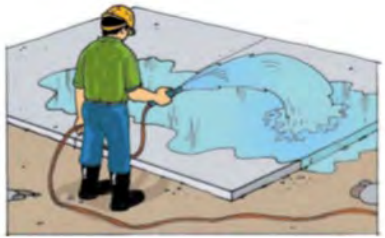

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From ***Recomendaciones para la rehabilitación sísmica de viviendas en PR***

Open Footing:
Wood Post on Concrete

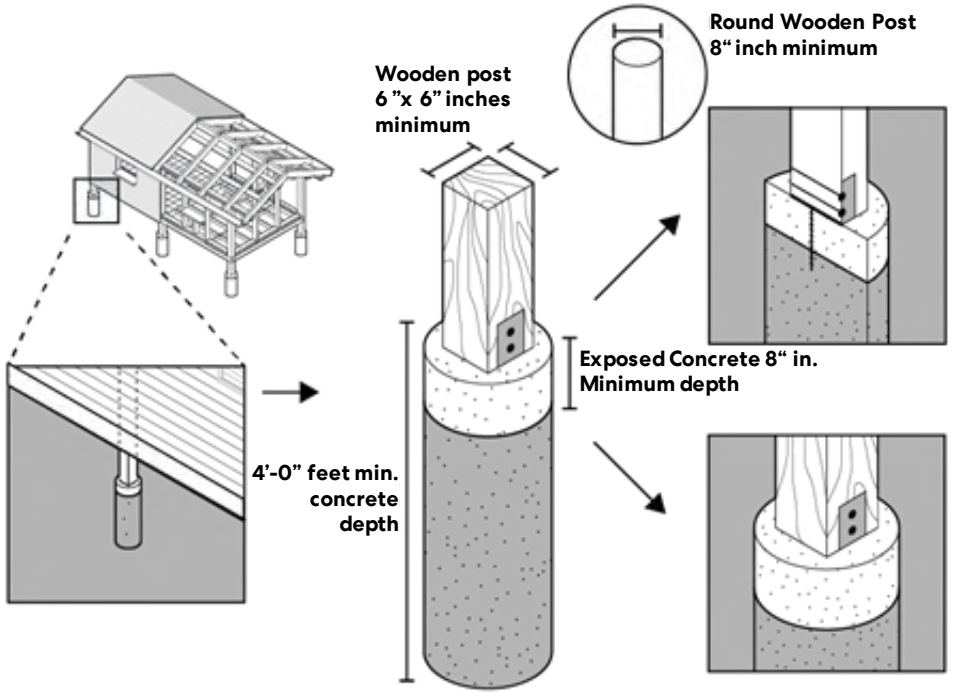
This type of footing supports light, single story wooden houses only

Avoid rot and leaks by raising wooden posts on concrete footings and floors, separating them from water

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. **Improper design** and detailing will make this difficult to do periodically.



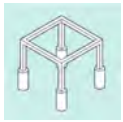
→
See Keep Safe guide, chapter 2, strategy 5.

Open Footing: Concrete

The following images are only for reference. Vertical reinforcement and foundations must be designed by a professional.

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.

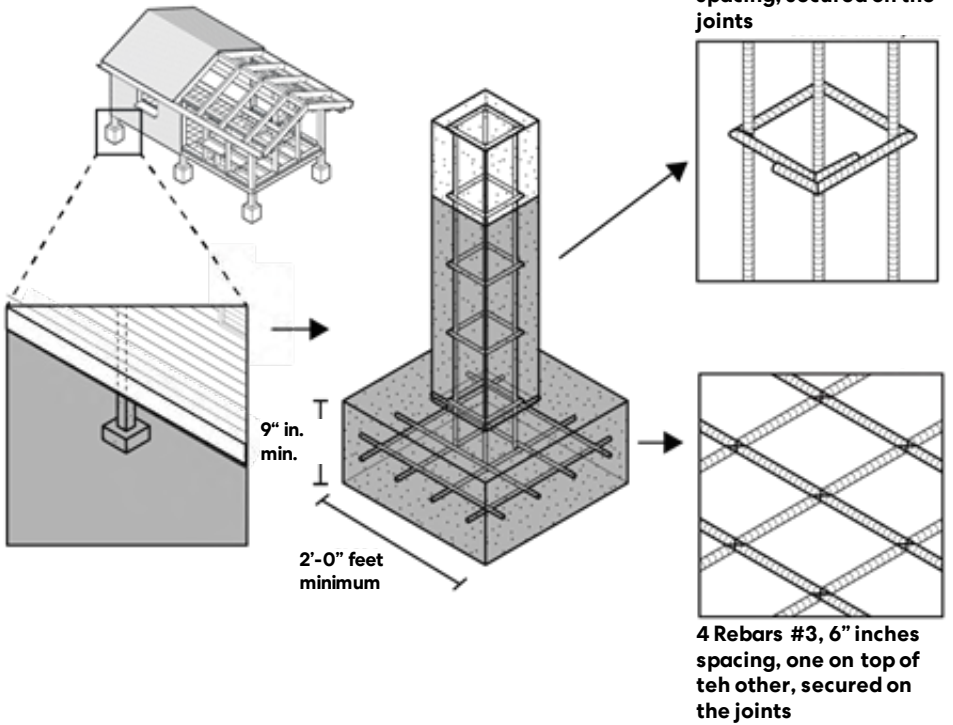


Open, sloping site

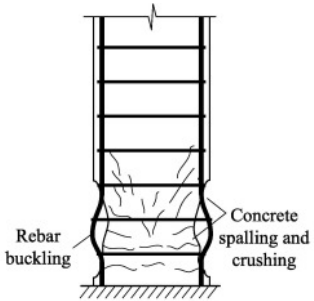
- Allows water to pass through, minimizing the chance of water collecting in unwanted areas.
- Reduces the lateral flood loads the foundation must resist.
- Less prone to damage from flood debris, because debris is less likely to get trapped.

→

See Keep Safe guide, chapter 2, strategy 5.

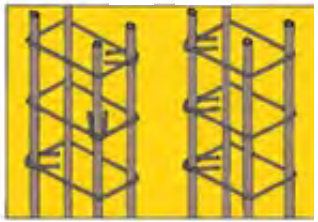


Open Footing: Concrete



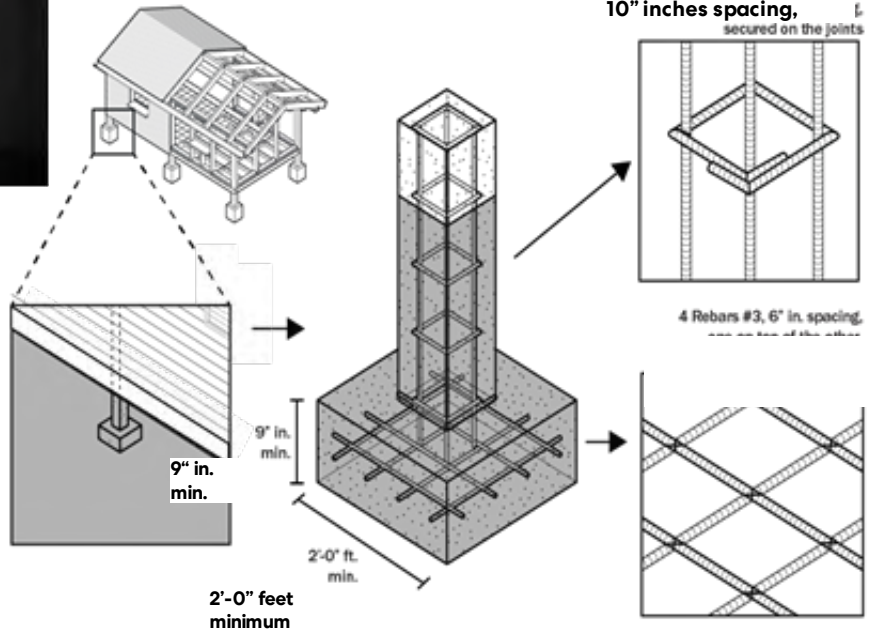
The following images are only for reference. Vertical reinforcement and foundations must be designed by a professional.

Columns must have adequate ties and anchors to the slab, roof, and walls to tran



Well bent stirrups

Poorly bent stirrups



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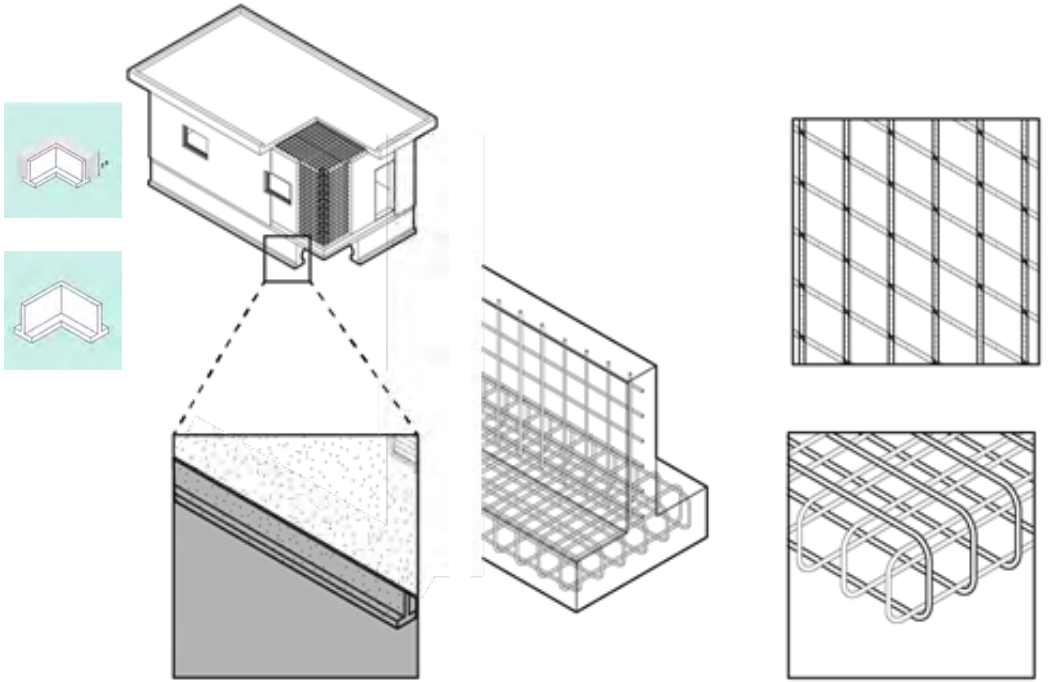
See Keep Safe guide, chapter 2, strategy 5.

Close Footing: Concrete

Shallow or Deep

Deep:

- Used when the structural loads are higher, 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 transfer the load to deeper soil layers or down to bedrock.



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See Keep Safe guide, chapter 2, strategy 5.

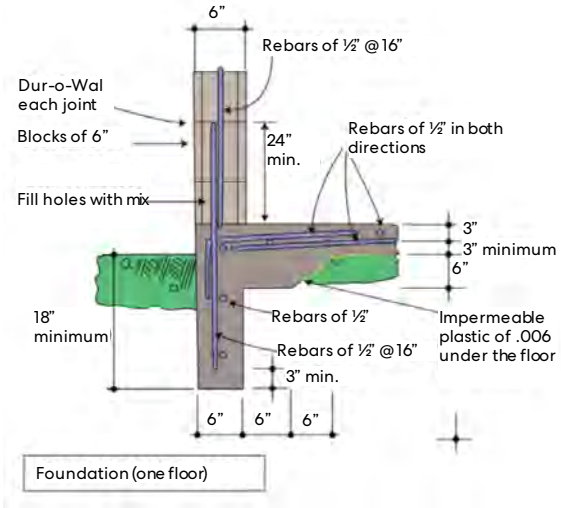
Cast-in-Place Concrete Slab

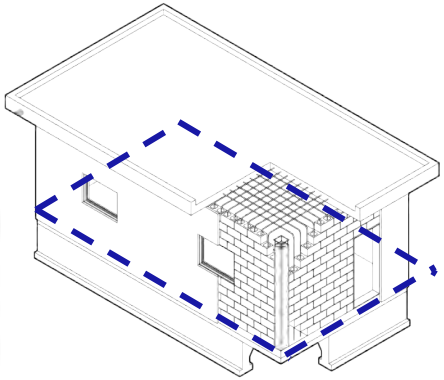
The following images are only for reference. Vertical reinforcement and foundations must be designed by a professional.

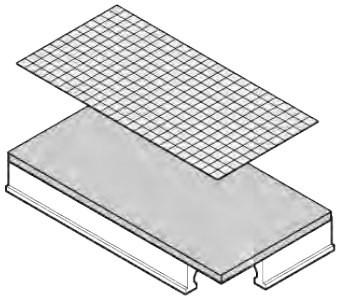
Typically used in non-coastal areas or terrains with higher scour resistance.

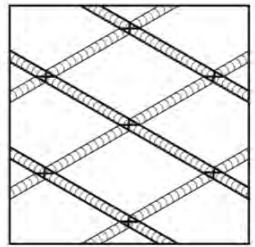
Can function as a base for the finished floor and should be reinforced with a grid of rebars.

Provide adequate connections between the structural walls and the slab foundation.







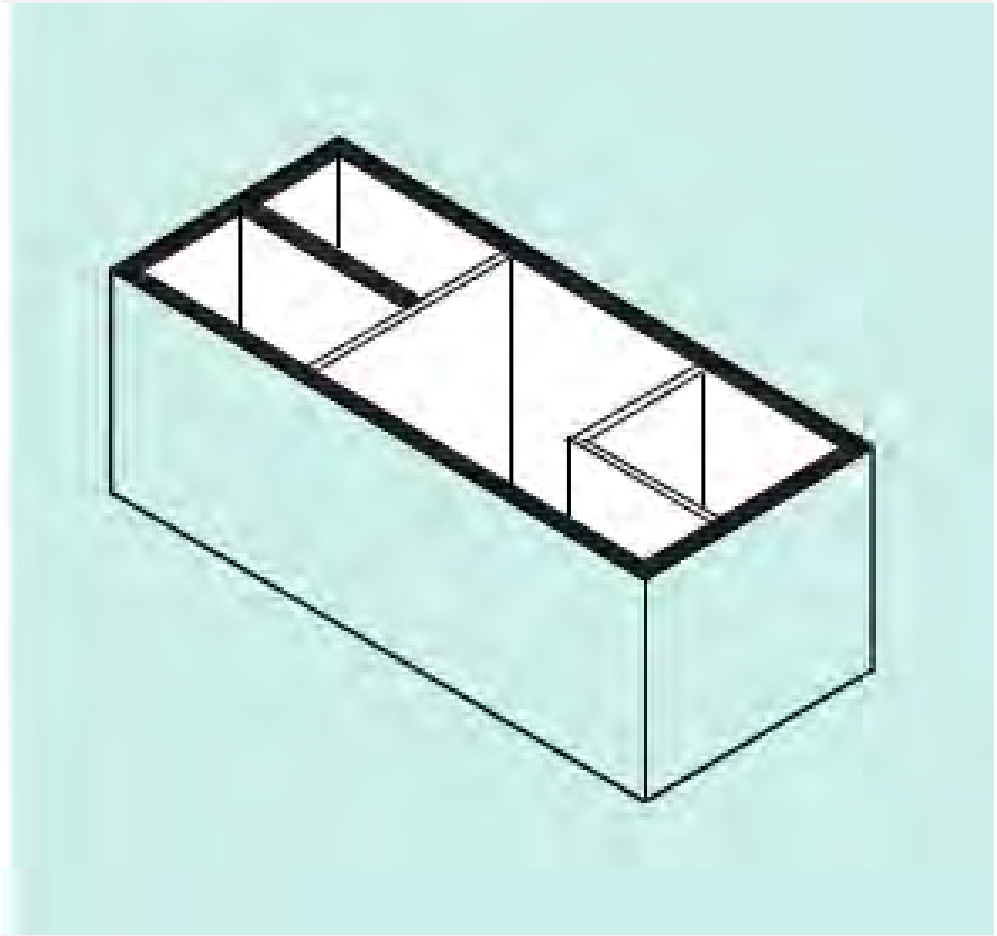


→ **See Keep Safe guide, chapter 2, strategy 5.**

Upper left image: ***Recomendaciones para la Rehabilitación Sísmica de Viviendas en PR***

Structural Wall

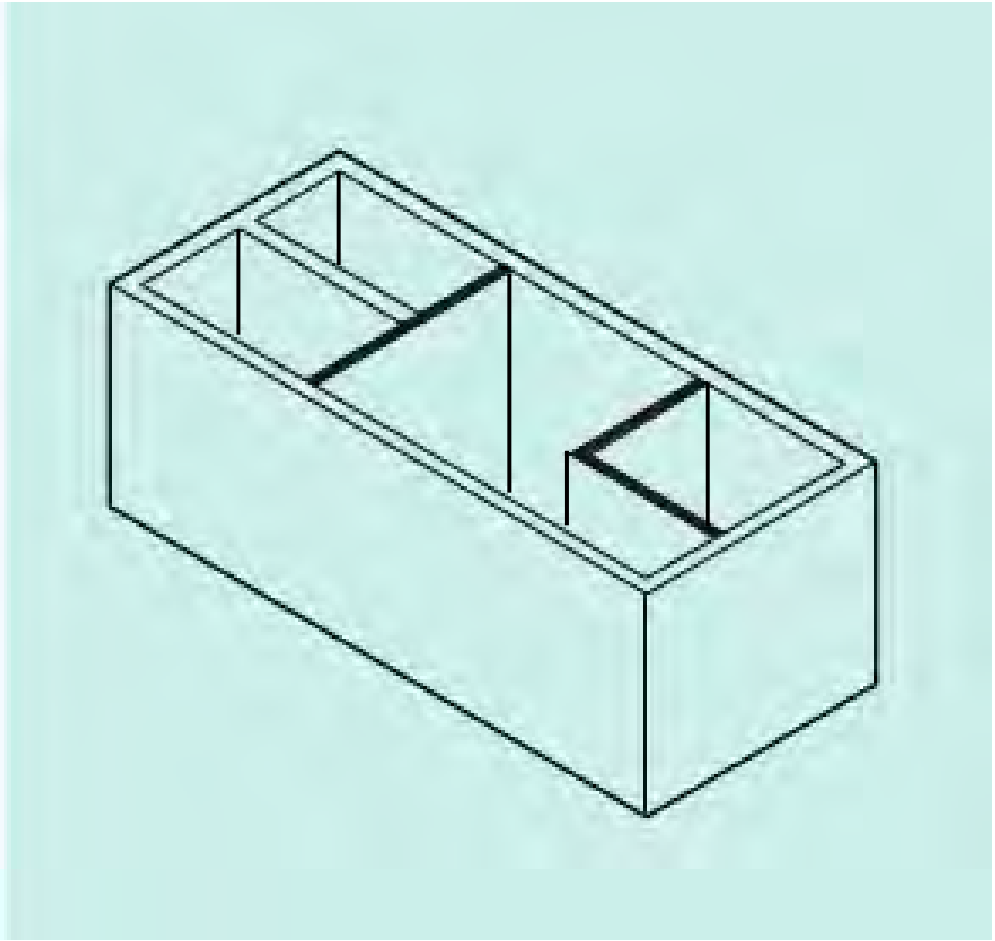
- Mainly exterior walls (interior in some cases).
- Vertically continuous from foundation, through all floors, and roof.
- Part of the continuous load path.
- Supports the home under vertical forces, like self weight and occupant loads.
- Transfer lateral loads through the house and into the foundation.
- In multi-family buildings, shear walls can be placed between units as demising and fire walls.



→ **See Keep Safe guide, chapter 2.**

Non-Structural Wall

- Interior walls.
- Not vertically continuous between floors.
- Not part of the continuous load path.
- Do not support any structure.
- Provide insulation and privacy.
- Prevent Toppling: Must be anchored to the slab and attached to the underside of the floor or roof above.



→ **See Keep Safe guide, chapter 2.**

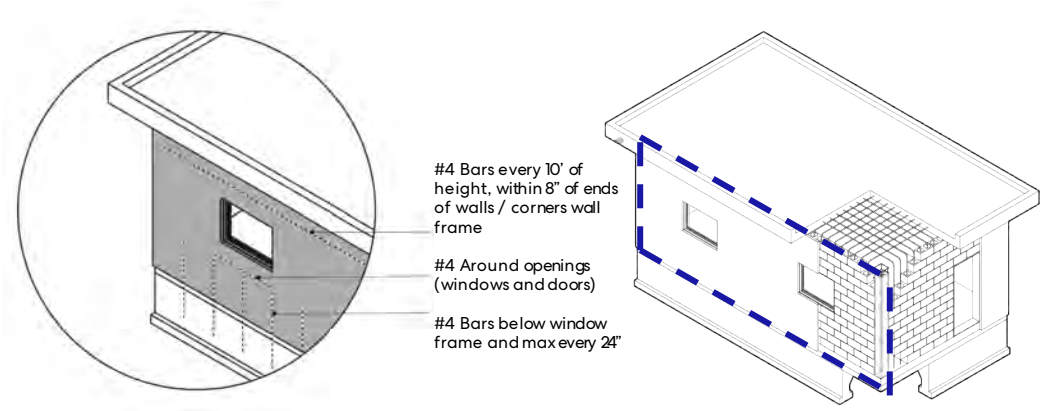
Reinforced Concrete Masonry Wall

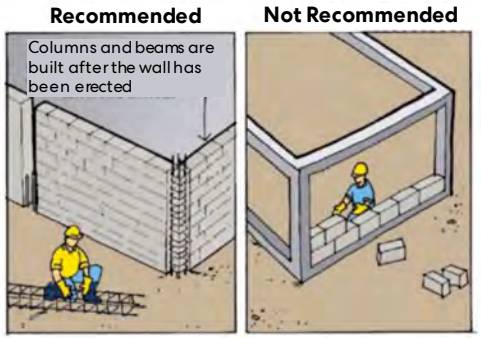
The following images are only for reference. Vertical reinforcement and foundations must be designed by a professional.

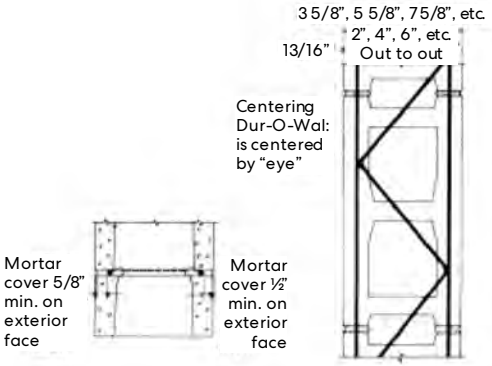
Walls must be anchored to the structural floor slab.

Reinforce openings (windows and doors) with additional reinforcing bars (above, below, and on either side)

Infill columns should have adequate reinforcement and closed ties.







→ **See Keep Safe guide, chapter 2.**

Hurricanes: How to build a safer wooden house
https://www.youtube.com/watch?v=vp7FxW0Ze6Y

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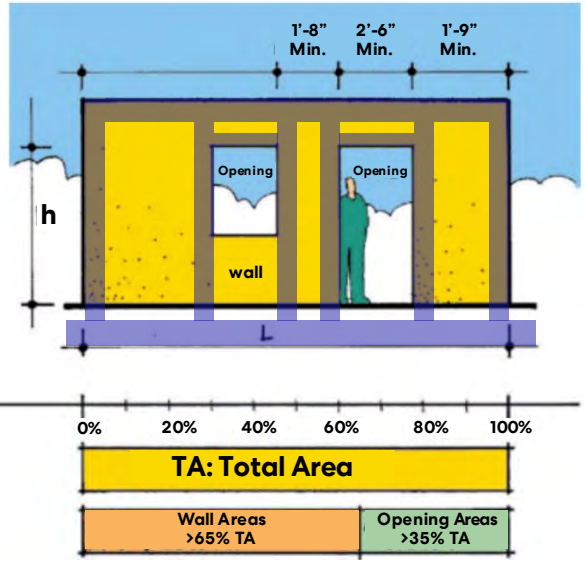

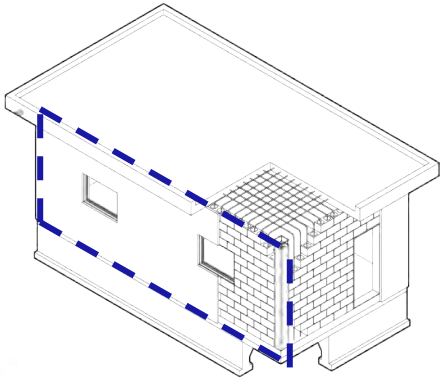

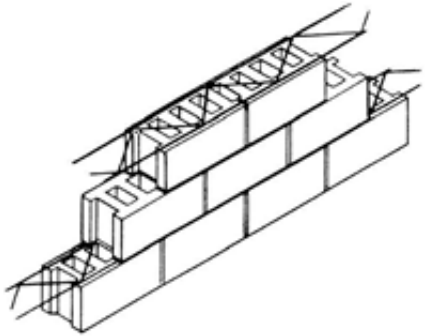

→ **See Keep Safe guide, chapter 2.**

Reinforced masonry wall, Concordia University

https://www.youtube.com/watch?v=tjXy0-kO8x0

Reinforced Concrete Roof

The following images are only for reference. Vertical reinforcement and foundations must be designed by a professional.

Walls must be anchored to the structural floor slab.

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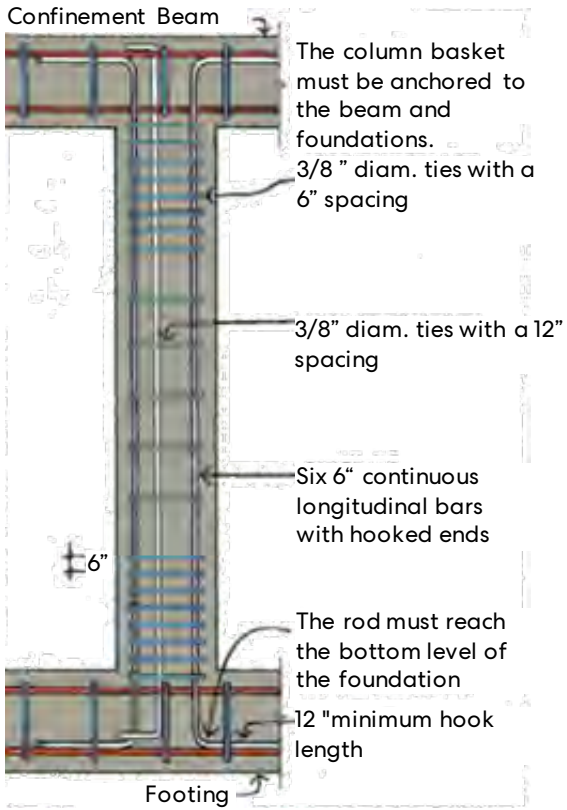
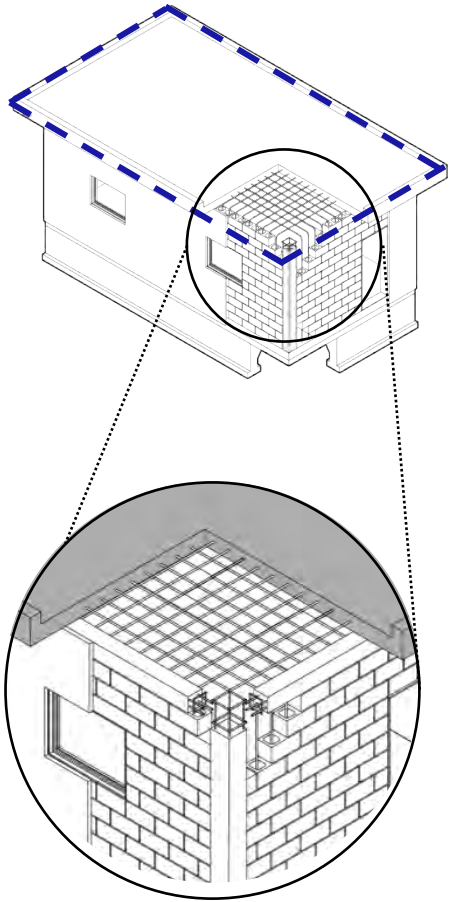
Infill columns should have adequate reinforcement and closed ties.



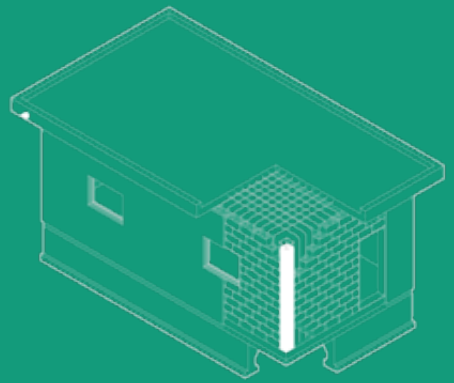


→ **See Keep Safe guide, chapter 2.**

Hurricanes: How to Build a Safer Wooden House

https://www.youtube.com/watch?v=vp7FxW0Ze6Y

Regular maintenance of a concrete house is critical for the longevity of the structure.



- Cover up exposed rebar with rust inhibitive coating and a patch of concrete.
- Plaster cosmetic cracks on walls or roofs to avoid leakage of water and break-in of insects or plants.
- Maintain and seal joints between windows, doors and walls to avoid humidity problems that may be harmful for users and deteriorate the concrete by promoting corrosion.
- Reapply roof waterproofing sealant, according to product manual.
- Do not penetrate load-bearing walls to install AC units or to make larger openings without consulting with an engineer or architect.
- Make sure roof and other drains are unclogged and working correctly to keep water flowing away from the structure and to avoid damage to walls and roof slabs.

Wood Construction:

General Principles and a Case Study

Techos : Prototyping Resilience Design Guide
MIT School of Architecture and Planning

Building with Wood

Wooden members and panels must be **pressure treated** in order to avoid rot, fungus and termite attacks over time.

Why? This will **increase the durability of the structure**. Rotten or delaminated wood should be discarded.

All **fasteners** (screws, ties, brackets, etc) **must be of exterior grade or galvanized** to avoid corrosion.

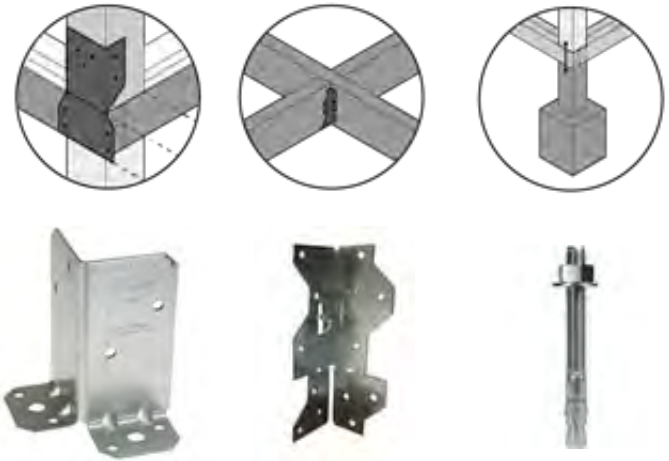
Why? This is especially necessary **to avoid rust** in Puerto Rico's coastal areas due to saltpeter. Must be designed to always shed water.

→

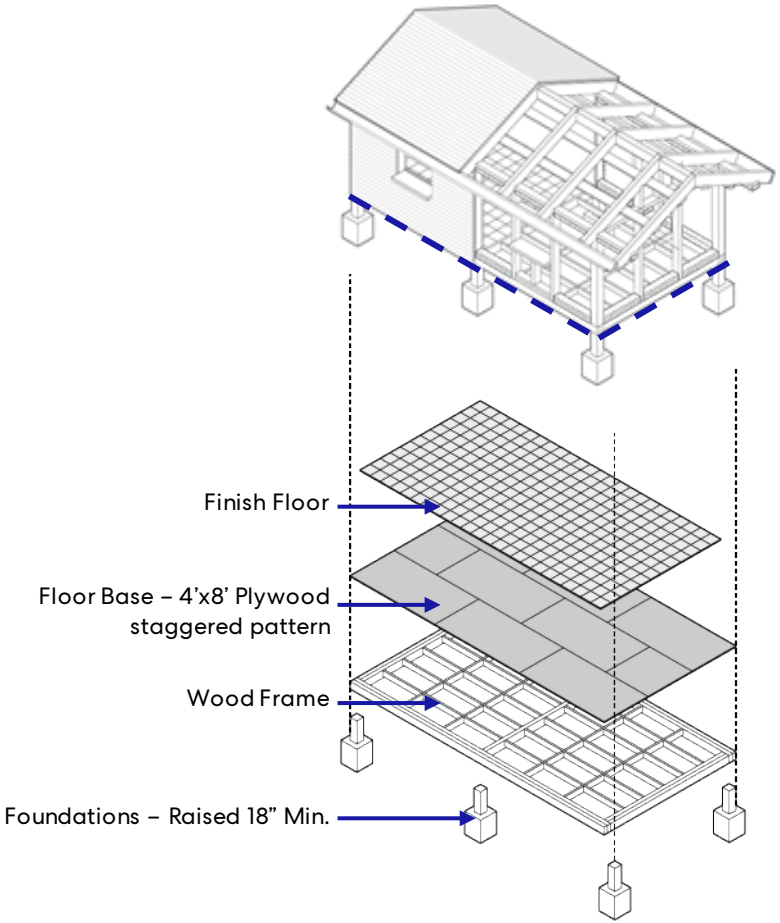
Pressure treated wood courtesy of Techos: Prototyping Resilience Design Guide MIT School of Architecture and Planning

Open Concrete Footing to Floor

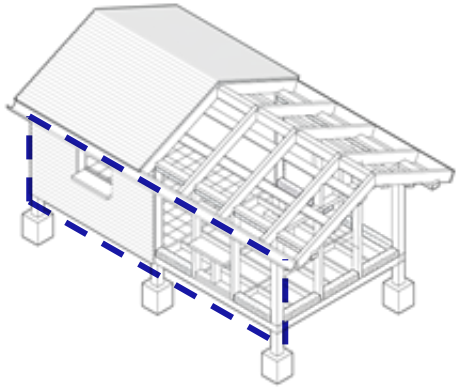
Floor and foundation details for a wooden diaphragm.



→ See Keep Safe guide, chapter 2.



Wall Frame



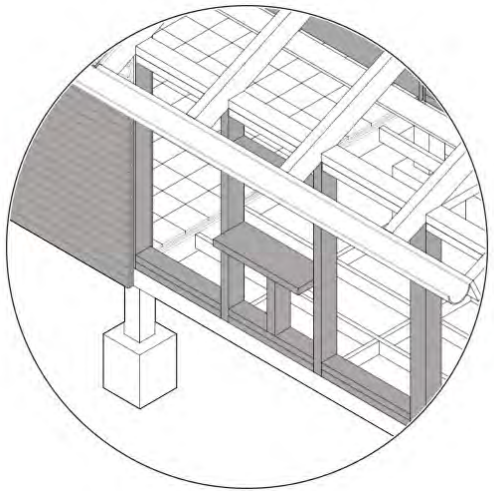
The building code provides prescriptive provisions for the adequate design of these systems.

Walls must be anchored to floor.

Use recommended spacing for members.

Use only **treated wood** (2x4 or 2x6), **exterior grade screws** and **galvanized framing angles**.

Reinforce openings - windows and doors - with additional framing above, below, and on either side.



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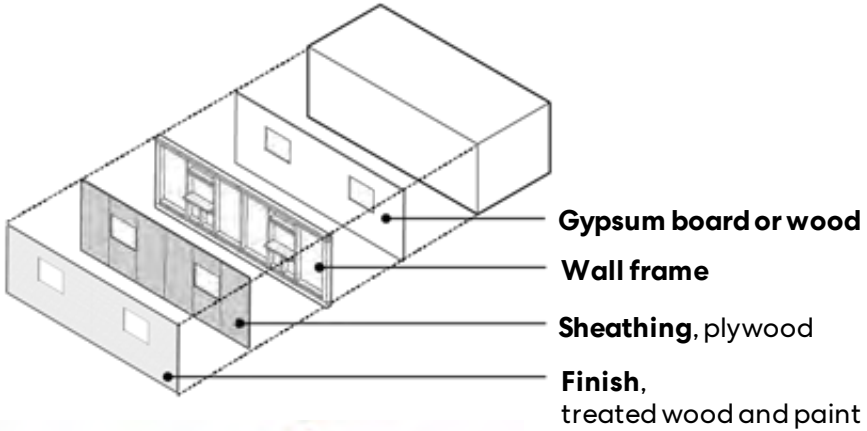
Gypsum board may be prone to mold in humid and tropical climates.



→

See Keep Safe guide, chapter 2.

Hurricanes: How to Build a Safer Wooden House
https://www.youtube.com/watch?v=vp7FxW0Ze6Y

Wall Frame to Foundation

Strong concrete **foundations** adequately designed for the soil type and weight of the structure.

Wooden posts must be anchored to floors and foundations.

Wood walls cannot be use as retaining walls.

Staple fasteners cannot be used to resist or transfer seismic forces.

The **quality of screws and nails** is important and should be mechanically driven nails used in wood structural panel. A structural engineer can help define the diameter, minimum length and head diameter of nails and screws.

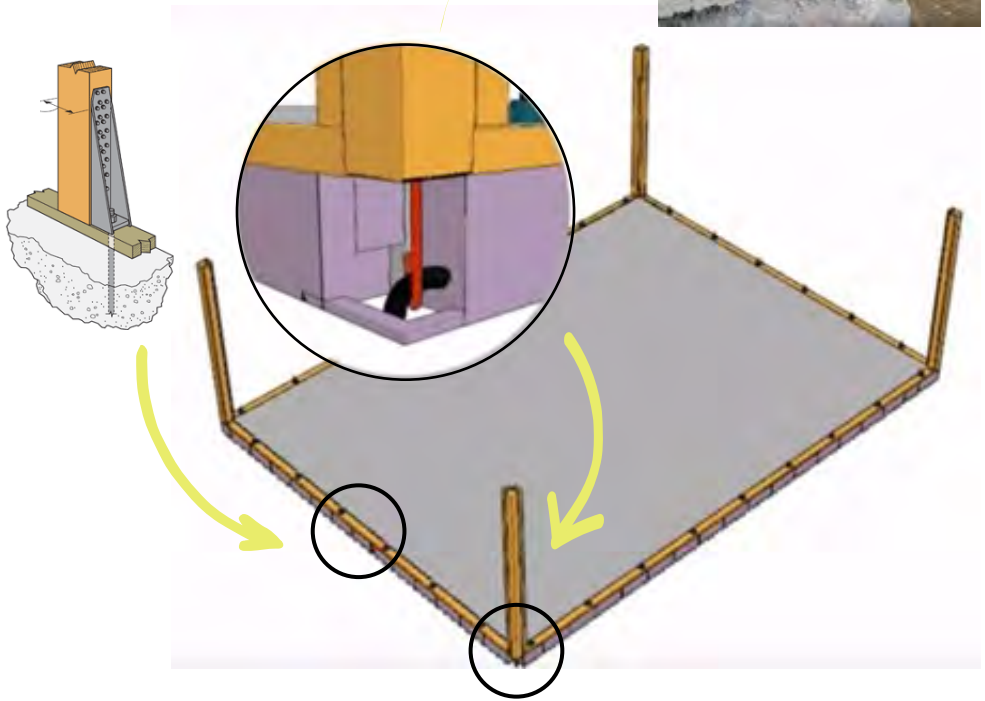
Hold Down Connectors need to resist overturning moments. Connectors require steel plate washers on anchorage device. Plate size minimum .2229 inch by 3" by 3" in size. Connector should be tightened.

Wood frame **diaphragms**, usually in the form of plywood sheathing, need to be applied directly to framing members.

→

Hurricanes: How to Build a Safer Wooden House
https://www.youtube.com/watch?v=vp7FxW0Ze6Y

J-Hooks, Anchor Bolts, Hold-Downs* and *Straps



Wall Frame

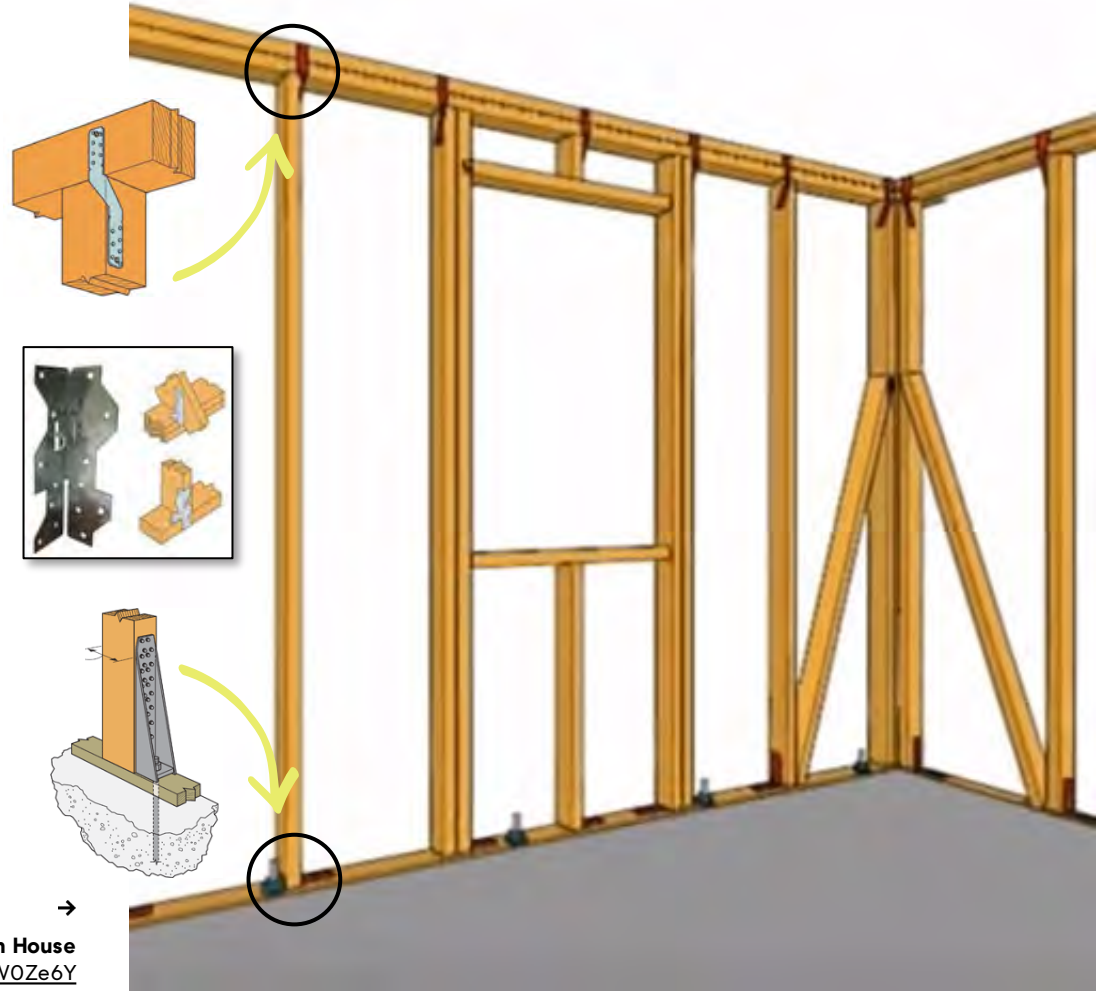
Wood-frame shear walls: no less than 3/8" thick and studs shall not be spaced more than 16" apart. Nails shall be placed no less than ½" from panel edge and not less than ¼" from edge of the connecting member.

Brace wall line support: shall be supported by continuous foundations and in the same plane as the foundation.

Alternative Brace wall: in one story building, each panel shall have a length of no less than 2'-8" and a height of no more than 10'.

Portal frame with hold-downs: door and windows with full-length header. See code for minimum thickness, sheathing nails and supports, etc.

Sheathing attachments: requires adherence to the prescriptive provisions of the building code.



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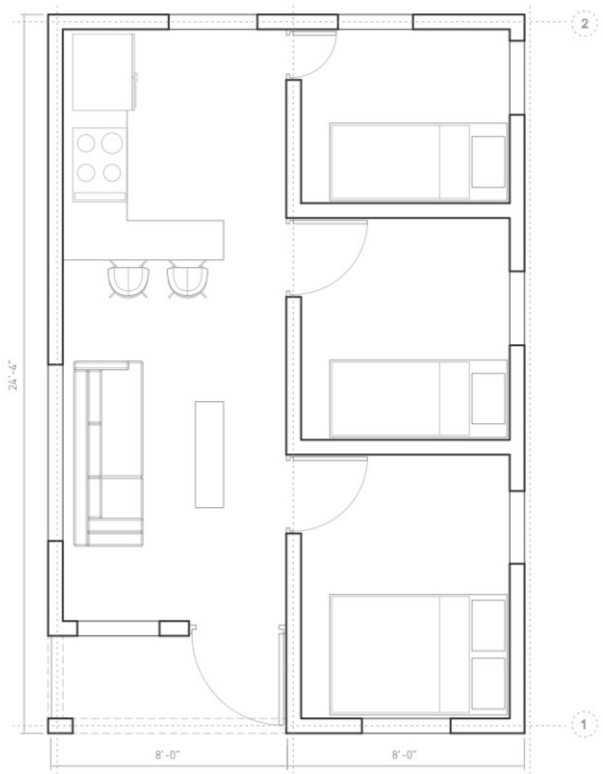
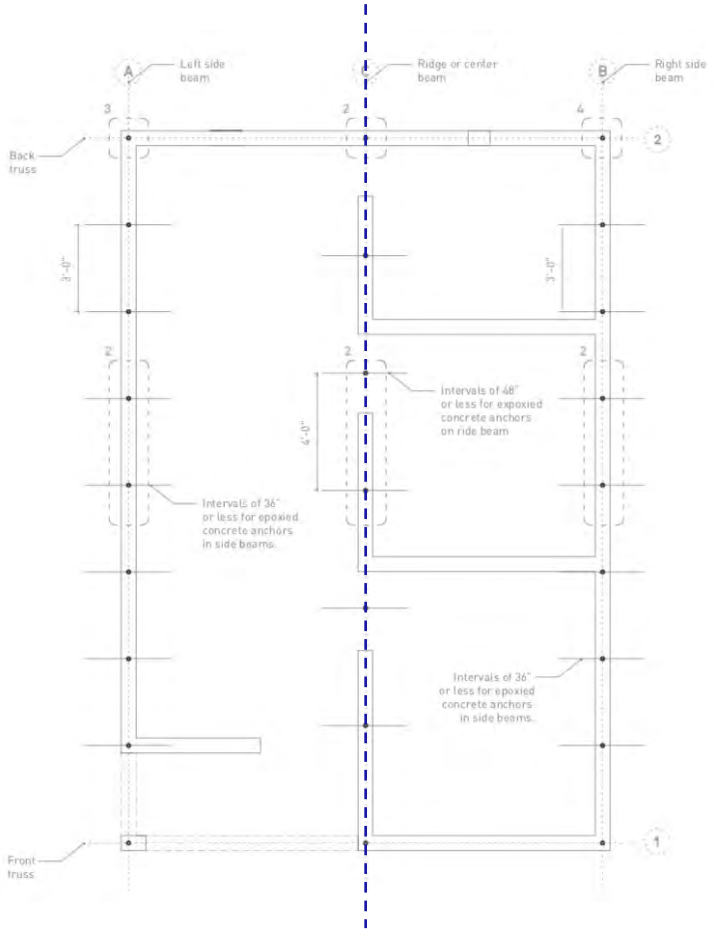
Hurricanes: How to Build a Safer Wooden House
https://www.youtube.com/watch?v=vp7FxW0Ze6Y

Roof Diaphragm



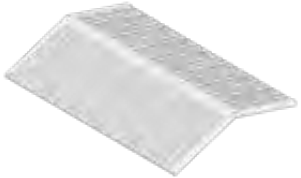


Simplified typical plan. Techos: Prototyping Resilience Design Guide
MIT School of Architecture and Planning

Roof System

Roof must be anchored to walls.

Special **galvanized, stainless, or coated screws (with gaskets)** protect metal against corrosive agents in pressure treated wood



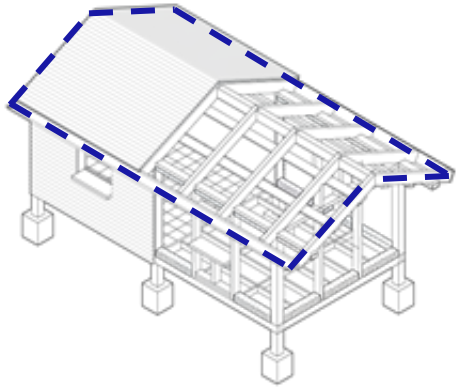
Galvanized roof panels

Perimeter and interval furring

Plywood panels

Wooden frame with plywood diaphragms

Wooden frame mechanically anchored or epoxied to bearing walls



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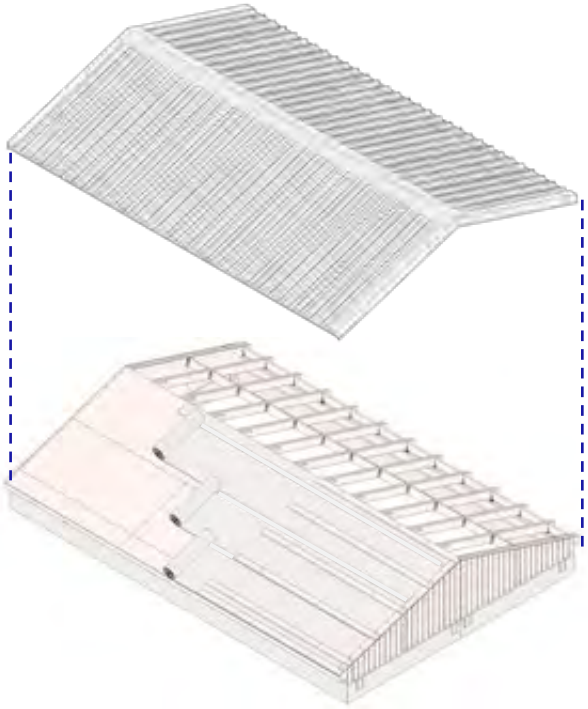
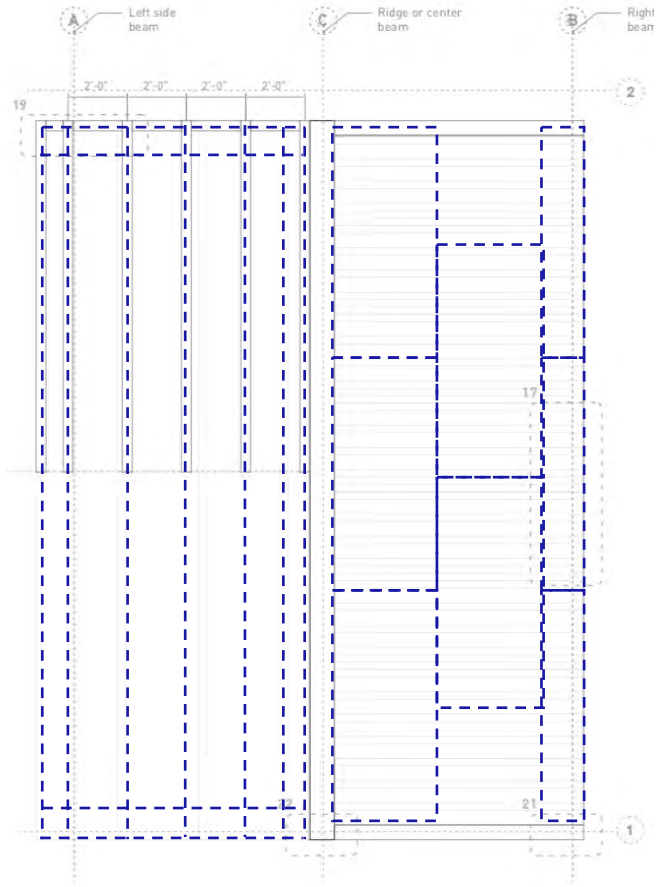
See Keep Safe guide, chapter 2.

Roof System





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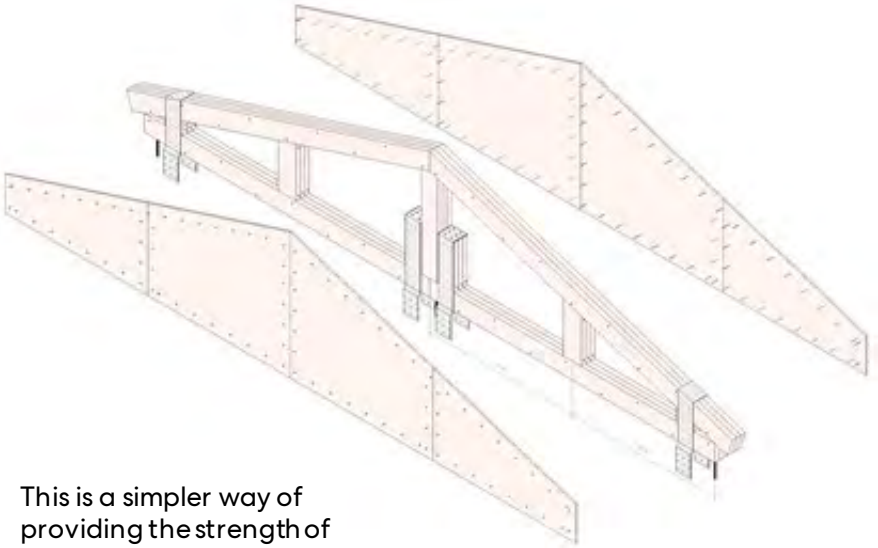
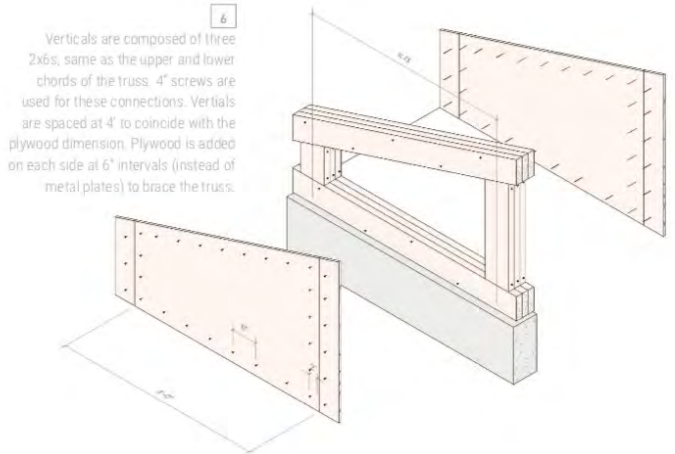
Simplified framing plan and axon. Techos: Prototyping Resilience Design Guide MIT School of Architecture and Planning

Roof Plywood Diaphragm



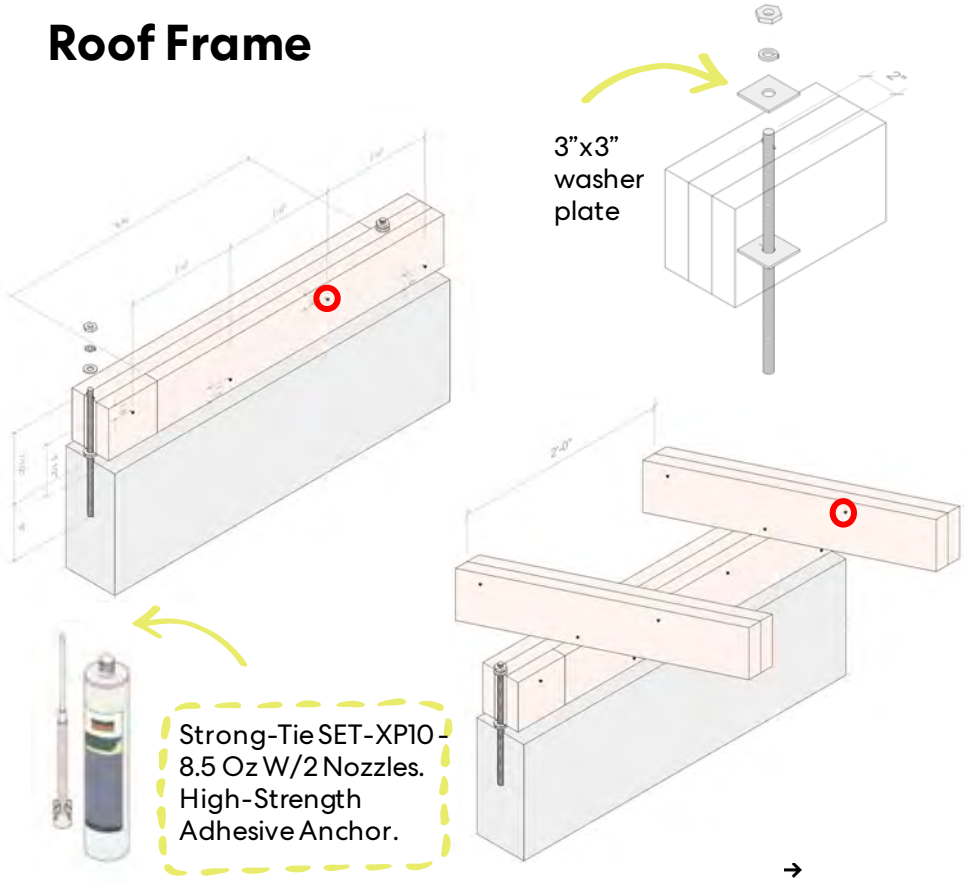


This is a simpler way of providing the strength of conventional steel-plated trusses with fewer metal connectors and manufacturer-specific specialized design.

→

Techos: Prototyping Resilience Design Guide
MIT School of Architecture and Planning

Roof Frame



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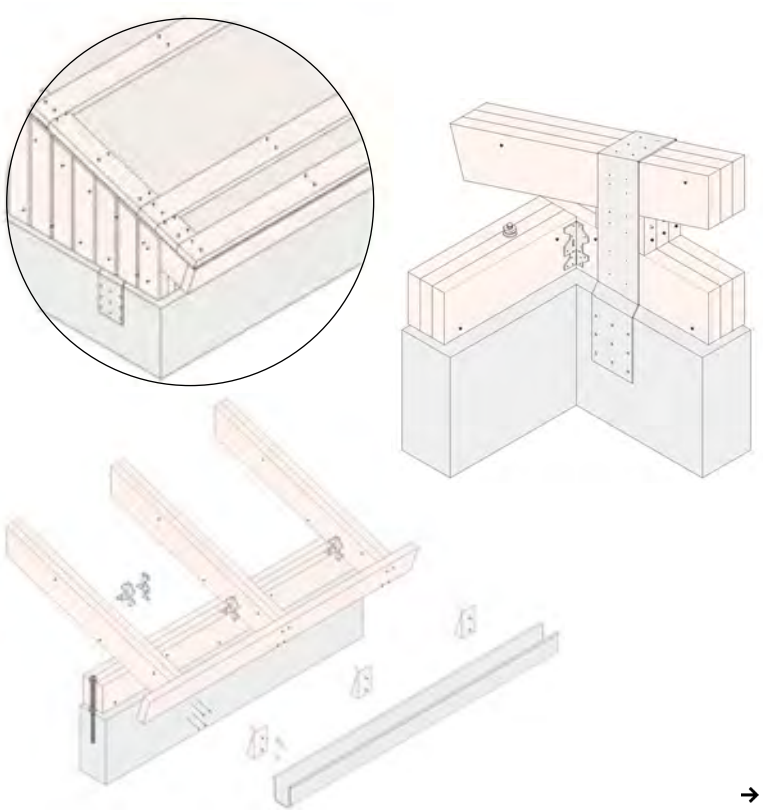
Roof Frame



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Techos: Prototyping Resilience Design Guide
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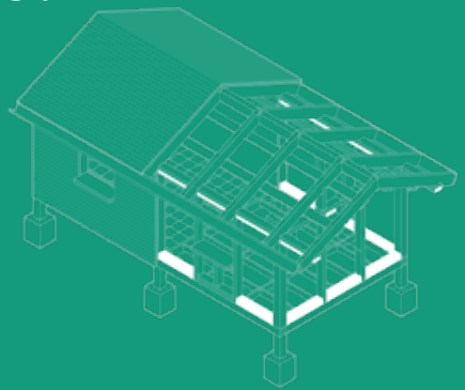
Quality of Space

→

Techos: Prototyping Resilience Design Guide
MIT School of Architecture and Planning

Regular maintenance and connection check-ups are important for the long-term strength of a wood house.



- Look for leaks in your wooden and metal roof that may signal fastener corrosion and failure.
- Check if there are lose nuts and lose or wrongly inserted screws that are not fulfilling their purpose.
- Identify and treat termites before they can damage any partitions or structural members.
- Paint or vanish walls periodically to protect wood.
- Check on anchors and tie downs that may corrode with time, water, or saltpeter.
- Check that drains are correctly located and unobstructed to shed water away from the structure at all times, and avoid the rotting of wood.
- Check that external equipment like cisterns, AC units or solar panels are correctly anchored, and preferably independent of the roof.

Hurricanes:

How can they affect our homes?

A **hurricane** is a type of storm called tropical cyclon, which is a rotating low-pressure system. Tropical cyclones with maximum sustained surface winds of less than 39 miles per hour (mph) are called **tropical depressions**. Those with maximum sustained winds of 39 mph or higher are called **tropical storms**. When a storm's maximum sustained winds reach 74 mph, it is becomes a **hurricane.**

oceanservice.noaa.gov

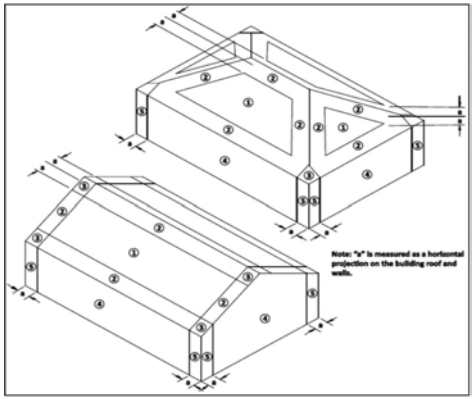
Hurricane Maria making landfall in Yabucoa. Image by NASA Earth Observatory

Hurricanes and Wind loads

Hurricane force winds 74mph or above can greatly **impact** the lateral force resistance of a structure *(Cal OES SAP manual)*. Maria reached Cat 5, but hit Yabucoa as a Cat 4 with 155mph winds *(weather.gov)*.

The **PRBC 2018** sets the wind load value for the eastern part of Puerto Rico at 170mph, and at 160mph for most of the North, South, and central areas. What does this mean for construction?

Different from an earthquake (where there may be aftershocks) it is not expected that a second storm event will follow in the near future. However, in 2017 we saw how Cat 5 Irma was followed by Maria within 10 days.



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[Ultimate design wind speeds for Risk II structures in Puerto Rico (ATC Hazards)]

Wind design zones by vulnerability (American Wood Council)

Hurricanes Hazards: Storm Winds

Small family houses are light-weight compared to bigger buildings, and susceptible to uplift and raking

Loss of cladding or windows and subsequent exposure to the elements

Projectile impact can cause damage

Loss of lateral or vertical load systems due to loss of roof

→

Hurricane Hazards from ATC-45 field manual

Projectile damage from Hurricane Georges. Source: FEMA 339

Poor quality construction, Hurricane Maria. Source: FEMA P-2020

Hurricanes Hazards: Flood & Rain

Storm surge and flood

The water may carry hazardous materials, bacteria, etc. (overrun septic tanks and sewage)

Damage to diaphragms by moisture warping

Erosion and scouring of foundations

Water-saturated walls or ceilings: mold growth

→

Hazards from SAP Evaluator Manual, 2016

Mold growth, Hurricane Katrina. Source: SAP Evaluator Manual

Storm surge at Ave. Isla Verde, Hurricane María. Source: Primera Hora

Hurricanes Hazards: Geotechnical

Settlement of the structure

Slope failure due to oversaturation

Undermining of foundation (scouring)

Erosion

Ground displacement

→

Damage to floodplain, Hurricane Georges in 1998. Source: FEMA P-2020

Slab foundations undermined due to storm surge, Maria. Source: FEMA P-2020

Common failures ATC-45

Gable ends failure *(subsequently, the entire roof fails)*

Rafter separation at peak of roof due to uplift

Overhang connection failure

Wall veneer separation

Masonry gable end failure

Wood gable end failure

→

Common failures from ATC-45 Field Manual.

Gable end failure. Source: USAID Building Back Housing in Post Disaster Situations

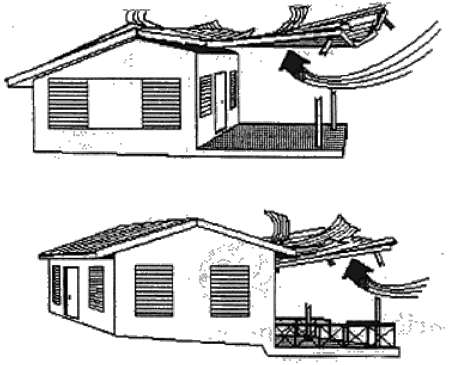
Gable end failure after Hurricane Maria. Source: FEMA P-2020

Common failures
ATC-45

Metal roof sheathing separation (leading to more damage)

Canopies / porches

Window / door failure due to lack of framing



Porches and overhangs make the structure vulnerable. Building them separate from the main roof can help protect it from uplift failure.

→

Failure of panel system with concealed clips. Source: FEMA 757

Porch failure: Source: OAS and USAID *Basic Minimum Standards for Retrofitting*

Part 5

Hurricane Season Tips

Damage prevention by Design

Wood has been proven to resist earthquakes in Puerto Rico since 1918.

A house can be built of solid or light wood frame with wood stud partitions and resist hurricane winds

Reinforced concrete or reinforced concrete block is also a good option.

Light wood framework buildings that survived the 1918 earthquakes

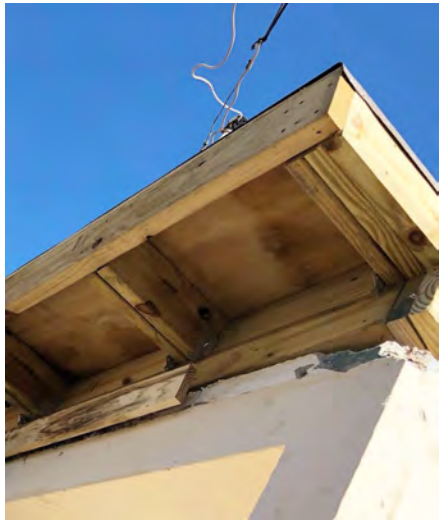
Beatriz del Cueto, Mother Nature versus Puerto Rican Building Technologies

Key Concepts: Roof Geometry

Hipped roofs perform best under hurricane winds

A medium roof angle is more effective (10-25°)

Awnings must be short and porches or canopies should be built as independent roof sections



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Independent porch roof and awning example. Source: MIT Techos

Gable vs. hip roof performance under wind. Source: Culbertson Insurance Agency

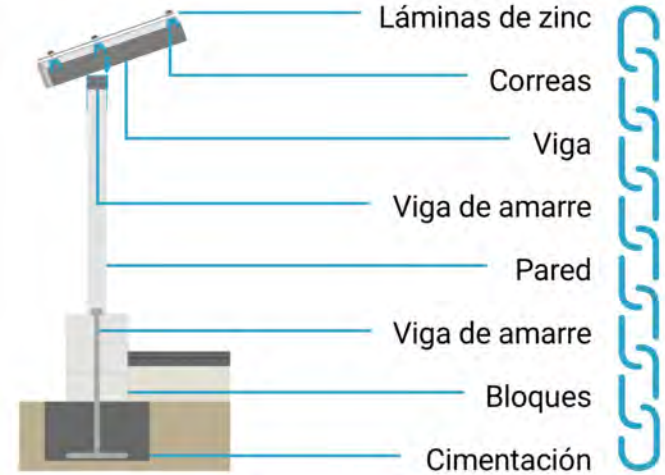
Reinforce zones where forces are greater

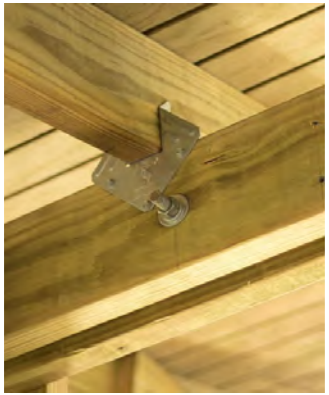
Roof to Walls

Walls to Corners

Walls to Foundations

For earthquakes or hurricanes, we must link each component together to achieve a greater overall strength.





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The importance of Connections. Source: Habitat for Humanity, Guía para aumentar la resiliencia de viviendas contra huracanes Connection details (bottom). Source: MIT Techos Case Study

Additional notes

If the **wall to foundation** connection or **roof to wall** connection is weak, consider using hurricane harnesses or cables to tie these down to a concrete post or foundation to resist **uplift** during the hurricane event.

Install **shutters** on compromised openings, like windows and doors to shield the structure from projectiles.

Keep updated **documentation** of your house and the components that make up the structure (location of structural supports, types of screws and fasteners used, etc).

Acquire a water resistant, temporary roof cover.

→

House with tie downs in Culebra that survived Maria. Source: FEMA P-2020

House with cables that survived Hurricane Georges. Source: FEMA 339

Blue tarp, for use as a temporary waterproofing element

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**.

Hurricane Maria flooding.

Wet Floodproofing / Two types

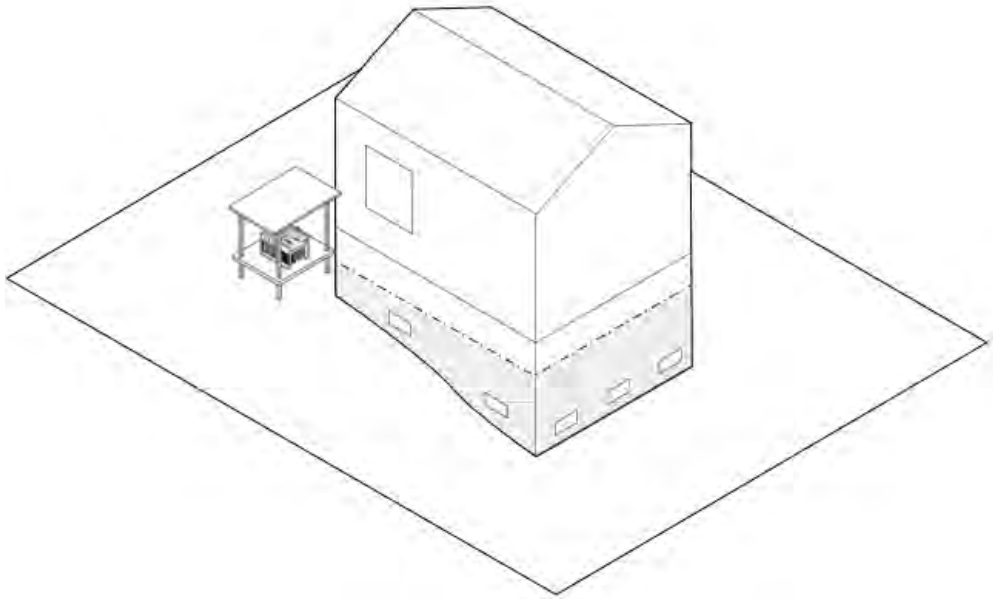
Wet floodproofing

Mitigates water damage to the home by **allowing water to freely flow** up to the DFE (Design Flood Elevation based on FEMA's Base Flood Elevation – critical for FEMA Flood Insurance Rate Maps) 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.



Wet Floodproof Home

1. Repurpose all floors below the DFE

2. Elevate critical systems

3. Install flood vents and / or flood openings in walls

4. Provide backwater valves for water, sanitary and stormwater systems

5. Elevate, secure or tie down tanks

6. Use flood damage-resistant materials up to the DFE

→ Wet floodproofing strategies.

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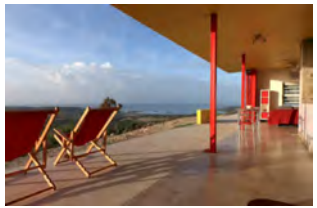

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Dry Floodproof Home

(non-habitable spaces only)

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.

4. Use waterproof covers for vents and louvers located under the DFE and install them before a natural disaster. Permanently seal floor drains

5. Install sewer backwater valves. 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.

→ **Dry floodproofing strategies.**

1

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Dry Floodproof Home, cont.

(non-habitable spaces only)

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.

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.

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

→ Dry floodproofing strategies.

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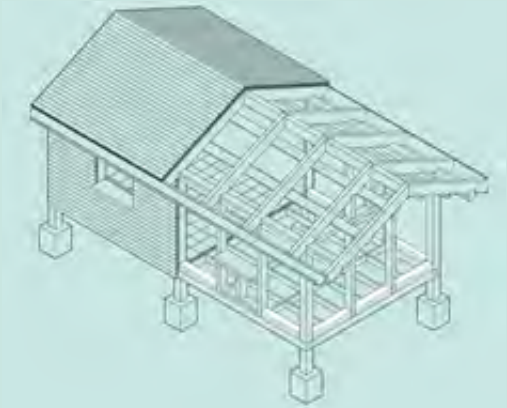
A House's structural system is like a family. Illya Azarof



Bibliography & Resources

Manténgase Seguro / Keep Safe
Una Guía para el Diseño de Viviendas Resilientes en Comunidades Isleñas

Techos: Prototyping Resilience, Case Study on Wood Construction

Recomendaciones para la Rehabilitación Sísmica de Viviendas en Puerto Rico

Rehabilitacion Sismica de Casas en Zancos

Sources and helpful links to expand knowledge.

Thank you.