

Earthquake and Typhoon Resistant Construction for Bohol

The Six Steps to Better Construction



Gordon Goodell
Benjamin Biddick
Build Change



Build Earthquake Resistant Houses
Change Construction Practice
Permanently



USAID Reconstruction Primer

(written by
Build Change)

BUILDING BACK HOUSING IN POST-DISASTER SITUATIONS – BASIC ENGINEERING PRINCIPLES FOR DEVELOPMENT PROFESSIONALS: A PRIMER

January 2012

This report was produced for review by the United States Agency for International Development (USAID). It was prepared by Build Change, for International Resources Group (IRG).

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Build Change Methodology: The Six Steps to Better Construction

1. Learn First
2. Design Disaster-Resistant Houses
3. Build Local Capacity
4. Stimulate Demand
5. Facilitate Access to Capital
6. Measure the Change

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1. Learn First

- Local context
 - Social
 - Economic
 - Cultural
 - Environmental
 - Governmental
- Risk of Disaster
 - Future Risk
 - Learning from previous disasters
- Existing Design and Construction Practices
 - Applicable codes and their enforcement
 - Common building systems and materials
 - Local standard of practice for design and construction

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How does the public relate to earthquakes?

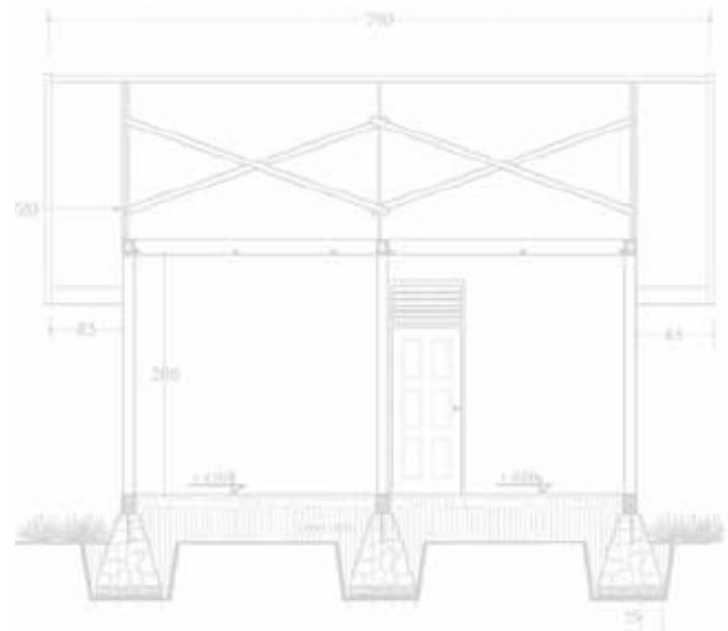


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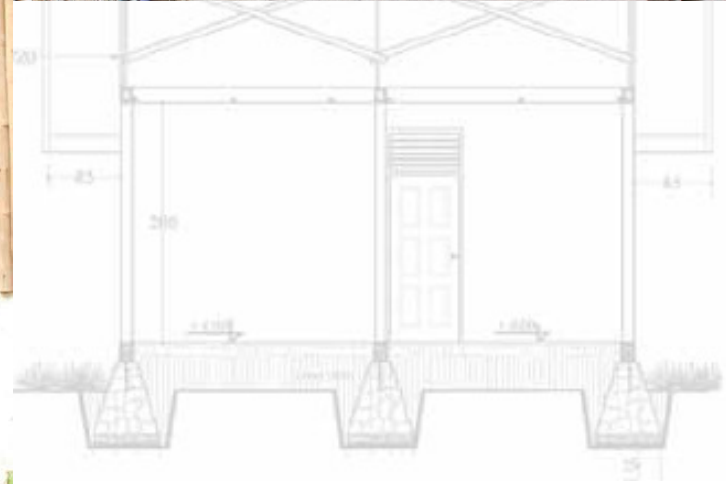
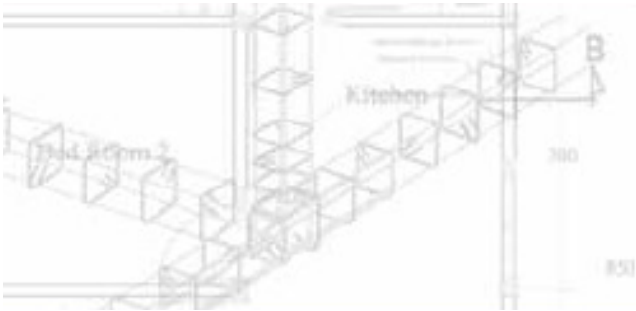
How does the public relate to the built environment?



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Step 1. Learn First



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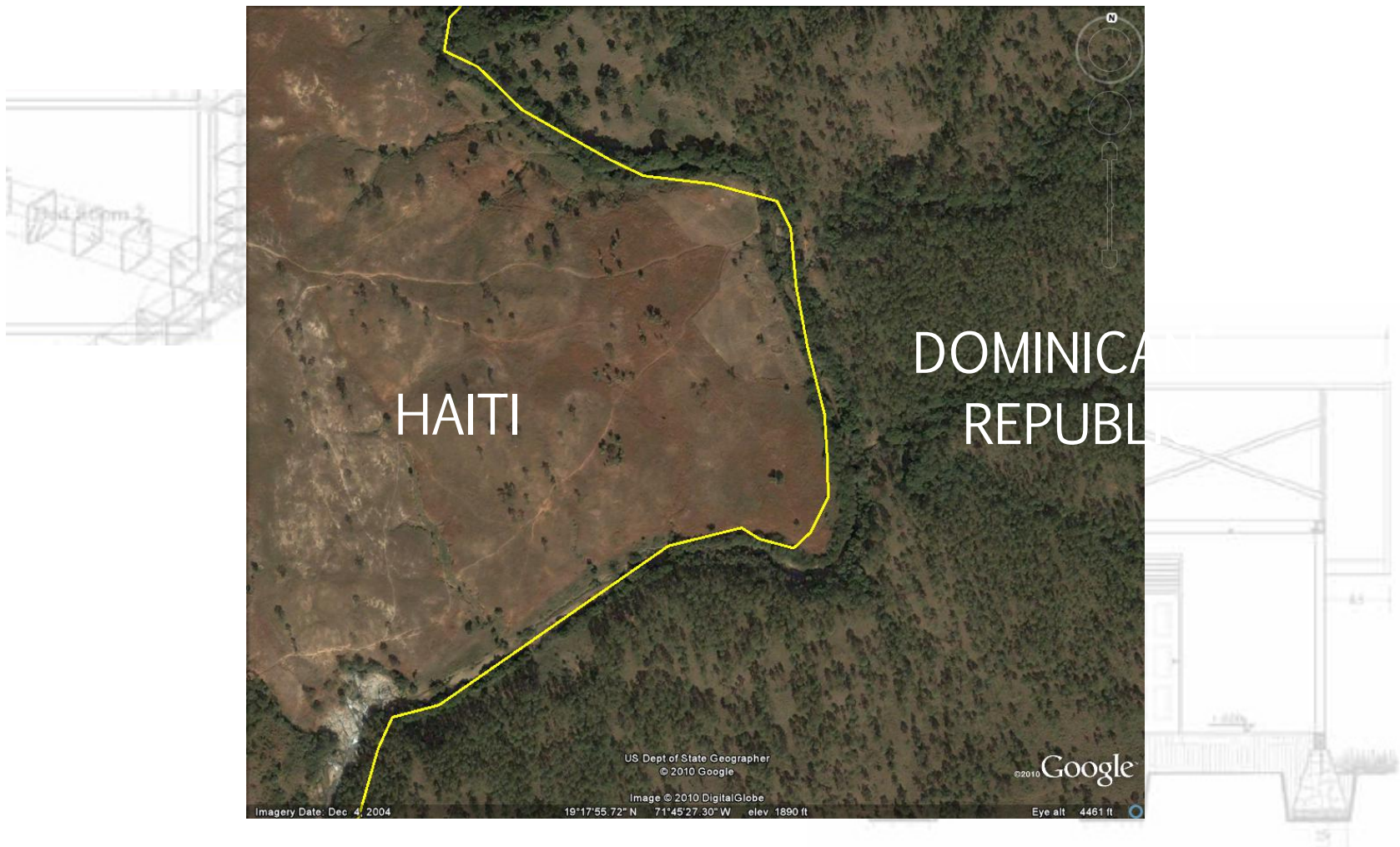
Step 1. Learn First



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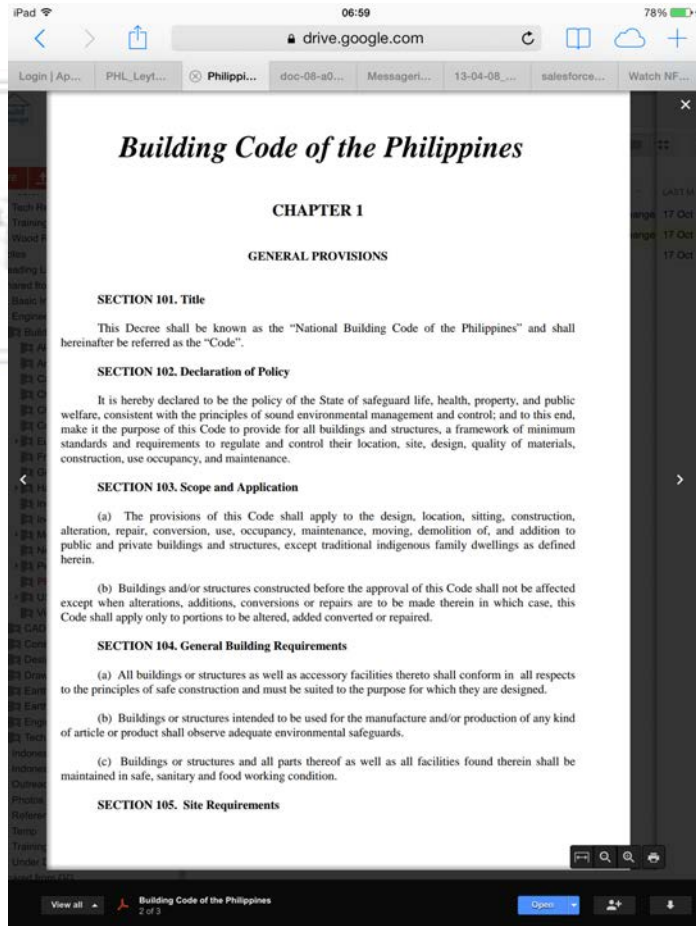
Environmental Context



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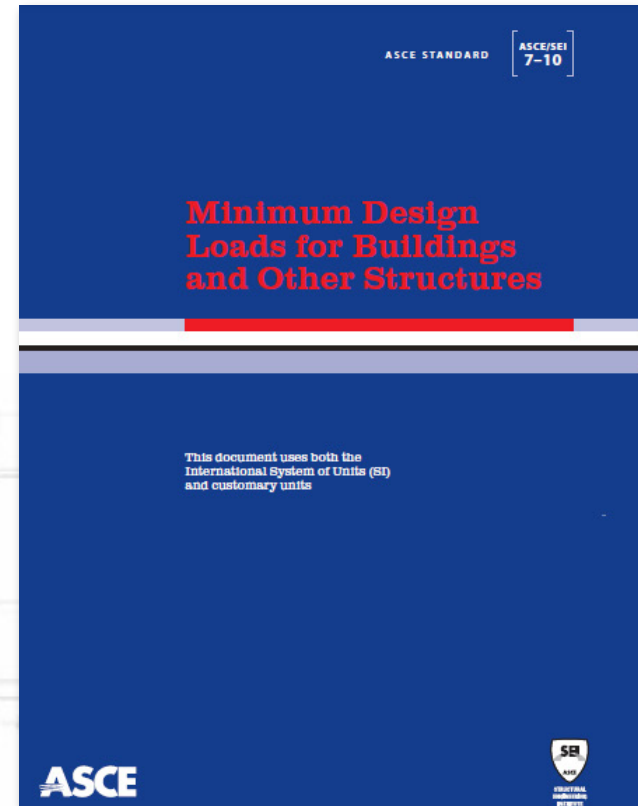
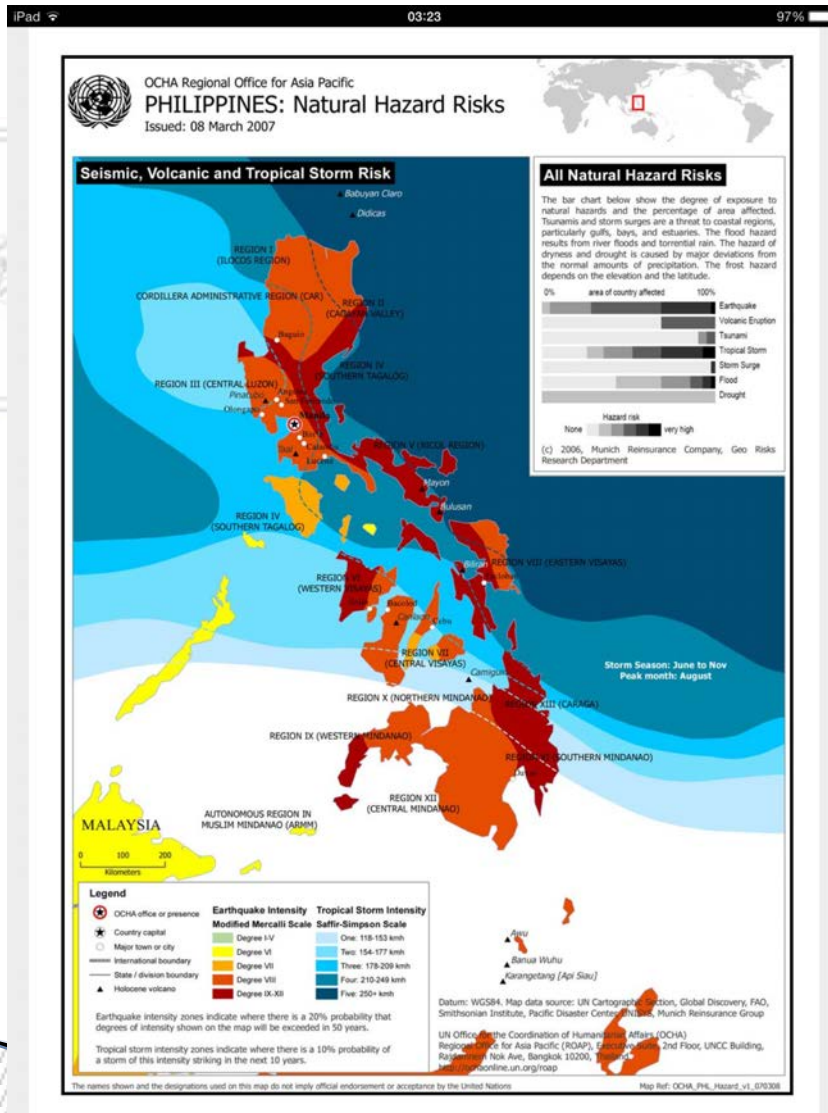
Government Oversight and Inspection



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Hazards



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Learn about Existing Building Systems and Construction Practices

- Materials
- Building systems
- Skills, techniques, tools
- Vulnerabilities and weaknesses



What can we observe about this building?



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Step 1. Learn First



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Step 1. Learn First



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Buildings and Systems



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Step 1. Learn First



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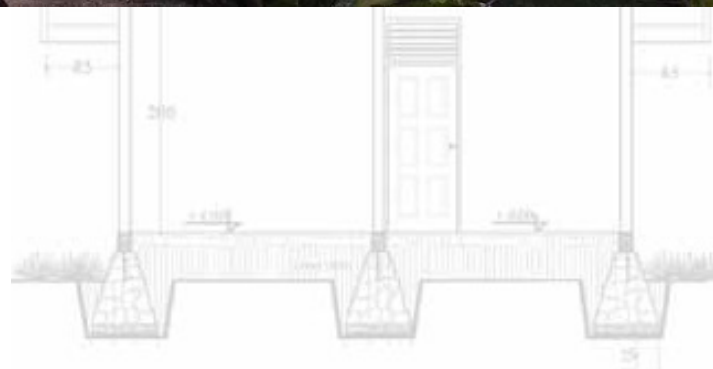
Step 1. Learn First



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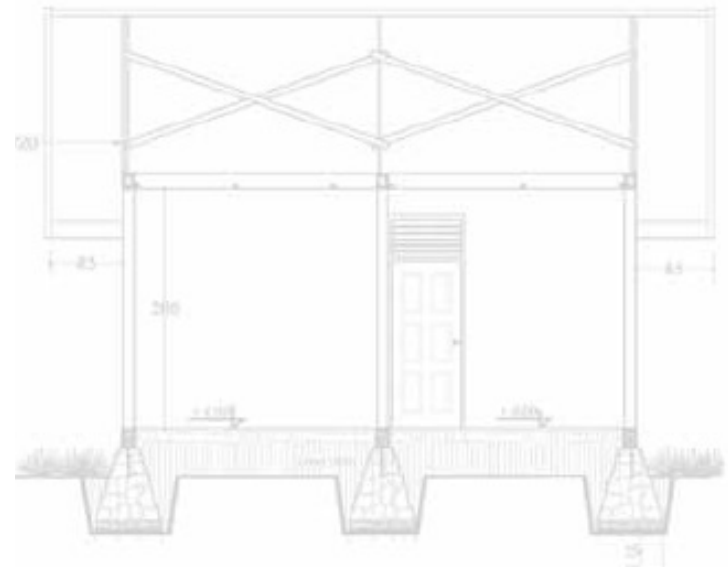
Step 1. Learn First



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Step 1. Learn First



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Step 1. Learn First



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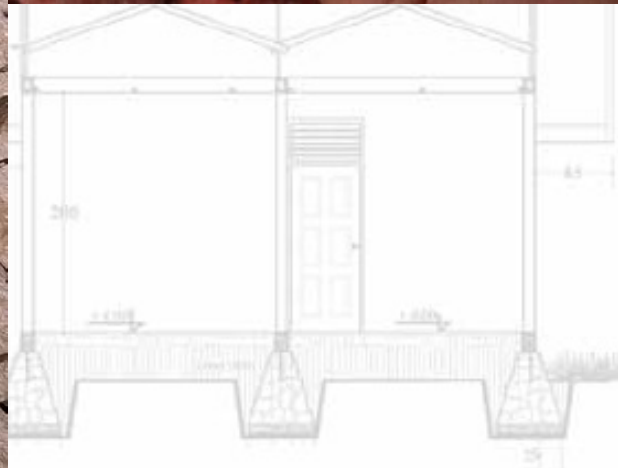
Step 1. Learn First



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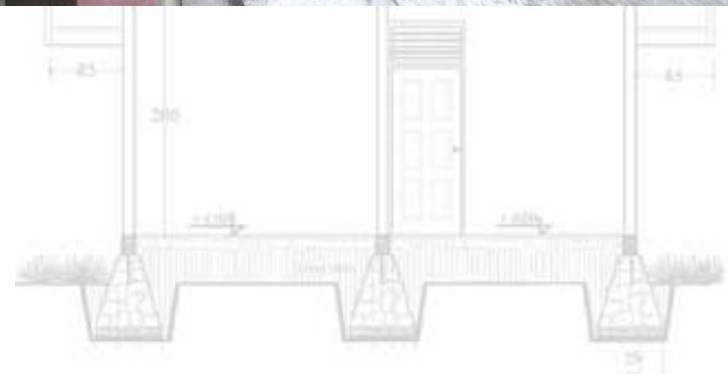
Materials and Construction Quality



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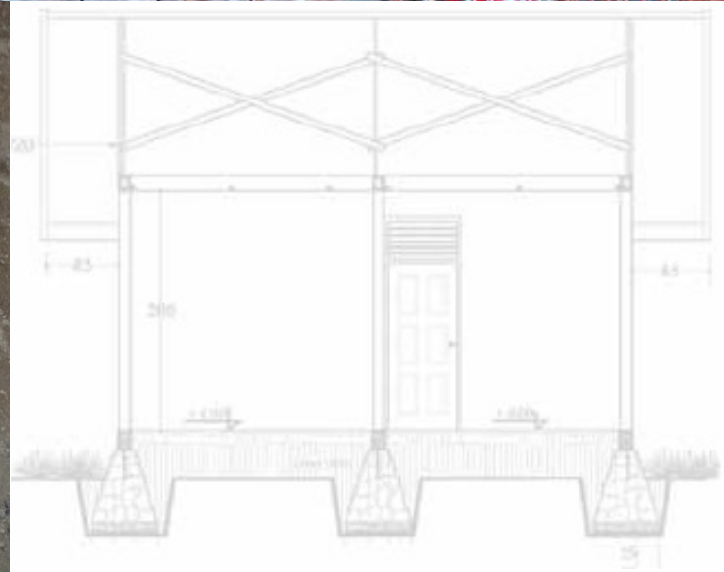
Step 1. Learn First



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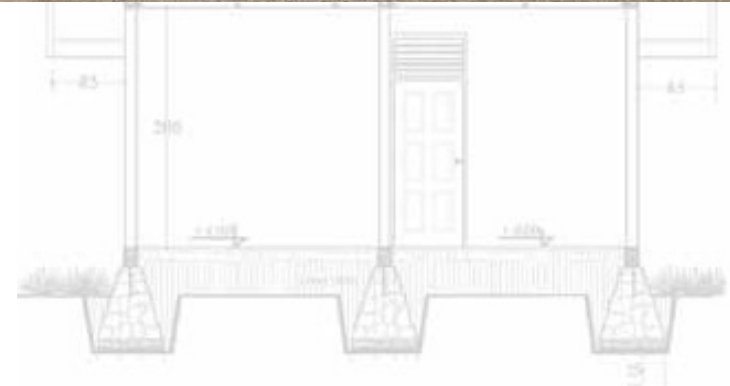
Step 1. Learn First



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Step 1. Learn First

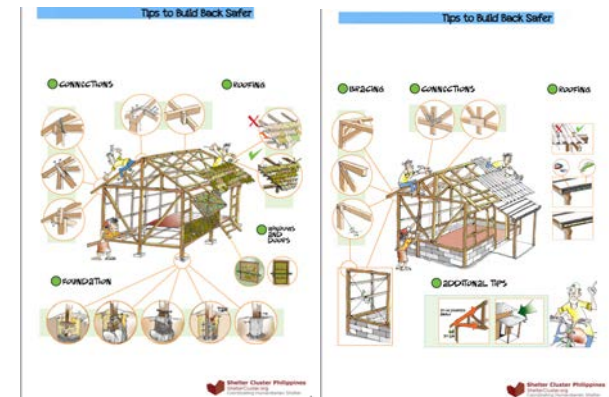


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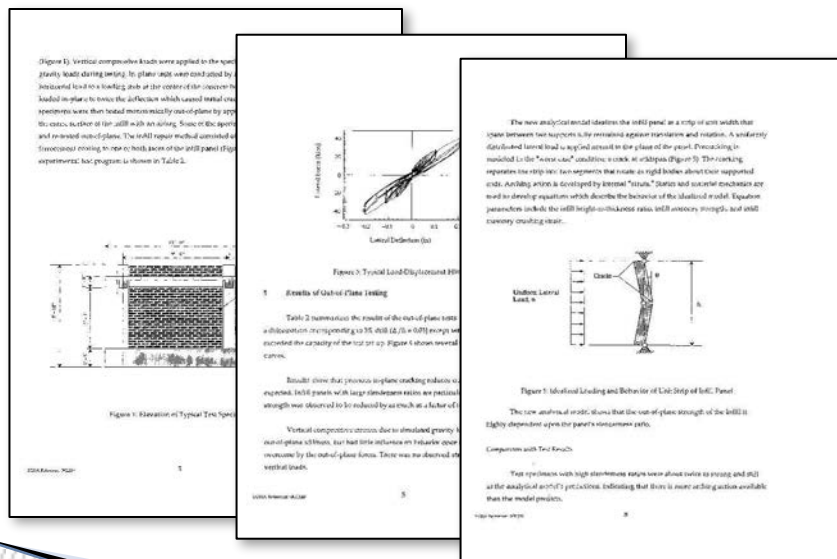
Step 1. Learn First

Existing Resources



World Housing Encyclopedia

A joint project by EERI and IAEE



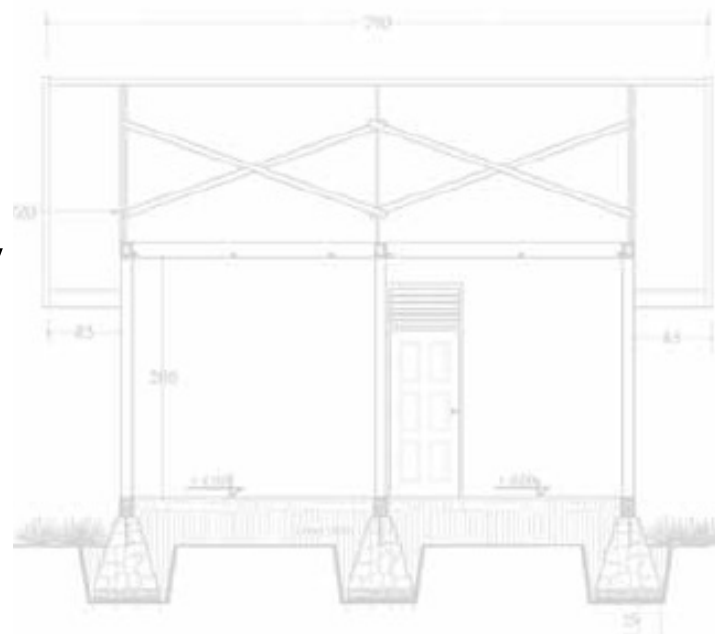
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Step 2. Develop Disaster-Resistant Design Solutions

Designs must be:

- Disaster resistant
- Culturally Appropriate
- Economical
- Feasible to execute correctly
- Flexible



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Disaster Resistant

Bring in experts to develop design guidelines and ensure designs comply with internationally recognized standards of safety.



In collaboration with:



Guy Nordenson and Associates



FORELL / ELSESSER ENGINEERS
Structural Engineers

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Culturally Appropriate

House fits its context



Maybe not so much



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Cost- and Resource-Efficient Solutions

- Take cues from common practice
- Using locally available materials
- Engineer economically
- Reduce waste
- Reuse materials



Step 2. Develop Disaster Resistant Solutions



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Earthquake-Resistant and Economical:



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Step 2. Develop Disaster Resistant Solutions



Earthquake-Resistant and Economical?

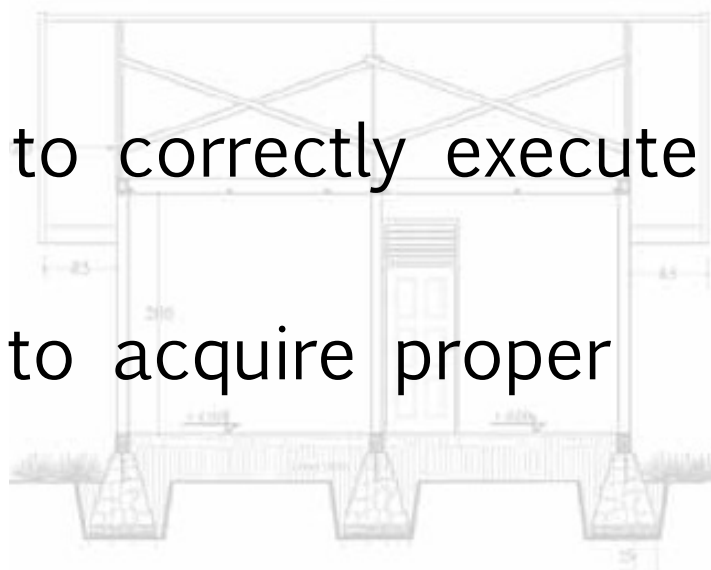
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Feasible to Execute Correctly

They must be built, after all.

- Feasible to train engineers to understand the design guidelines
- Feasible to train builders to correctly execute construction
- Feasible for homeowners to acquire proper construction materials



Feasible to Execute Correctly



Existing Practice



Recommended Practice



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Flexible

“Design” in the form of guidelines that can be used to tailor the house to fit:

- Budget
- Specific Needs and Desires of the homeowner



“Cookie Cutter” approach



VS.



Individualized Solutions

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Step 2. Develop Disaster Resistant Solutions



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COST (Materials and Labor) *as of 10/23/2012*

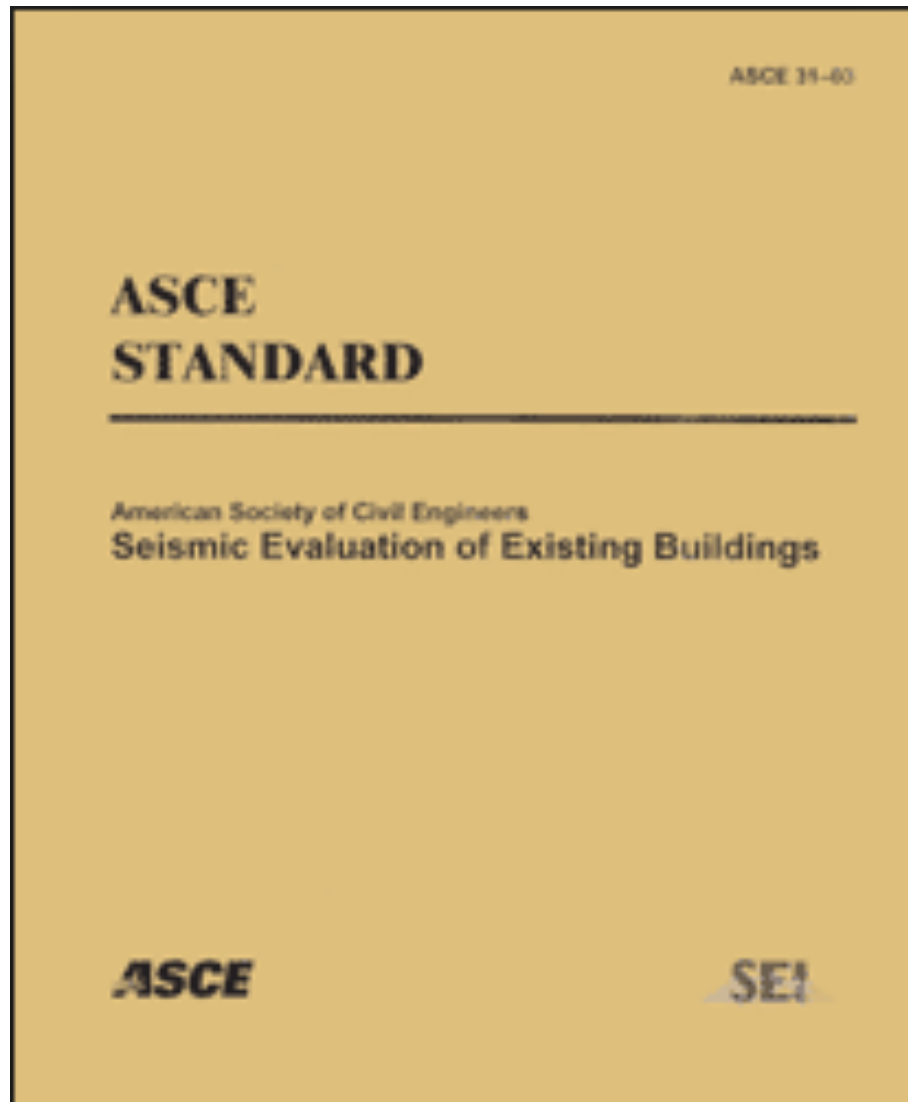
COST (US\$)	Villa Rosa (Canape Vert)	Ti Sous (Carrefour)
RETROFITS		
Red Tag Cost/m ²	\$99/m ²	\$84/m ²
Yellow Tag Cost/m ²	\$40/m ²	\$56/m ²
NEW BUILDS		
New Build Cost/m ²	\$219/m ²	\$182/m ²
Avg Cost Per Bldg	\$3,507	\$3,423



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Step 2. Develop Disaster Resistant Solutions



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Step 2. Develop Disaster Resistant Solutions



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Step 2. Develop Disaster Resistant Solutions

Seismic Evaluation Checklist: Low-Rise Haitian Masonry Construction Unreinforced, Confined, or Infill Masonry

		MASONRY WALLS	NOTES																																		
4.4	<div><div><div><div>Transverse</div><div>Story C-NC-N/A</div><div>3</div><div>2</div><div>1</div><div>Longitudinal</div><div>Story C-NC-N/A</div><div>3</div><div>2</div><div>1</div></div></div><div><p>WALL AREA PERCENTAGE: The provided Wall Area Percentage shall be greater than the required Wall Area Percentage at each level and in each direction. Note the Wall Area Percentage provided and required on the right, and C, NC, or N/A in the column to the left.</p><table><tr><th></th><th colspan="3"># Stories in Building</th><th></th></tr><tr><th>Level</th><th>1-Story</th><th>2-Story</th><th>3-Story</th><th>Notes</th></tr><tr><td>3</td><td>-</td><td>-</td><td>4.7</td><td rowspan="3">For buildings with heavy floors and roofs having concrete slabs, concrete joists, and masonry void forms.</td></tr><tr><td>2</td><td>-</td><td>4.6</td><td>8.1</td></tr><tr><td>1</td><td>4.0</td><td>6.9</td><td>9.6</td></tr><tr><td>3</td><td>-</td><td>-</td><td>3.0</td><td rowspan="3">For buildings with light roofs made of sheet metal and wood framing.</td></tr><tr><td>2</td><td>-</td><td>3.0</td><td>5.2</td></tr><tr><td>1</td><td>3.0</td><td>4.0</td><td>6.9</td></tr></table><p>Assumptions:</p><p>S_{ds} = 1.05g, for other design ground motion values ratio accordingly.</p><p>URM construction. For compliant CM or IM construction use 50% of these values, 1.5% minimum..</p><p>"Average" quality construction. For poor quality construction increase by 50%.</p><p>Concrete block strength is 4.8MPa. See Manual for adjustment to other strengths if required.</p><p>Building Evaluation, increase by one third for evaluation of a proposed Retrofit Design.</p><p>Block is typical 15cm, between 50% to 60% solid and not plastered. For other thicknesses and net solid area ratios adjust the required WAP accordingly.</p></div></div> <div><div>Wall Area Provided and Required</div><div>Transverse</div><div>Story Required Provided</div><div>3</div><div>2</div><div>1</div><div>Longitudinal</div><div>Story Required Provided</div><div>3</div><div>2</div><div>1</div></div>		# Stories in Building				Level	1-Story	2-Story	3-Story	Notes	3	-	-	4.7	For buildings with heavy floors and roofs having concrete slabs, concrete joists, and masonry void forms.	2	-	4.6	8.1	1	4.0	6.9	9.6	3	-	-	3.0	For buildings with light roofs made of sheet metal and wood framing.	2	-	3.0	5.2	1	3.0	4.0	6.9
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1	3.0	4.0	6.9																																		
5.0		BUILDING CONFIGURATION	NOTES																																		
5.1	C NC N/A	<p>TORSION: Walls are located on all exterior sides of the building, or within 25% of the plan dimension at the wall location, including L-shaped and T-shaped plans.</p> <p>Alternatively the estimated distance between the center of mass and the center of rigidity shall be less than 20% of the maximum building width in either plan dimension.</p>																																			
5.2	C NC N/A	<p>ADJACENT BUILDINGS: If floor and roof slabs of adjacent buildings are not vertically aligned, then the contact distance shall be greater than 3 cm for single story structures, 6 cm for two-story structures, and 9cm for 3-story structures. If floors and roof slabs are aligned the item is compliant.</p>																																			

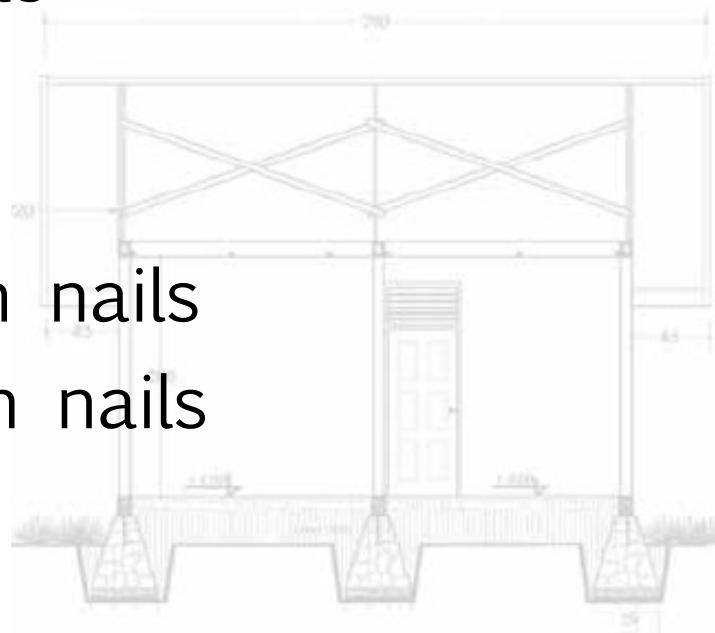
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Repair Kits

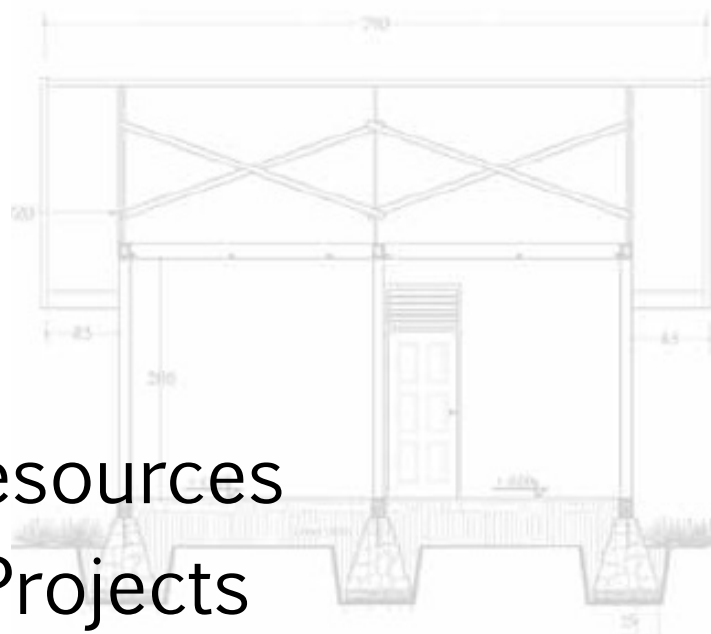
Rumored contents:

- 18 CGI roofing sheets
- 12 plywood sheets
- 1 kilo roofing nails
- 1 kilo large common nails
- 1 kilo small common nails



3. Build Local Capacity

- Build a Local Staff
- Deliver Trainings for:
 - Engineers
 - Builders
 - Homeowners
 - Government Officials
 - Students
- Create and Distribute Resources
- Supervise Construction Projects



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Train Engineers

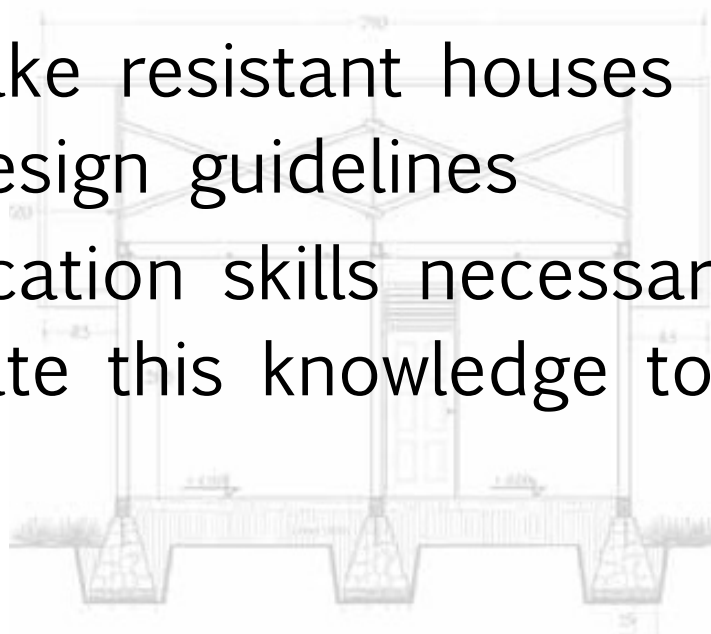


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Seek and Build Capacity Internally

- Practical Construction Knowledge and Ability
- Conceptual Understanding of Seismic Design Principles
- Ability to design earthquake resistant houses according to simplified design guidelines
- Leadership and communication skills necessary to execute and disseminate this knowledge to others



Design and Engineering Skills



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The Ability to Communicate this Knowledge to Others



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Build Engineering Capacity



① Seismic forces distributed according the first mode of vibration

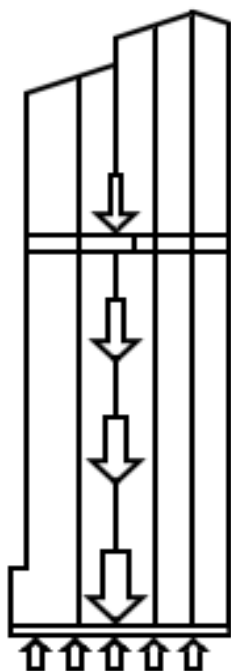
$$F_{id} = F_{bd} \frac{s_i W_i}{\sum s_j W_j}$$

② Seismic forces calculated according inverse triangular distribution of lateral displacements

$$F_{id} = F_{bd} \frac{z_i W_i}{\sum z_j W_j}$$

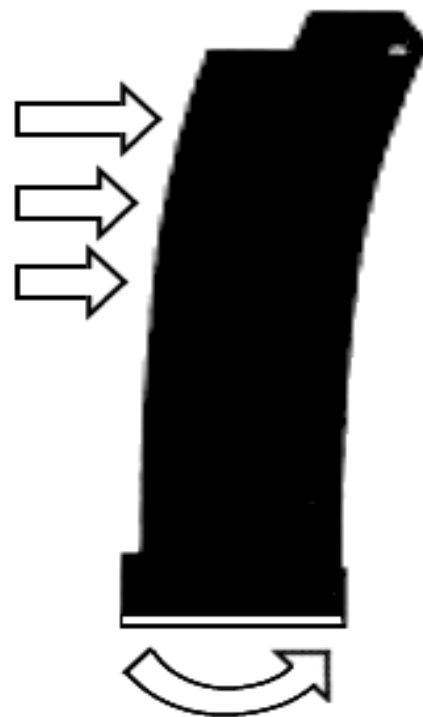
F_{bd} = design base shear force
 s_i = displacement of storey i in the 1st mode of vibration
 F_{id} = design horizontal seismic force acting at i -th storey

Conceptual Understanding of Seismic Design Principles



Gravity

vs

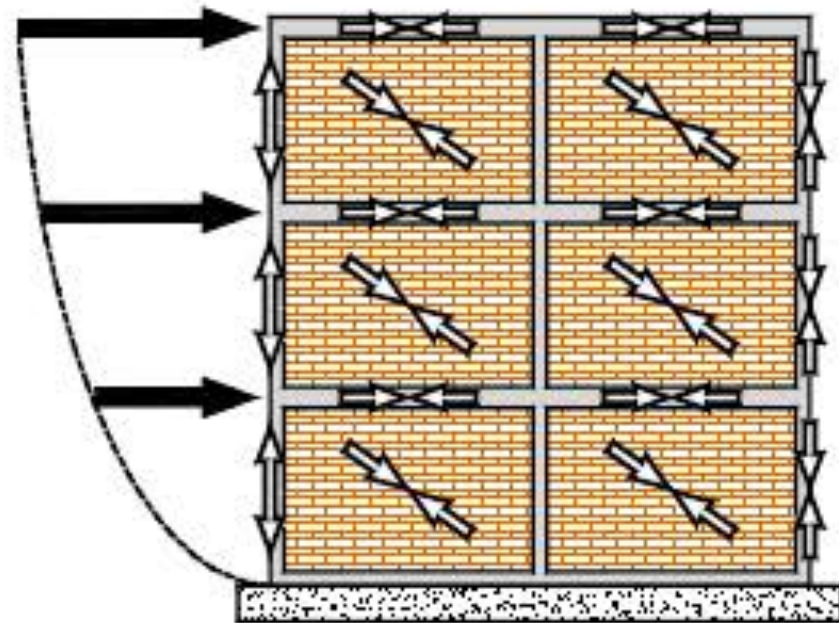
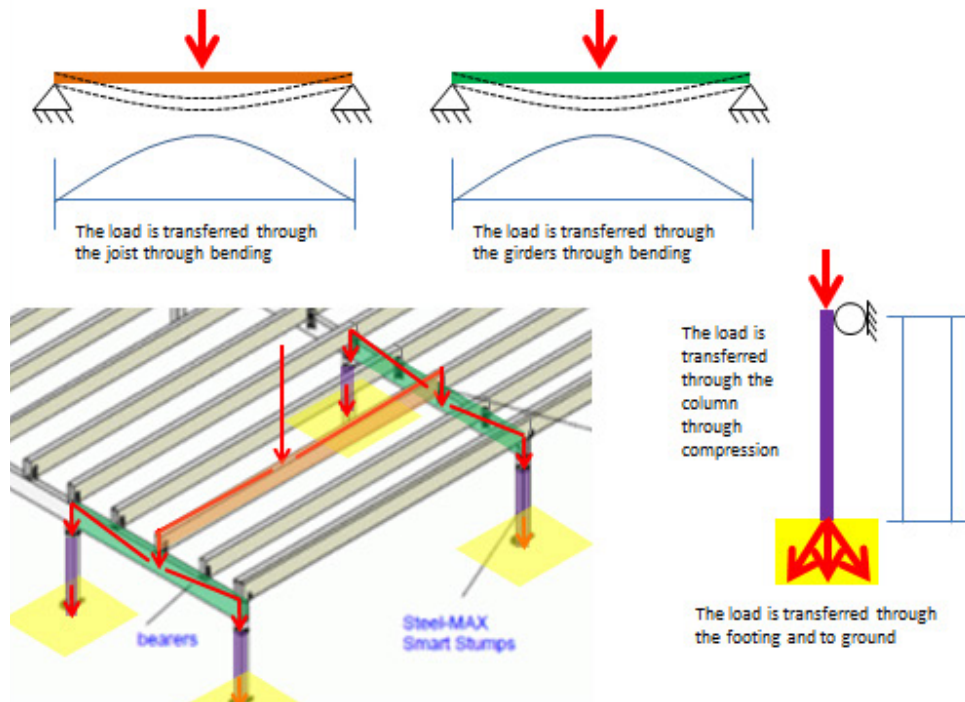


Seismic

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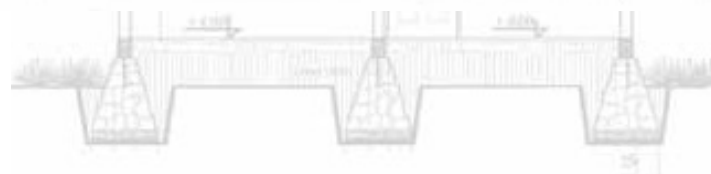
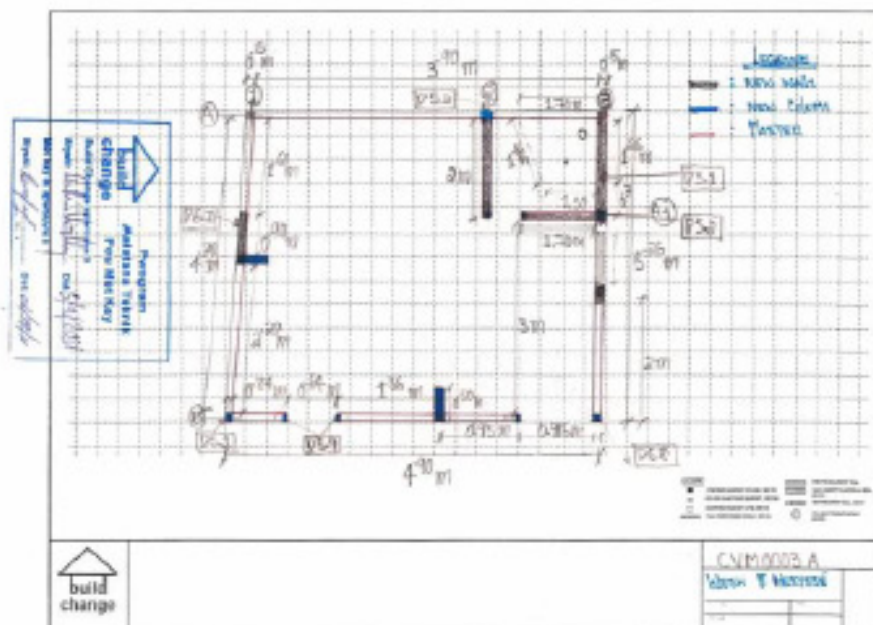
Step 3. Build Local Capacity



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Design Earthquake Resistant Houses According to Simplified Design Guidelines



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Step 3. Build Local Capacity

YOU CAN KEEP YOUR FAMILY SAFE FROM EARTHQUAKES!

Follow these important rules to build an earthquake resistant permanent house!



Why do some permanent houses collapse while others resist the earthquake? Learn the 3 **Cs**:

Configuration: Build a simple, symmetric shape, a square is the best!

Connections: Connect beams and columns together using steel overlap detail. Connect masonry to tie columns using steel reinforcement bar.

Construction Quality: Buy good quality materials and follow these important techniques...

PROBLEM

SOLUTION



Problem: No sloop beam, ring beam or tie columns



Use tie columns and bond beams to tie the walls together. Cast the column and ring beam concrete after you build the wall.



Problem: No overlap in steel connection



Make strong connections between confining elements (like columns and beams) by overlapping bars at least 40 cm



Problem: Collapsed masonry gable wall



Do not use masonry in the gable wall. It is heavy and can easily tip over and collapse. Use timber or build a hipped roof.



Problem: Walls with large windows and doors can collapse easily



For all walls with windows and doors, use a lintel beam or horizontal steel reinforcement, tied into the columns



Problem: Bricks laid dry, joints not filled completely with mortar



Build a strong wall by soaking the bricks in water before laying and filling joints completely with mortar



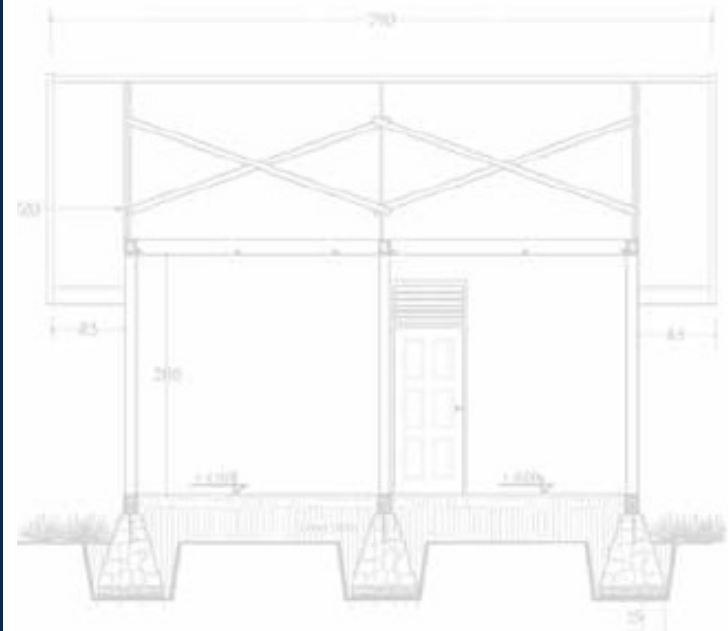
Problem: No connection between the walls and tie column



For all walls without openings, use besi stick to connect the bricks and column



Train Homeowners



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Step 3. Build Local Capacity

YOU CAN KEEP YOUR FAMILY SAFE FROM EARTHQUAKES BUILD WITH TIMBER INSTEAD OF MASONRY



Destroyed Masonry Home



Intact Timber Home

Timber is more flexible and lighter weight than bricks. It is easier and less expensive to build a safe, comfortable house from timber. A timber house is a better choice if you are building on soft soil or a sloped site as the timber house has fewer problems due to settling. It is also easier to repair if damaged.

FOLLOW THESE SIMPLE RULES TO BUILD AN EARTHQUAKE RESISTANT SEMI PERMANENT HOUSE:



Diagonal bracing in all 4 corners



Every connection must have peg



Keep wood column off ground with concrete starter



Wind bracing between truss



Use proper splice joinery



The masonry skirt may be made from bricks or concrete blocks but it must have a nail connecting masonry to column



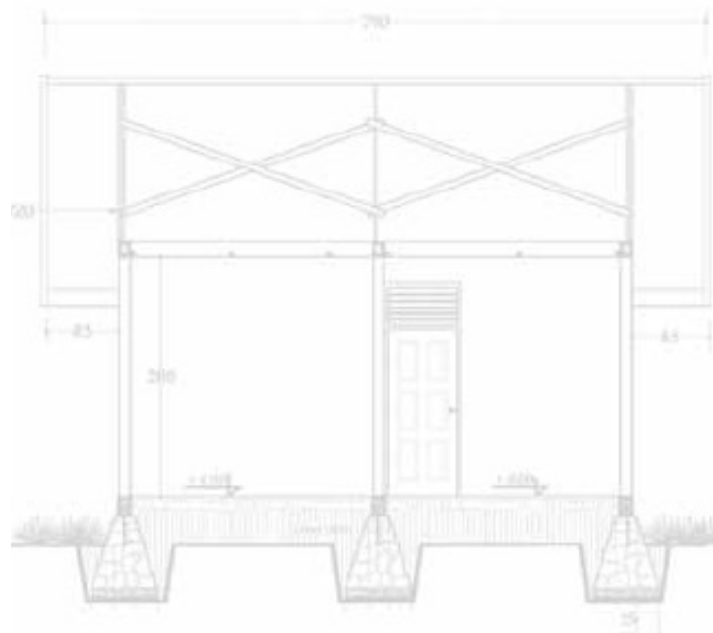
Before plastering, be sure to paint all timber with preservative paint



Install the chain-link lath and bend nails over to stretch it tightly



Install backing boards and plaster



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Step 3. Build Local Capacity

Big Messages

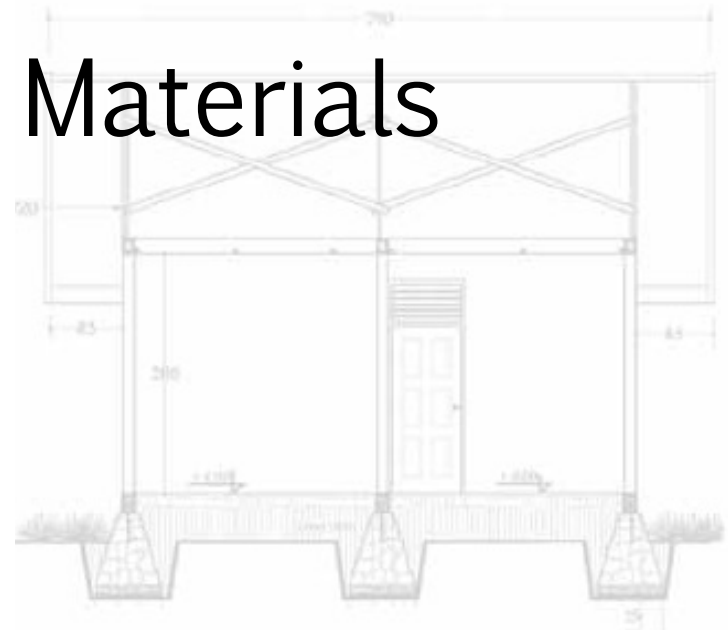
1. You CAN keep your family safe from earthquakes.
2. Build back better. More earthquakes and typhoons are coming.
3. Build a timber house. It's safer than a masonry house.
4. Don't use masonry in your gable wall. It's too heavy.
5. Don't use concrete blocks that break when dropped on the flat side on hard earth from chest height.
6. Plastering your masonry house makes it stronger.
7. Use diagonal bracing in your timber house.
8. Build a ring beam at the top of your masonry wall.
9. Make connections strong, from the roof to the foundation.
10. Use 40cm overlaps to connect rebar, not short laps or short hooks.
11. Use rebar dowels to connect masonry walls to columns.
12. Use reinforced concrete lintels above windows and doors.
13. Don't use limestone or coral or beach sand or aggregates to make concrete or concrete blocks.

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The Three C's:

- Configuration
- Connections
- Construction and Materials Quality







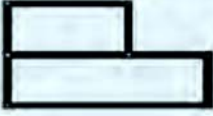

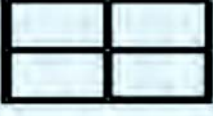
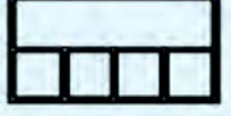




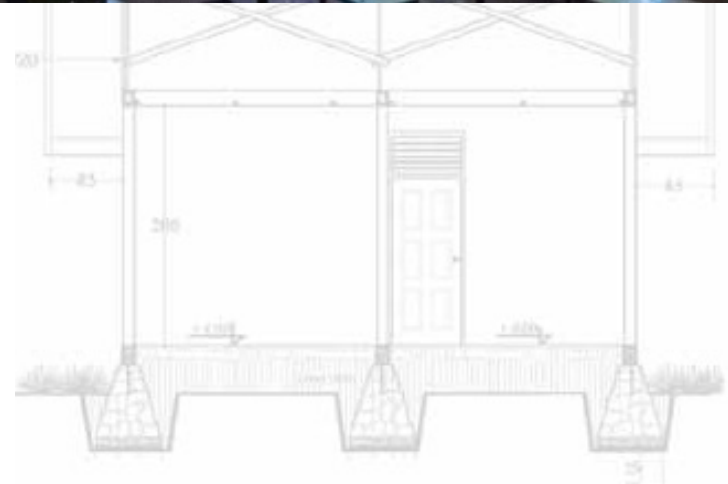
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Configuration

iPad 06:54 74%

No	BUILDING FORM	
	 Good	 Poor
1		
2		
3		
4		
5		



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Connections



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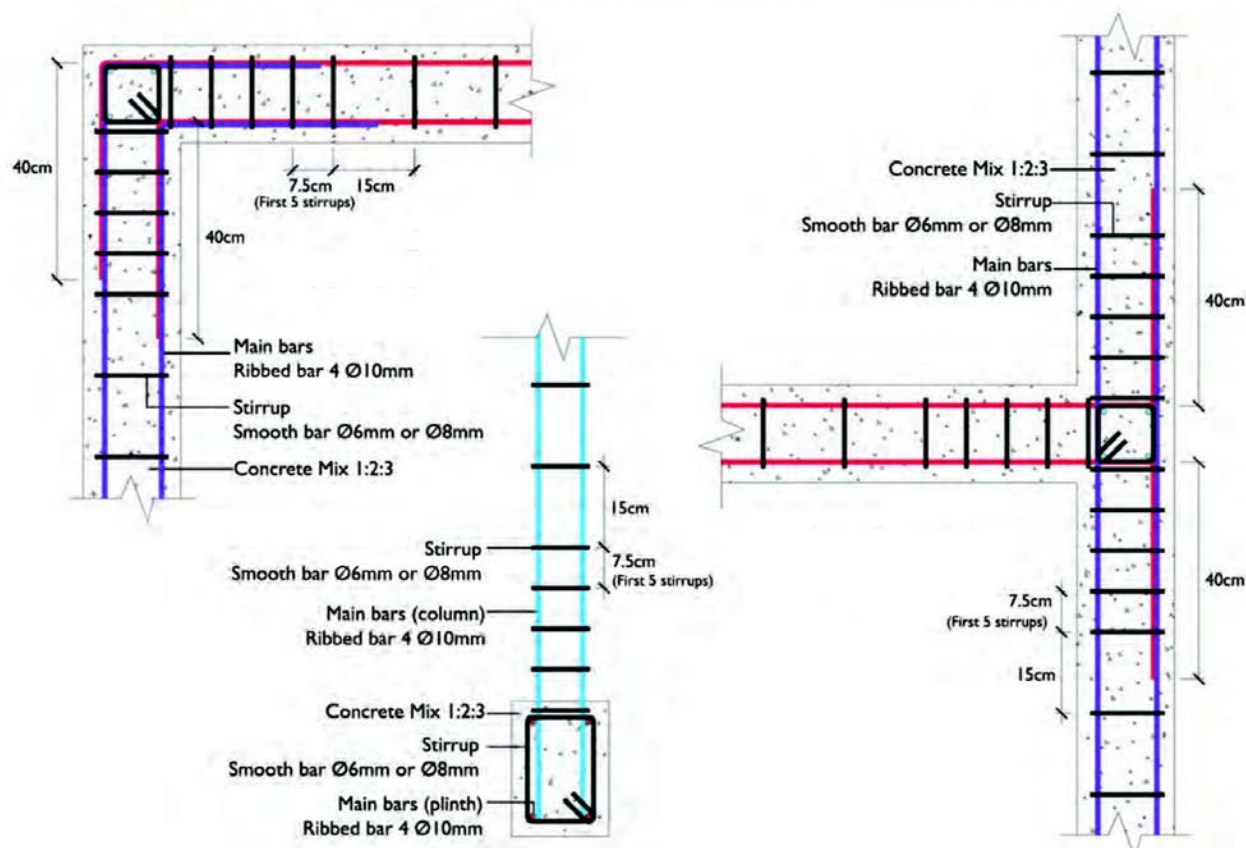
Construction Details

iPad

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72%

STEEL REINFORCEMENT CONNECTION DETAIL: L AND T JUNCTION



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50

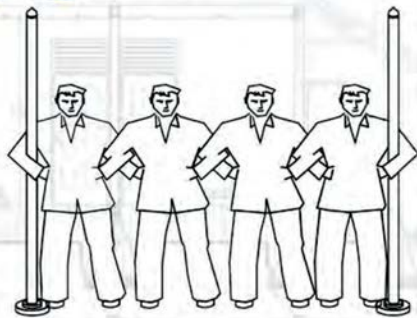
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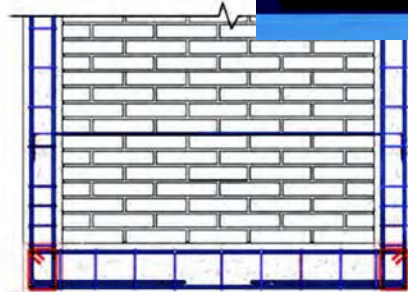
Graphic Explanations

iPad 06:56
SOLUTION

 **BEST**



Using steel reinforcement in the wall will strengthen the wall itself and connect the wall to the tie columns, like linking arms together against the earthquake.







Use steel reinforcement in the horizontal bed joint every 7 courses of masonry and above and below all window and door openings.

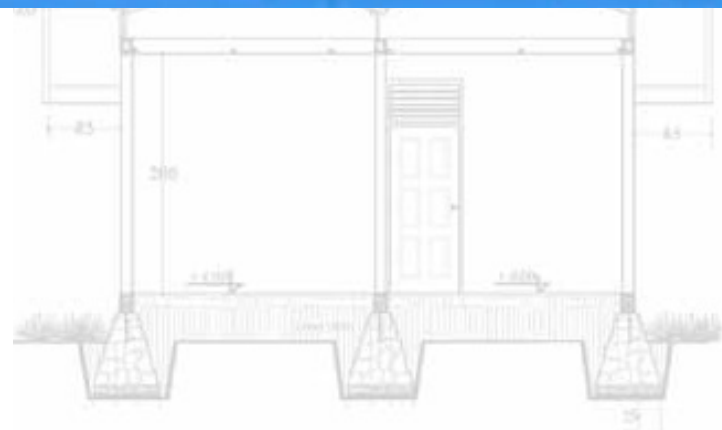
For more information see page 62-63

Option 2:

Use steel reinforcement in the horizontal bed joint

iPad 06:55 73%

 <p>Good Strong steel reinforcement connections will save our lives and families</p>	 <p>If we hold together tightly, we will stand against earthquake shaking; we won't separate or release easily</p>
 <p>Bad Weak connections will endanger our lives and families</p>	 <p>A loose grip will not withstand earthquake shaking; it will separate easily</p>



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Connections



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13 Connect the Truss to the Ring Beam



Good



Install U plate at locations where the truss cord can tie to the plate



Good



Install U plate so that it sticks out above the ring beam approximately 10 cm



Good



Poor



Use bolt diameter $\frac{1}{2}$ " to tie U plate with truss



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Change Construction Practice Permanently

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Step 3. Build Local Capacity



Good Quality Materials, for YOUR SAFE HOUSE !

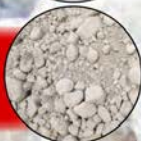
BUILDING MATERIALS Examine before buying for your home.
If not, you will be in danger during the next earthquake!



NOT RECOMMENDED



Avoid using **SMOOTH STEEL** and **USED STEEL** that is rusty, especially for primary reinforcement.



For concrete work, do not use smooth gravel / mixed with soil or sand.



Do not use sand mixed with mud or soil.



Avoid using stones with a smooth or muddy surface for stone masonry work.



Do not use warped wood, wood with fibrous texture, or wood that has a lot of knots and bark.



Do not use weak brick from old buildings and has a lot of cracks.
(Test bricks before buying them using the simple method shown. If at least 3 of 7 bricks break when stepped on by an average size man, then the bricks are too weak. Find stronger bricks elsewhere.)



Test concrete blocks by dropping them from shoulder height. If at least 2 of 5 blocks break, the blocks are not good, and you should search elsewhere for strong blocks.



RECOMMENDED



For Main Reinforcement, use (SNI) min. Ø 10 mm (new ribbed steel without rust).



Use gravel / crushed stone. Crushed aggregate will be angular instead of round. The maximum diameter should be 2 cm.



Use clean sand / not dirty and mixed with mud or soil



Use **MOUNTAIN STONE**, sized 15-30 cm, with rough surfaces clean of soil.



Use wood grade I & II with a smooth surface.



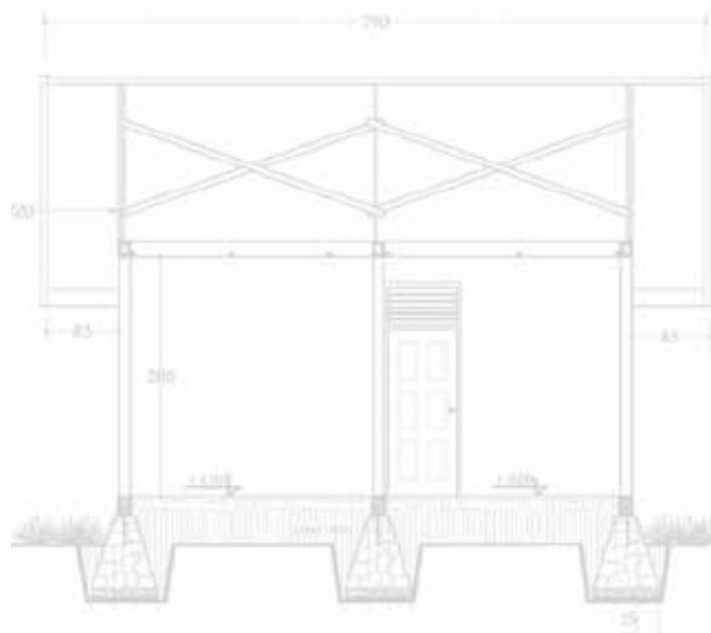
Good bricks will not break when subjected to the simplified test. Good bricks are reddish crimson in color and makes a shrill sound when tapped.



Use **STRONG BLOCK**. Strong block will not break when dropped and make a metallic sound when tapped.



Train Homeowners



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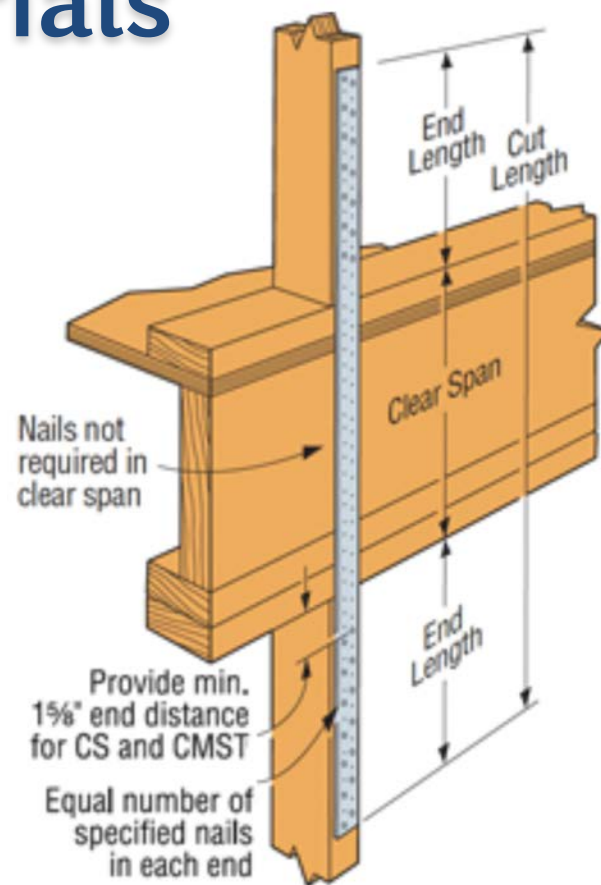
Train Materials Producers and Suppliers



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Construction Materials Quality



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Train Builders



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Practical Construction Knowledge and Ability



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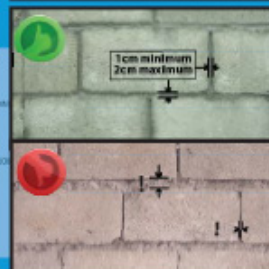
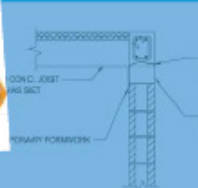
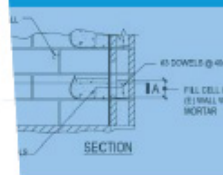
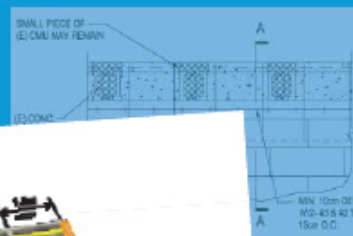
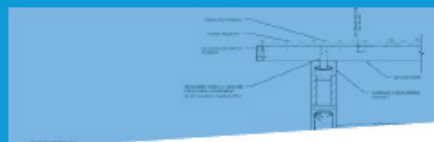


Step 3. Build Local Capacity



GUÍA FOTOGRÁFICA DE REFORZAMIENTO

Ayuda visual en la ejecución de refuerzos anti sísmicos



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Work with Local Agencies



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Vision

TESDA is the leading partner in the development of the Filipino workforce with world-class competence and positive work values.

Mission

TESDA provides direction, policies, programs and standards towards quality technical education and skills development.



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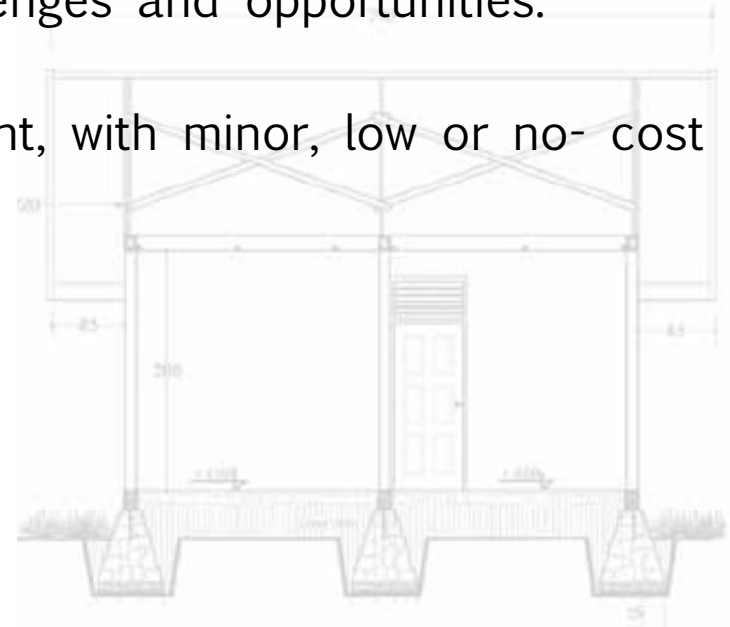
4. Stimulate Local Demand

Importance of low cost designs

— We develop our designs to be as low cost as possible, so they are accessible to the poorest, most vulnerable communities.

— We undertake research in communities to understand their views on making a home safe, noting the challenges and opportunities.

We make the design easy to implement, with minor, low or no- cost changes to existing ways of building.



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Step 4. Stimulate Local Demand

- We encourage the use of local materials to stimulate demand for local suppliers.



- However many countries import a lot of their materials so there are limits to this approach.

Use of Local Builders

- Encourage hiring of local builders to invest in local economy.



- Aim to have trained network of builders in ERDC that can be hired directly following disaster.

**Build Earthquake Resistant Houses
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Permanently**



Market creation and improving local economy

- Aim to create a market for better building materials.
- Safer materials will have mark to show they are earthquake resistant.
- Raise awareness through campaigns and training among local communities, builders, government on benefits of these safe products.



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Challenges

- Lack of education about good practice
- Bad practice is passed down throughout the generations
- People are reluctant to change their ways
- People are reluctant to invest in good quality home, builder, and materials if costs are higher.

5. Facilitate Access to Capital

- Not all homeowners can afford the additional financial cost to create a safe house.
- Often, these homeowners are the most vulnerable to disaster, from a poorer background lacking access to capital.
- It is important they too, live in a safe home.

Financial Assistance and Incentives

- Donor funds, Government funds
- In form of:
 - Money
 - Vouchers for Materials
- Given in Tranches (installments)
- Contingent upon meeting minimum construction standards



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Example 1 of Disbursement Structure

All Needed Funds Provided

Most
Pressure

- Tranche 1 -30%
 - Foundation + Plinth
- Tranche 2 -30%
 - Walls, Columns, Beams
- Tranche 3 -30%
 - Roof and Finishing
- Tranche 4 -10%
 - Holdback/Bonus

Most Critical
Tranches
for Structure

Least
Pressure

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Example 2 of Disbursement Structure

Homeowner Contribution Required (at beginning)

Most
Pressure

- Homeowner's Pocket

- Foundation + Plinth

- Tranche 2 – 50%

- Walls, Columns, Beams

- Tranche 3 - 35%

- Roof and Finishing

- Tranche 4 - 15%

- Holdback/Bonus

Most Critical
for Structure

Least
Pressure

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Quality Assurance Checklist

- Used as verification tool to confirm construction meets standards
- Confirms whether the homeowner is eligible to receive the next tranche



Step 4. Stimulate Local Demand

Cordin No.: _____
BC Engineer: _____

Homeowner: _____
Boss: _____

Homeowner telephone: _____
Boss Telephone: _____

D0.2

Repair of wall to roof connection

Method

- 1a Remove loose and flakey masonry using chisel and wire brush
- 1b Roughen underside of slab using chisel
- 2 Mix dry-pack (Cement:Sand 1:2). Add just enoght water so that you can form a ball of mortar that sticks together.
- 3 Pack gap with mortar using a hammer and wooden dowel to completely fill joint.



Checklist

1	Surface Preparation	Implemented correctly ?	Date	Photo #	If step not correctly implemented, following advice given:	Advice followed?	Date	Photo #	Action taken if advice not followed:
a	All loose and flakey material has been removed	Yes / No				Yes/No			
b	Roughen underside of slab using chisel	Yes / No				Yes/No			
2	Mortar Mixing	Implemented correctly ?	Date	Photo #	If step not correctly implemented, following advice given:	Advice followed?	Date	Photo #	Action taken if advice not followed:
a	Use mortar 1:3 mix	Yes / No				Yes / No			
b	Use clean, fine river sand	Yes / No				Yes / No			
c	Use clean water (not salty or muddy)	Yes / No				Yes / No			
d	Use Type 1 Cement	Yes / No				Yes / No			
e	Mix on a clean, concrete or asphalt surface, not on dirt	Yes / No				Yes / No			
f	Turn over 3 times or until color is uniform	Yes / No				Yes / No			
g	Add just enoght water so that you can form a ball of mortar that sticks together.	Yes / No				Yes / No			
3	Implementation	Implemented correctly ?	Date	Photo #	If step not correctly implemented, following advice given:	Advice followed?	Date	Photo #	Action taken if advice not followed:
a	Use hammer and wooden dowel to pack mortar into joint	Yes / No				Yes / No			
b	Joint completely filled	Yes / No				Yes / No			

Homeowner Signature: _____

Date: _____

BC Engineer Signature: _____

Date: _____

BC Team Leader Signature: _____

Date: _____

Overall Assessment: Meets Minimum Standard?

Yes / No

Comments:



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Permanently**



Step 4. Stimulate Local Demand

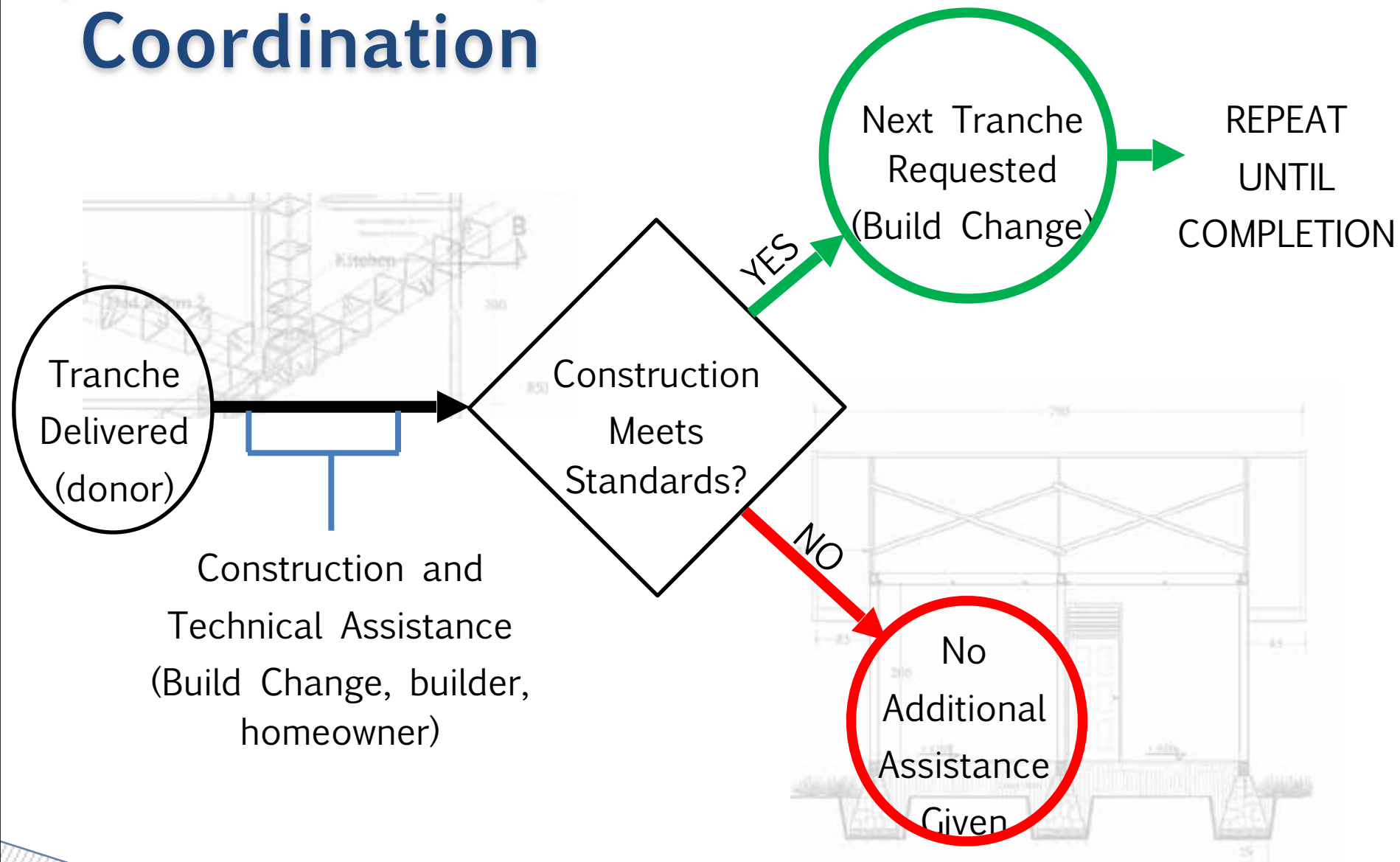


Checklist Photos

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Coordination

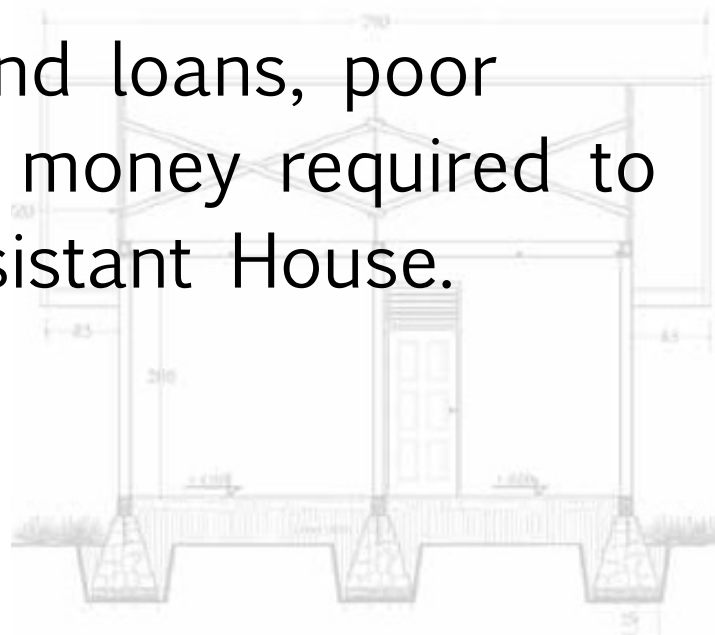


However...

- A minimal percentage of “lost” houses should be expected
- The more supervision, the greater the success rate.
- Quality technical assistance requires a lot of human resources
- Money may be allocated elsewhere to meet other demands such as food, healthcare, education.
- *Discussion Lessons Learned: Haiti and Indonesia*

Microfinance

- Microfinance is the supply of loans, savings and other financial services to the poor.
- With access to savings and loans, poor households can save the money required to create an Earthquake Resistant House.



Microfinance: Challenges

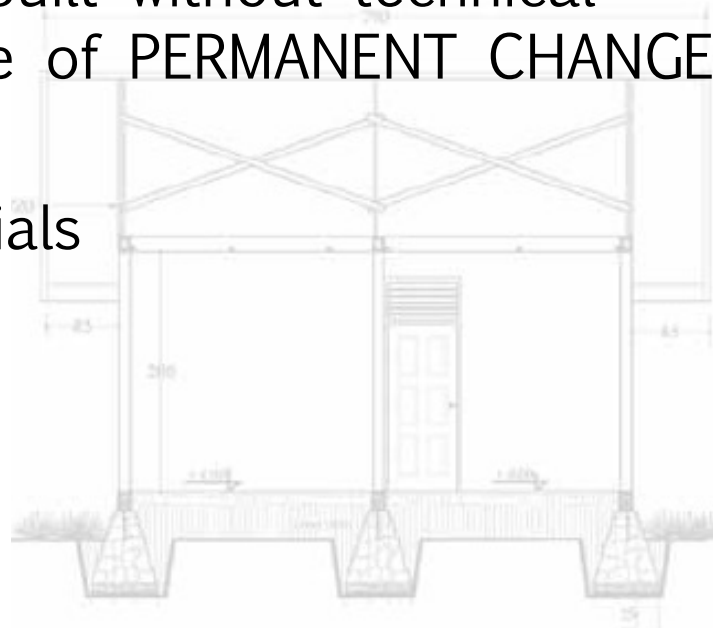
- However, as the loan is small with high risk, interest rates can be high because transaction costs remain high.
- Gender issue: women are more likely to invest money in their household/home than men
- Will the investment of a house help the homeowner gain the financial capital to pay back the loan?
- High risk involved, will people pay the money back?
- NGO programs in microfinance often fail, but are more successful when communities run them themselves

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Step 6. Measure the Change

- Direct impacts: Safer homes, Homeowners, Builders, Engineers, Government officials trained
- Indirect impacts: Safer homes built without technical assistance... This is the essence of PERMANENT CHANGE!
- Losses: Homes, Builders, Materials
- Lessons Learned



*Thank you. Please contact
any of us at Build Change.*

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+63 939 466 9884

www.buildchange.org

Build Change so far:

15,000 people trained in earthquake-resistant construction

20,000 earthquake-resistant homes built or retrofitted

80,000 people safer



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