REBUILDING 101 MANUAL

Rebuilding Strategies for Haiti
March 2010

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This document is intended for use by AfH employees and Design Fellows.

architecture for humanity

INTRODUCTION

This manual seeks to provide basic advice on proper construction methods and job site safety specific to rebuilding efforts in Haiti after the January 2010 earthquake. Haiti is in the initial stages of reconstruction, and much of the destruction and injuries that occurred could have been prevented by following proper construction methods. The strategies herein are intended to be used by Architecture for Humanity staff and volunteers, and are in no way meant to provide a comprehensive strategy for rebuilding. Rather, we seek to highlight the most basic and necessary elements and strategies for building in earthquake and hurricane zones.

The content is divided into three illustrated sections: Site Safety highlights proper conduct on the construction site; Construction Guidelines outlines principles and techniques necessary for buildings to withstand earthquakes and hurricanes, as well as maintenance; Construction Materials and Techniques addresses the availability of building components and their proper manufacture.

Reconstruction will be a long, extended process, but taking action from the earliest days can avert future disaster and is significant to the overall introduction of expertise needed to successfully build back better.

Architecture for Humanity
San Francisco, California, USA
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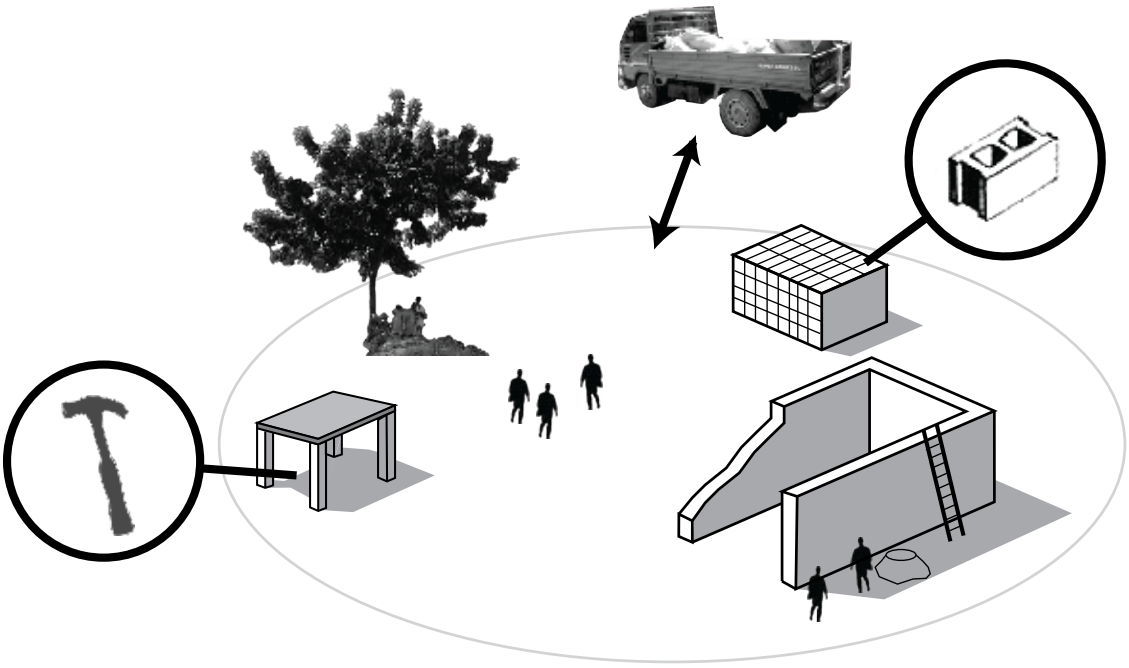
I. SITE SAFETY

Construction sites share a set of components. No matter the size of the job, the site demands care, precaution, and organization. Before a building is completed materials must be secured, assembled, organized and deployed by a team of individuals. Tools can range from small hardware to large trucks, and each has its own use, hazards and appropriate handling methods. This section discusses necessary safety rules applicable to every construction site.



1.1 Pay Attention

There's a lot of activity on a construction site. Be aware of what's going on and avoid distraction. Think before doing a task and know what you are doing. When in doubt, ASK QUESTIONS FIRST! Show respect for your work, the site and other workers. Do not smoke or drink alcohol while working, or drink before work.

1.2 Proper Attire

Falling, flying and abrasive objects cause injuries that can be avoided through protective clothing. If at all possible, wear a hardhat and closed-toe shoes. Wear gloves when handling concrete, lumber, cable, or any material that can cause injury to your hands. Wear eye protection when there's risk of flying debris. Always wear dust masks when working in dusty conditions--particles of drywall, cement and wood can be hazardous to your health if you breathe them in.

1.3 Site Cleanliness

An organized and tidy site leads to safety and ease of operation. All items have a place and tools should be placed in a protective shed when not in use. Clear site of scraps and debris daily, and make sure to put away your tools so they do not get stolen or lost.

1.4 Tools

Make sure the tool you are using is the correct tool for the job, and is clean and sharp. Be sure you know how to handle the tool before using it. Keep points and blades facing downward. Do not leave tools in precarious positions when unattended--put them away when not used. Keep tools clean, and make sure they're not broken. Ensure guards are in place and adjusted before use. When working with power tools be sure that you are familiar with their proper use. Never carry a tool by its cord. Never use a power tool if cord is frayed.

1.5 Ladders and Heights

Ladders can easily become hazardous. Make sure the top reaches 1 meter (or 3 feet) beyond the point of support. Be sure the ladder is leaning against the wall and is not supporting its own weight. Make sure ladder rests solidly and level on the ground. Do not extend both shoulders beyond ladder. Make sure it is sturdy and never use in inclement weather.

1.6 Lifting

Keep heavy loads close. Lift with your knees, never bend at the waist. Lift smoothly–if you have to jerk your body, the object is too heavy. Don't be afraid to ask for help!

1.7 First Aid

Injuries can happen regardless of how much precaution you take. Keep a first aid kit on site and know where it is located. Know who has first aid training and how to contact them immediately when there's an injury. Look out for the safety of others and take preventative action to avert catastrophe. Identify someone trained in first aid on each site early on and establish an emergency action plan, including a designated assembly area.

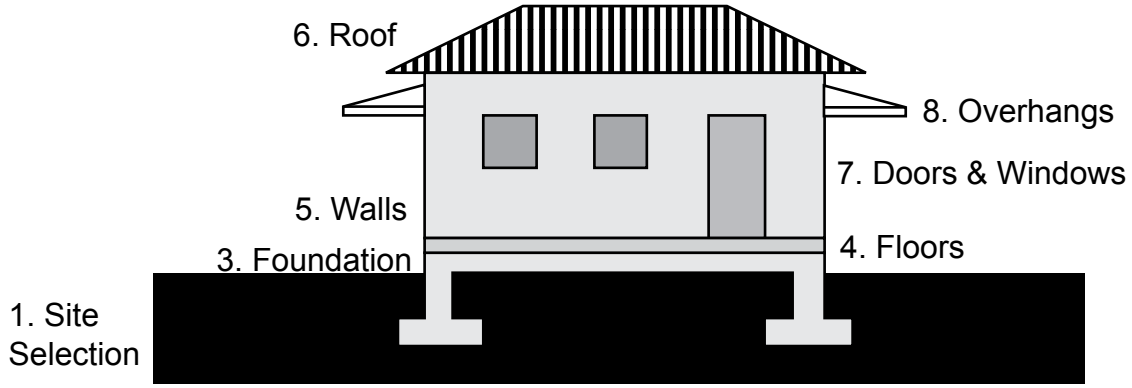
1.8 Working in Heat

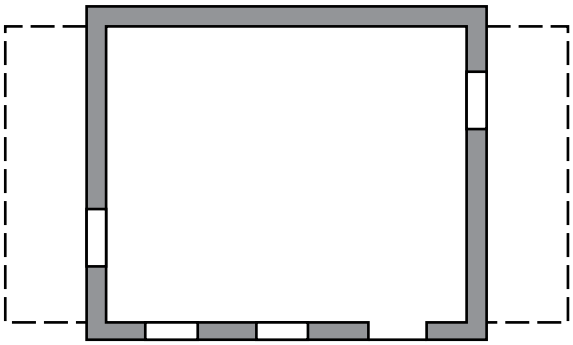
Stay hydrated, and when overheated get out of the heat quickly. Rest in a building that has air-conditioning. If you can't get inside, find a cool, shady place. Drink plenty of water or apply cool water to your skin. Take off any tight or unnecessary clothing. If you do not feel better within 30 minutes, you should contact a doctor. A heat stroke victim's skin is hot, usually dry, and the victim is mentally confused, delirious, in convulsions, or unconscious. Unless the victim receives quick and appropriate treatment, death can occur. If you think someone might have heatstroke get medical assistance immediately. If medical assistance is not immediately available remove unnecessary clothing to cool him or her down. Fan air over the person while wetting the skin with water. Also apply ice packs to armpits, groin, neck and back.

II. CONSTRUCTION GUIDELINES

Buildings of one to two stories can be safely built by hand, provided general guidelines are followed and appropriate materials found. Haiti is an especially hazardous part of the world as it is vulnerable to hurricanes, earthquakes and tsunamis. Proper construction precautions are a necessity to preserving life and livelihood and can certainly be accomplished if the proper principles and techniques are followed.

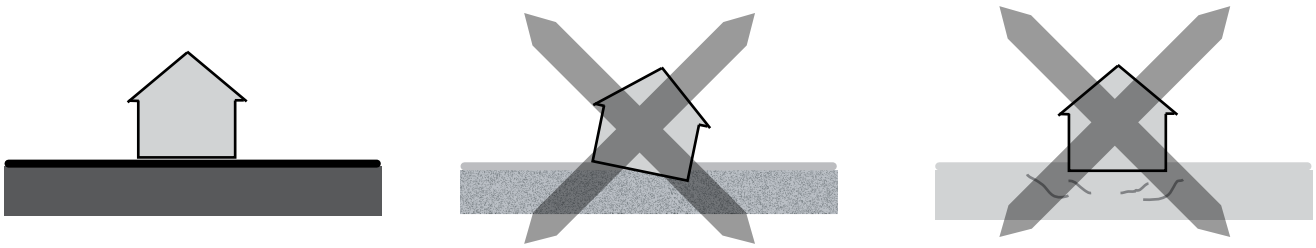
The following guidelines cover some of the most important strategies for proper construction. These construction tips are divided into elements of a building that correspond with how buildings are constructed: site selection, layout/planning, foundation, floors, walls, roof, windows, doors, overhangs and porches.



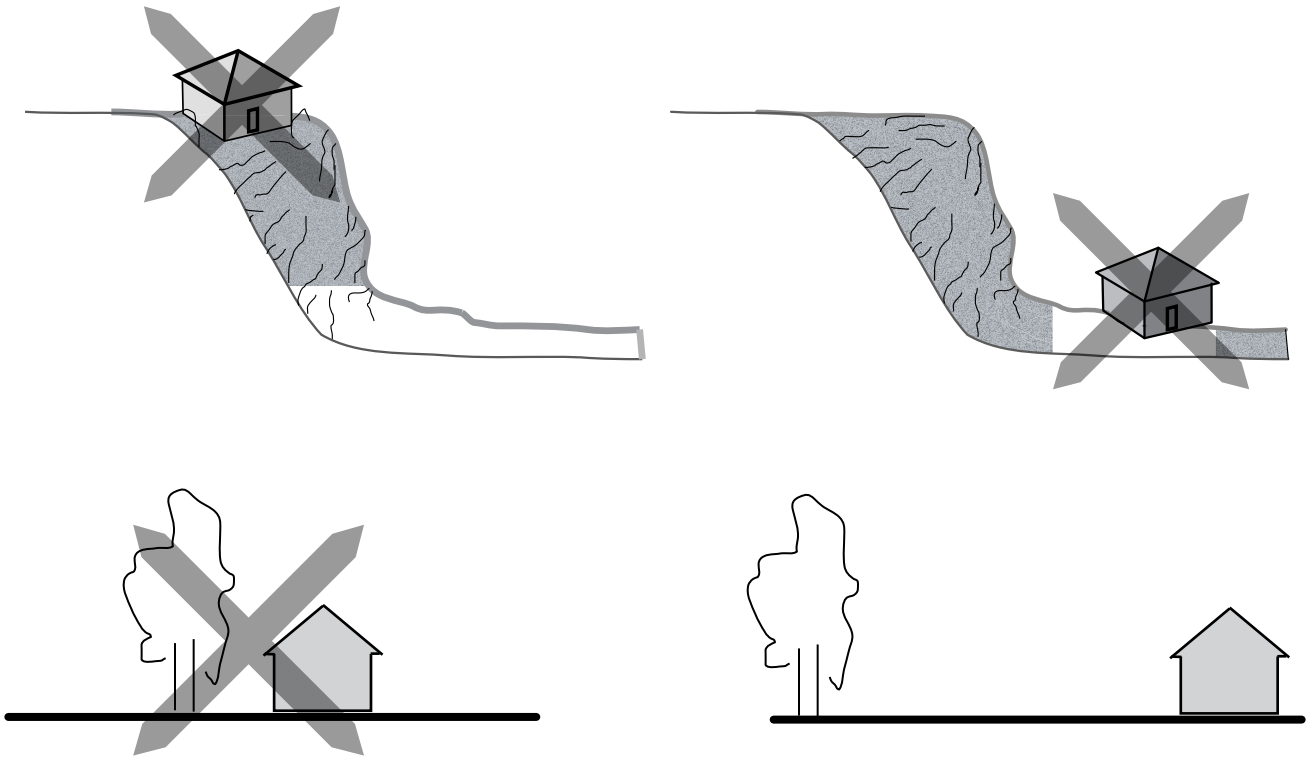


2.1 Site Selection

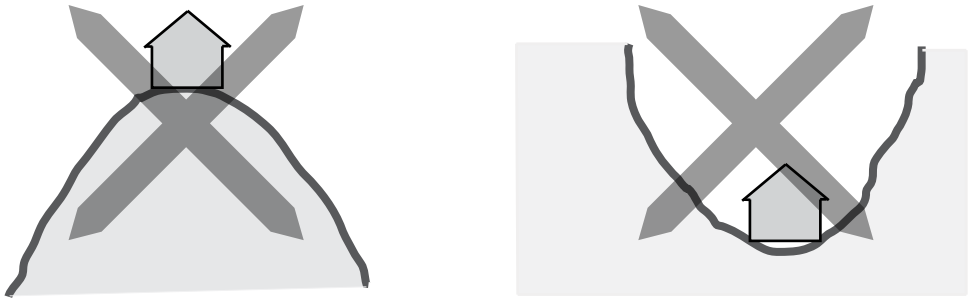
Selecting an appropriate site is a very important step to ensure building stability. Make sure that the ground is firm and will remain stable in severe weather. Unprotected and gusty sites should be avoided as strong winds are a major concern. A proper site should be safe and stable. Because surface soil conditions are sometimes false signs, dig down in several spots of the site to verify consistency–see Foundations for more information.



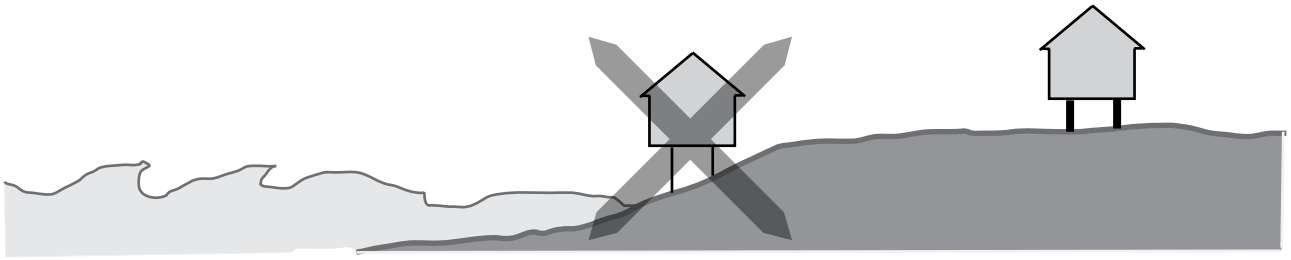
2.1.1 Solid ground is important for the stability of a building. Avoid sites with loose sands, gravel, or sensitive (expansive) clays.



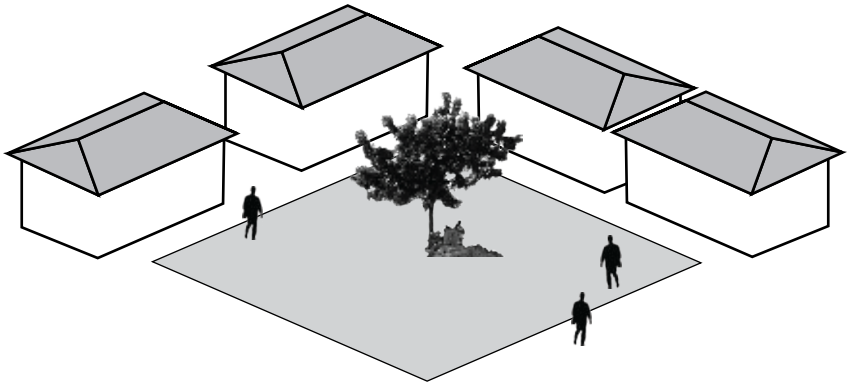
2.1.2 Dwellings should not be built below or above potentially loose rocks or boulders. Avoid building beside or beneath large trees, as they may fall in a large storm.



2.1.3 Avoid building on tops of hills or in deep closed-in valleys. Winds are concentrated in these areas.



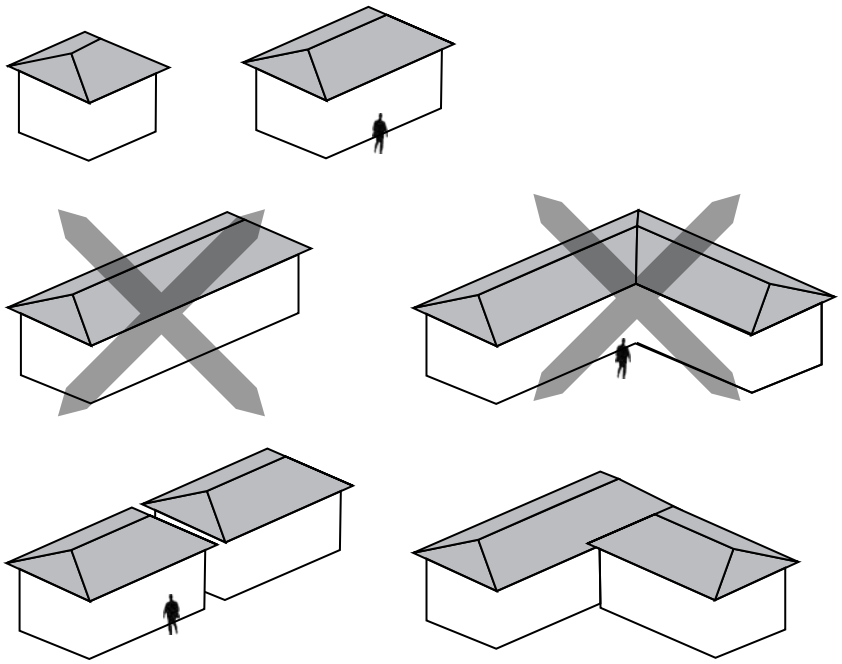
2.1.4 Hurricanes and heavy storms cause floods. Buildings should be away from the open sea, river banks, bodies of water, or slopes prone to torrents in rainfalls. On sites where the risk of flooding is unavoidable, bulidings put on knee walls or piles reduce the possibility of damage.



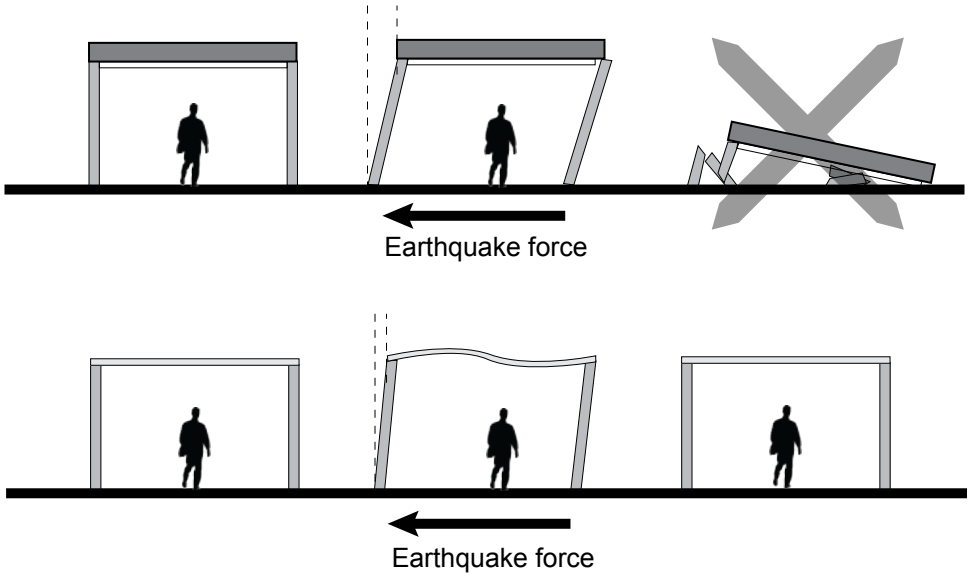
2.1.5 Coordinate construction sites with neighbors. Consider saving room for a town square, garden or soccer field. Consider an appropriate place for amenities, toilets, and kitchens.

2.2 Layout / Planning

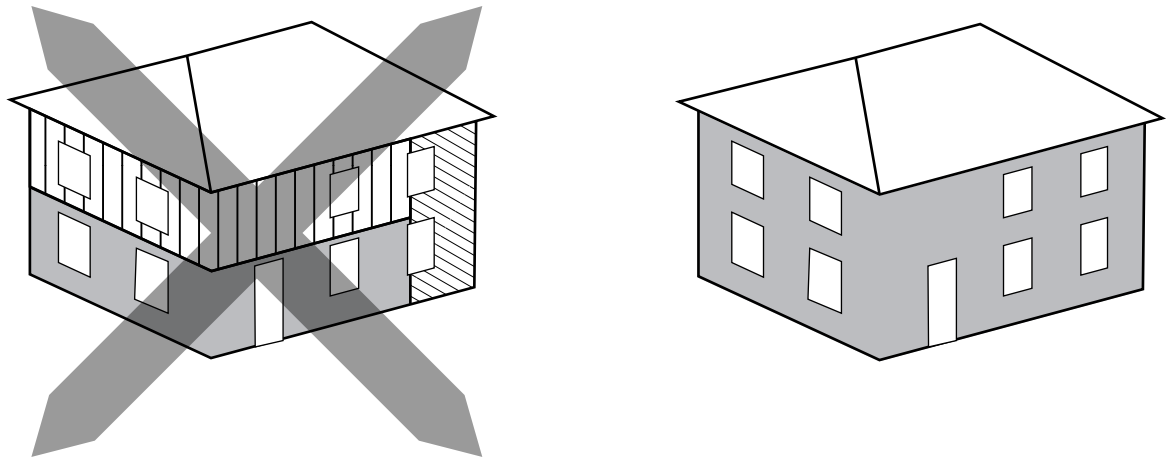
The most stable buildings have simple layouts and are uniformly built. Where complexity cannot be avoided, buildings should be divided into simpler, structurally autonomous pieces.



2.2.1 Buildings should be rectangular and limited to two or fewer stories. Squares and small rectangles are best. If the footprint is complex, or if the building is of varying levels, seismic separation is needed. Separate the structures into smaller, self-sufficient rectangles.



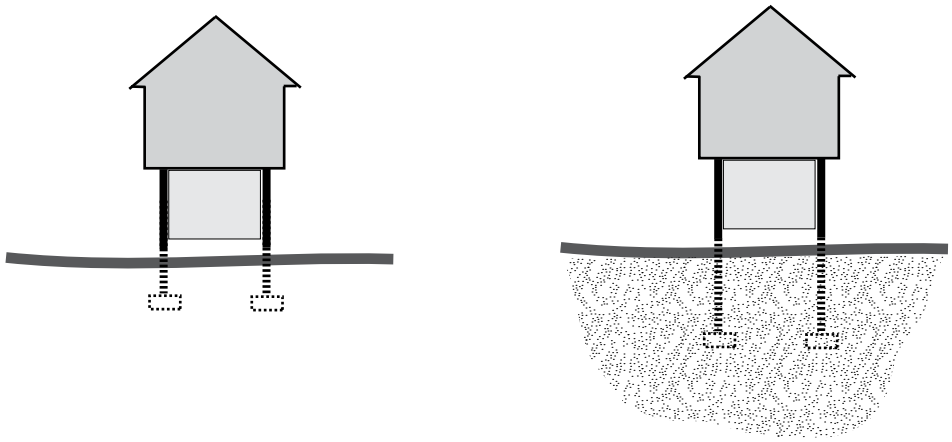
2.2.2 Do not make buildings top-heavy. Heavy roofs are dangerous in earthquakes. Keep the roof light and flexible and keep large objects or machines off the roof.



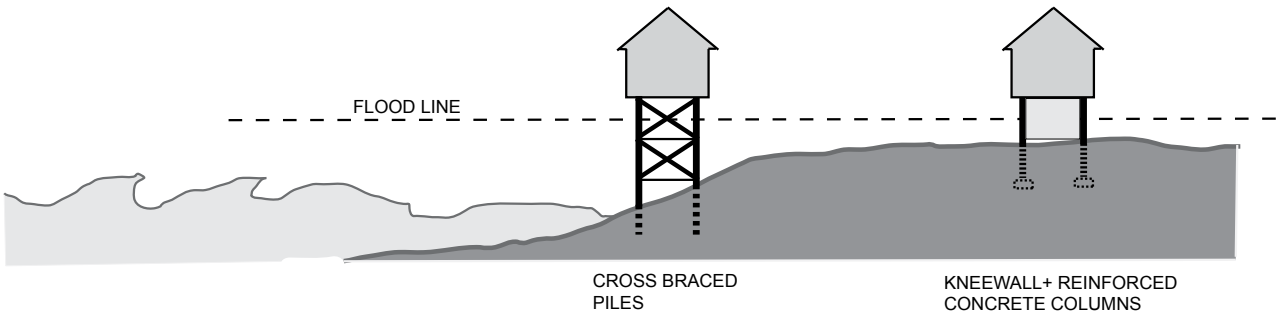
2.2.3 Maintain a consistent construction type for all the building's walls. Failure often occurs at the junction of different construction types.

2.3 Foundation

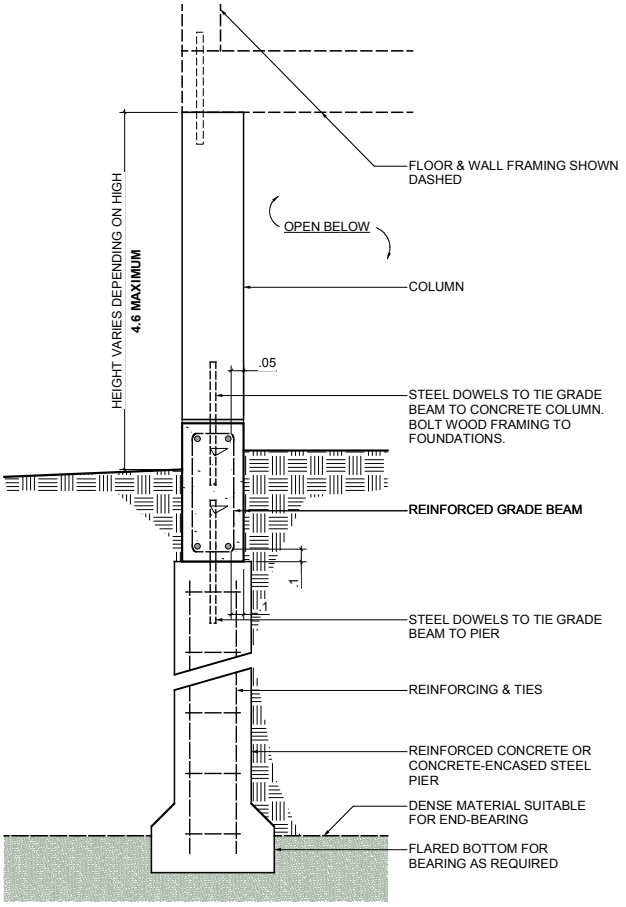
The foundation must have a strong grip with the ground. This is usually achieved by building knee walls along the edges of the building. The foundation must be securely attached to the floor and walls of the building it is supporting. This is done by tying rebar from the foundation into the floor and walls.



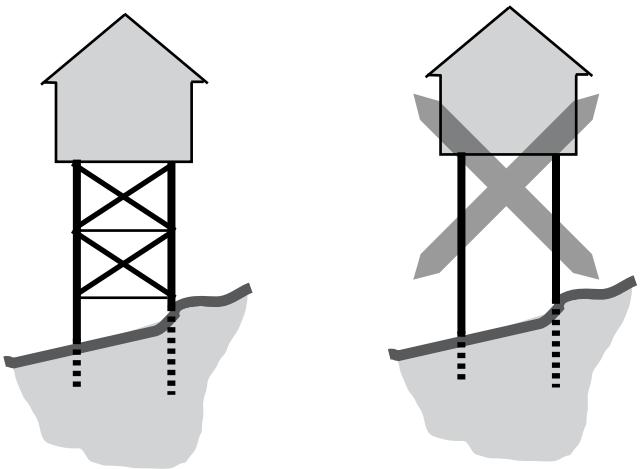
2.3.1 Increase the depth of foundations into the ground if soil is loose beneath the surface.



2.3.2 Elevate the building in areas prone to flooding. This can be achieved through a knee wall or, in more dramatic flood zones, reinforced and braced concrete piles.



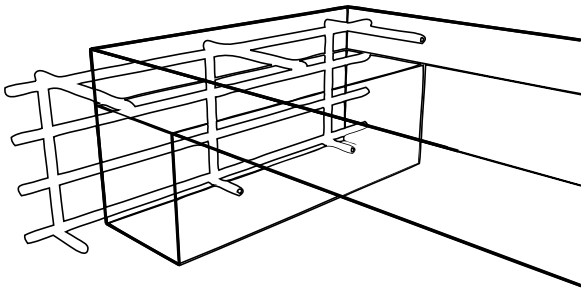
2.3.3 Reinforce knee walls and piles.



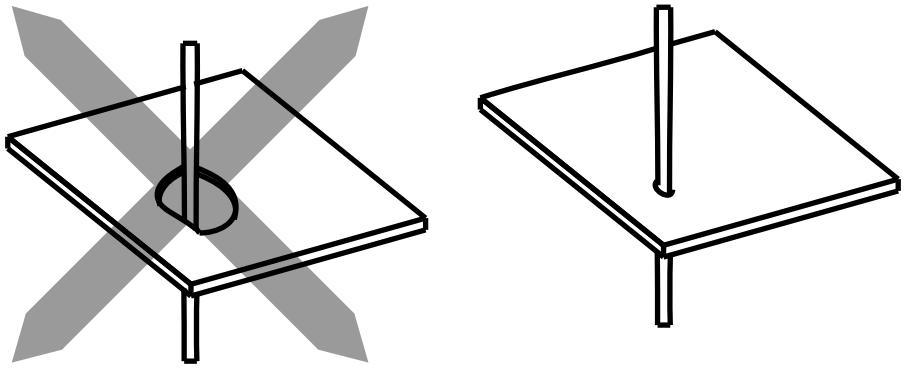
2.3.4 In the event that piles are used, they must be braced for lateral stability.

2.4 Floors

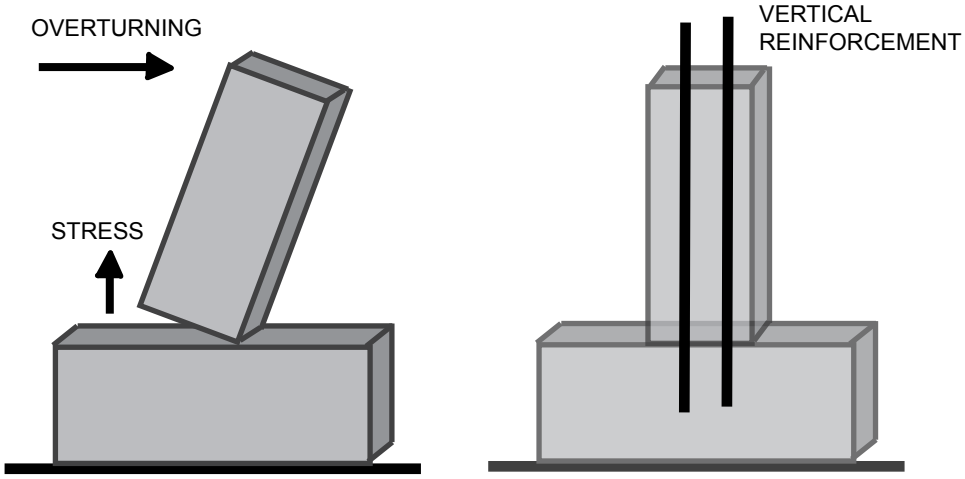
Floors are just as important for stabilizing the building against severe events as walls and the foundation. Floors must be uniformly constructed and reinforced, and tied into the foundation and walls of the building.



2.4.1 Concrete floors must be reinforced with a web of rebar or mesh. The steel must be completely covered by concrete or it will corrode and eventually shatter the floor. Cover steel with 2.5 cm (1 in) of concrete.



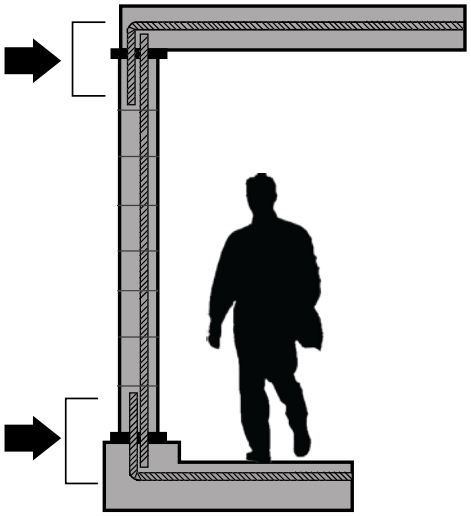
2.4.2 Keep floor slabs continuous. Do not puncture with holes larger than what is needed for pipes.



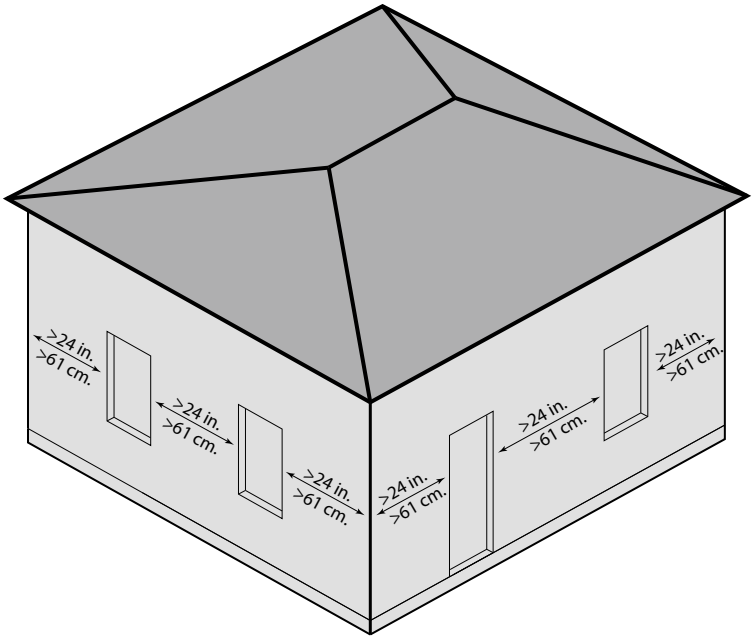
2.4.3 The floor must be tied with steel reinforcing into walls and foundation wherever they meet. See Section 3 for more information.

2.5 Walls

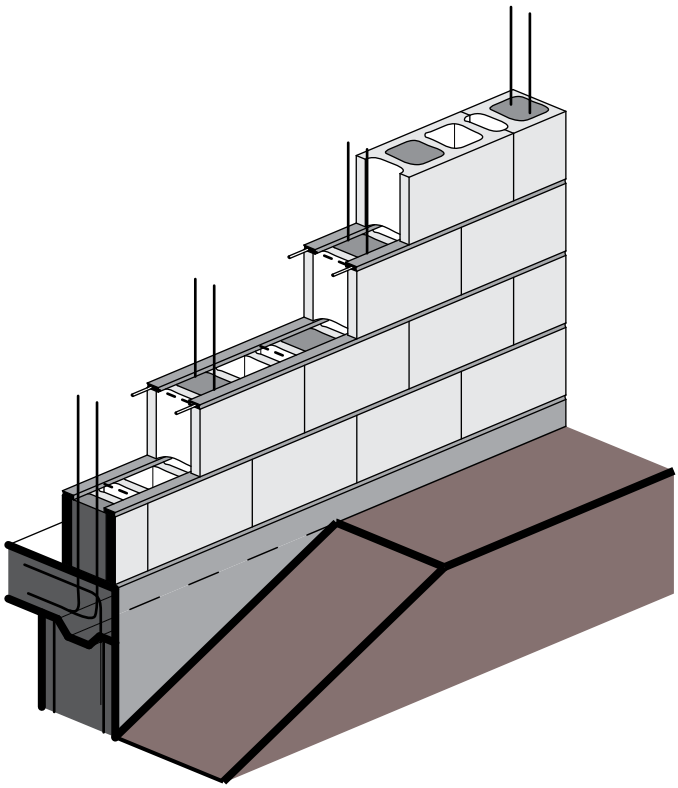
Walls are very important in resisting lateral forces of hurricanes and earthquakes. The key to a solid wall is to construct solid bonds between all wall components and provide wide, unbroken areas of wall along each exterior wall.



2.5.1 Walls must be anchored to the foundation, floor and roof.



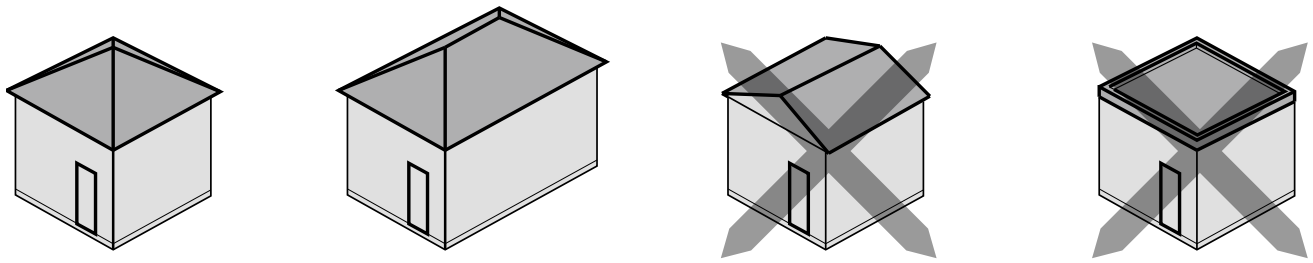
2.5.2 Walls must resist lateral forces and need to be as continuous as possible. Keep openings 60 cm (2 ft) from the corners and from one another. Walls must be at least 2.5 m (8 ft) high to the base of the roof. Each wall must have an uninterrupted “shear” section at least as wide as the wall is tall, ideally twice as wide as its height.



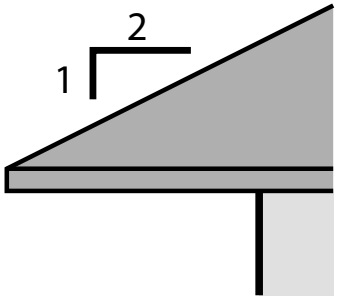
2.5.3 Walls should be made of reinforced concrete block. Reinforcement should run both vertically through the voids in the block and laterally between courses.

2.6 Roof

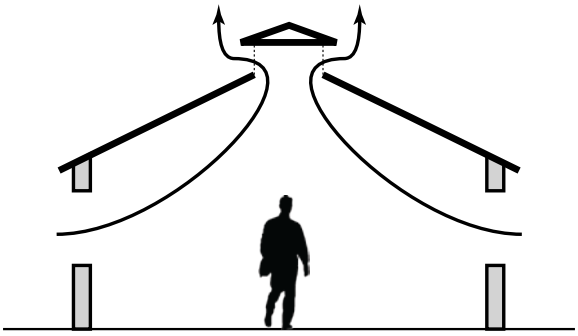
There are few alternatives to a hurricane resistant roof. If at all possible follow these recommendations for constructing a hurricane resistant roof.



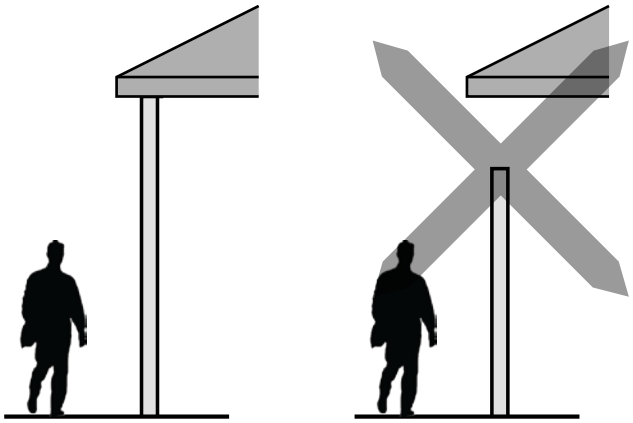
2.6.1 Four-slope roofs suffer less damage in hurricanes than two slope roofs.



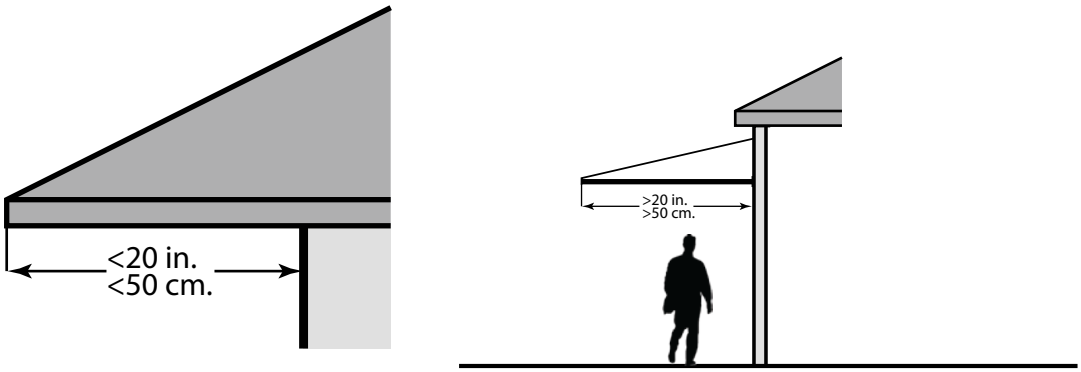
2.6.2 A rise-to-run ratio of 1:2 for roof slope is an ideal slope against hurricane winds.



2.6.3 Openings towards the ridge reduces pressure differences between interior and exterior, and encourages air movement through the building for comfort.



2.6.4 Avoid openings between the top of the wall and the bottom of the roof.

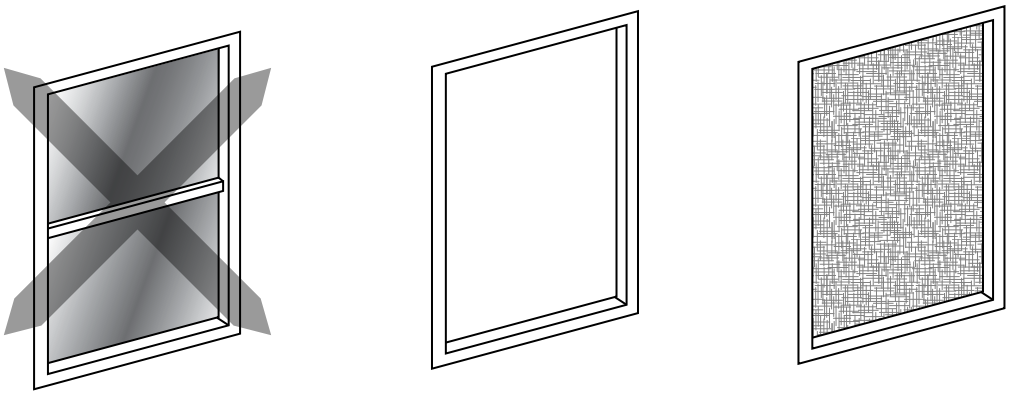


2.6.5 Eaves should not exceed 50cm (20”). Do not attach longer overhangs or porches to the roof. Attach these to the walls instead.

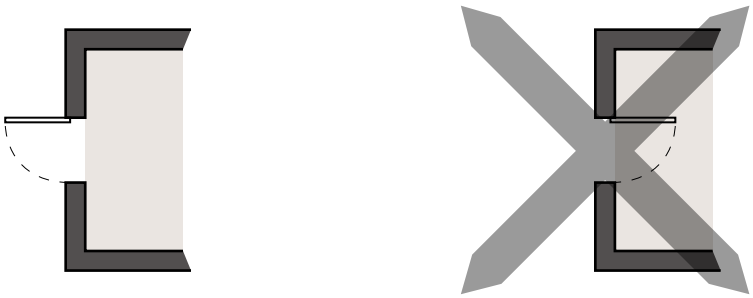
2.6.6 Keep the weight of the roof as small as possible–use metal sheeting instead of making a concrete roof. While of poor construction, the building on the right survived the earthquake much better than the building on the left.

2.7 Windows and Doors

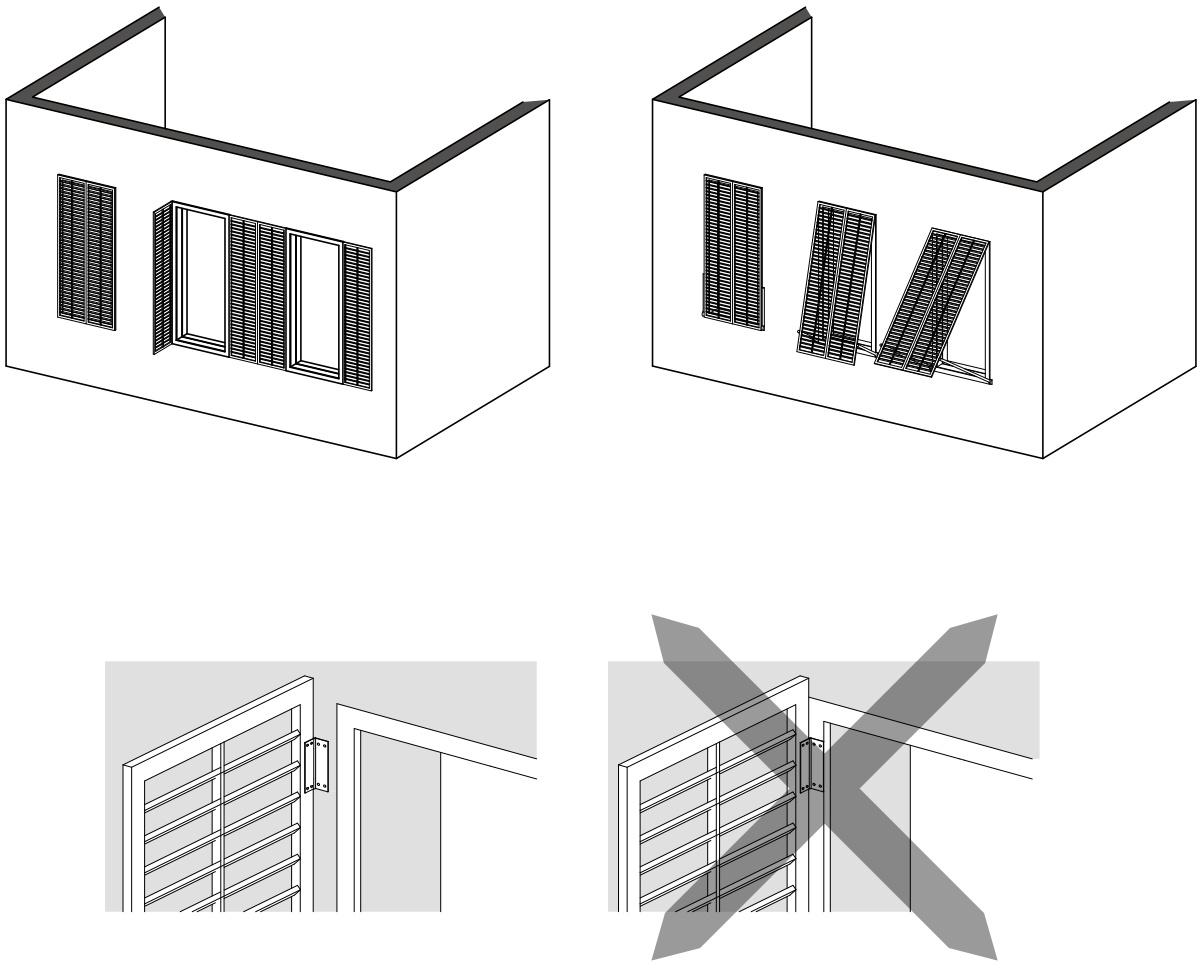
Wall openings are encouraged in buildings so long as they are separated from one another by at least 60cm (2 ft) of wall. All openings must be framed and supported by a reinforced lintel.



2.7.1 Avoid using glass. Glass used in a building should be tested against 240 km/h (150 mph) winds, be plastic or shatterproof. Leave windows open or faced with a screen.



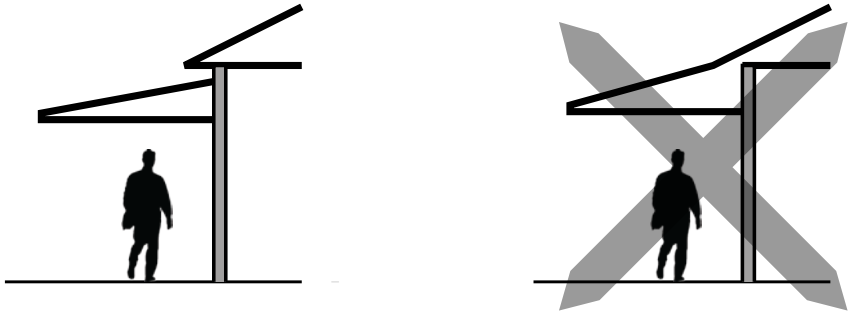
2.7.2 Make sure doors swing out. Inward-swinging doors can, in a hurricane, become unhinged and become an interior projectile.



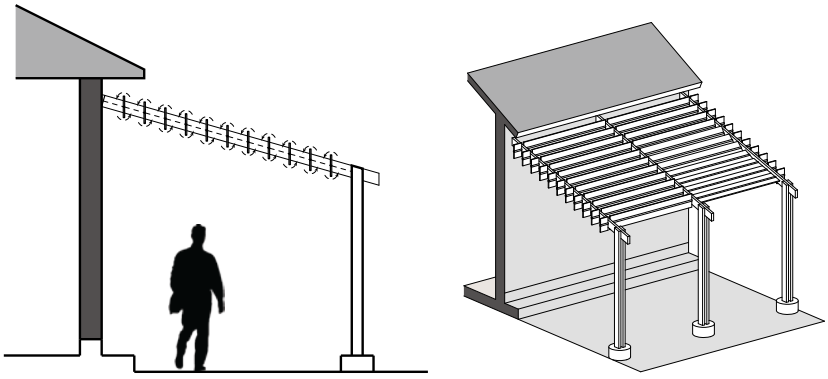
2.7.3 Glass windows must be accompanied by hurricane shutters. Attach hurricane shutters to the walls of building; do not attach them to the window frame.

2.8 Overhangs and Porches

Overhangs, while great for shading, can be a hazardous element during wind storms and hurricanes. Large roof overhangs can be lifted by the wind, displacing the roof and causing immense damage. Overhangs must therefore be separated from roofs.



2.8.1 Keep overhangs detached from roof.



2.8.2 Overhangs with periodic openings can prevent uplift damage during storms. They promote equal air pressure on either side of the overhang.

III. CONSTRUCTION MATERIALS AND TECHNIQUES

The rigorous construction guidelines of the previous section can be achieved through materials presently available in Haiti. The surest construction practice, and most abundant resource, is concrete block, which will be the focus construction method outlined below.

The most hazardous aspects of block construction is the risk of imprecise mixture of ingredients, poor quality of ingredients and lack of steel reinforcing. However, with correct proportions and the identification and employment of suitable ingredients, concrete and concrete block can perform solidly in the worst environmental conditions, ensuring the longevity of a building. Improper proportions or ingredients are greatly responsible for building failure and endanger the lives of building occupants.

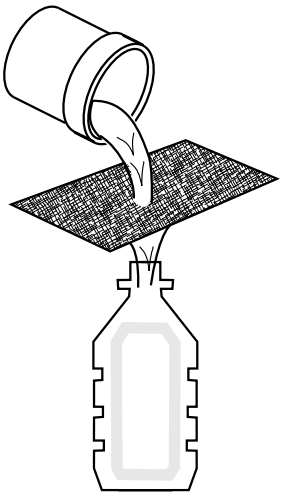
Note: Alternative construction systems are constantly being proposed, especially ones employing recycled rubble, but would require more guidance than this manual can provide. This manual applies only to CMU construction, and is in no way comprehensive. Details of alternative systems, as well as augmented house systems beyond structural needs will be outlined in subsequent manuals.

3.1 Mixing Concrete

Concrete mixtures are very sensitive to proportion and ingredients. Be sure all the proper ingredients are available and measured before mixing concrete.

3.1.1 Ensure that the sand is coarse and grainy. It must not be substituted with dirt or clay. Be sure to use river sand–do not use beach sand!

3.1.2 Ensure that the aggregate is rough and 1-2.5cm in diameter (1/4-1 in.). Crushed rubble should not be used as aggregate–rubble is at best only as strong as the fallen buildings it came from.



3.1.3 The water must be clean, free of impurities such as silt and organic matter. Run water through a fabric filter before mixing it into concrete.

To mix concrete:

1 part cement | 2 parts sand | 3 parts aggregate | water (varies*)

3.1.4 Concrete proportions: 1 part cement + 2 parts sand + 3 parts aggregate + water.
The amount of water varies. Use 19 L (5 gal) of water per bag of cement if the sand is moist. Use 23 L (6 gal) of water per bag of cement if the sand is dry.

3.1.5 Make sure the ingredients are mixed thoroughly. Mixed concrete will heat up as the cement is activated. The mix must be placed within 90 minutes after mixing, as it will soon begin to harden. After it is poured and set, concrete must be given at least a week to reach an acceptable strength.

3.1.6 You can test the quality of a concrete mix by hand. If water and cement run through the fingers, the concrete is not mixed enough and/or is too watery.

3.1.7 If any of the ingredients are substituted, or if they are mixed in improper proportions, the concrete will be too weak.

3.2 Concrete Blocks

Properly created and reinforced blocks can form walls strong enough to withstand the most extreme weather and seismic events. Blocks are widely available and affordable. In the event blocks are not purchased, making them requires little more than properly mixing concrete, using pre-built forms and drying them in the sun.

3.2.1 Concrete blocks can be found in various sizes. However, there is the possibility the blocks have been improperly made. Be sure the block you are purchasing is sturdy. It should be consistent, with clean, flat sides. Well-made blocks will not break when dropped off the back of a truck.

3.3 Mortar

Mortar bonds concrete blocks to one another creating a solid wall and must be used between all block-to-block surfaces, as well as between blocks and floor slabs. Again, the quality and proportion of ingredients is important. An amount the width of a finger should be applied between blocks.

3.3.1 Inspect the quality of the ingredients. Water and sand should both be clean. Sand should not contain clay. Lime and cement must also be of reliable quality.

To mix mortar:

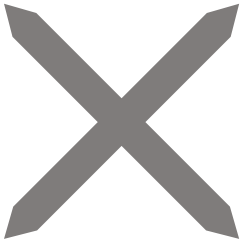
1 part cement | 1/4 part lime | 3 parts sand | water (varies*)

3.3.2 Mortar proportions: 1 part cement + ¼ part lime + 3 parts sand + water

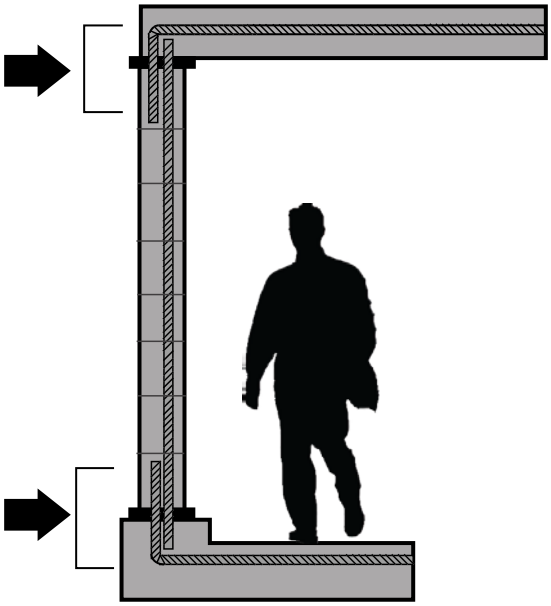
Make sure the ingredients are mixed to a thorough consistency. Add enough water that the mix is pliable and consistent.

3.4 Steel Reinforcing

Steel reinforcing bars (rebar) put strength in concrete slabs and block walls [against lateral forces]. It must be strategically placed to be effective; towards the outside, but not on the edge of slabs and columns, and vertically throughout the inside of walls. Rebar must also be placed laterally on the tops of walls in bond beams as discussed below.

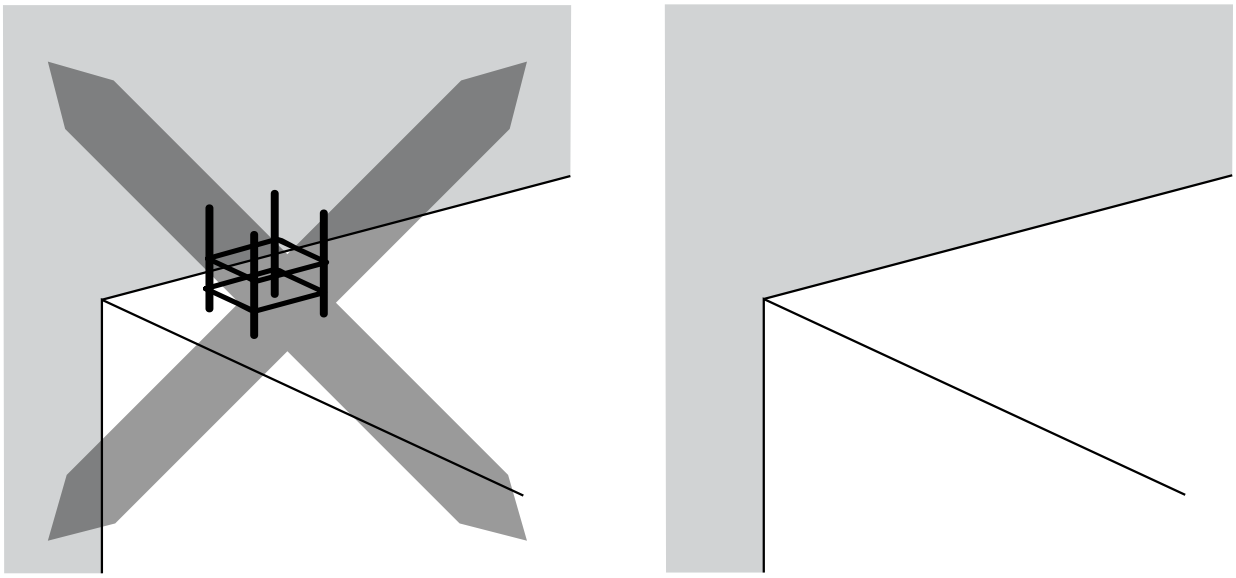


3.4.1 Be sure the rebar is ribbed, not smooth. Rough rebar grips the concrete around it and will not allow the slab or wall it supports to slip out of place during a severe event.



3.4.2 Be sure rebar extends from foundation into wall and overlaps with rebar in floor and walls. Overlap rebar at intersections between foundation and floor, floor and wall, wall and roof. Overlap bars by 20-40 bar diameters.

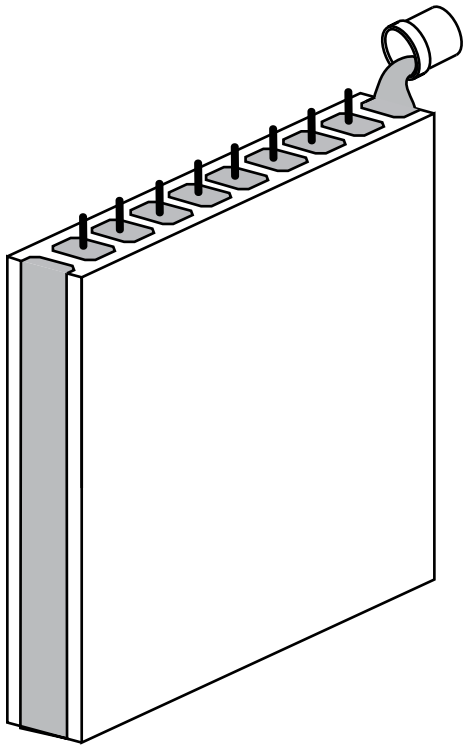
3.4.3 Place rebar laterally in walls at intervals and at the top in bond beams (see bond beams section below).



3.4.4 Do NOT leave rebar exposed on any part of the building. Water and air will infiltrate the concrete through the rebar and corrode the structure of the building.

3.5 Grout

Grout is the fill poured into the concrete block walls. Grout binds the blocks to the rebar within, as well as to one another, making the wall a solid whole. Pea gravel grout is easy to manufacture and will fill large cavities in concrete block walls.



3.5.1 Apply grout as a fill in concrete block walls.

To mix pea gravel grout:

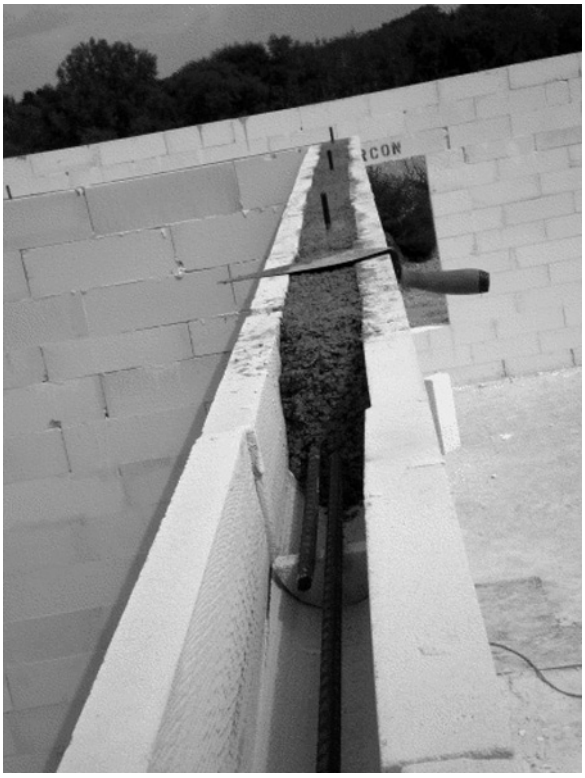
1 part cement | 2 parts sand | 2 parts pea gravel | water (varies*)

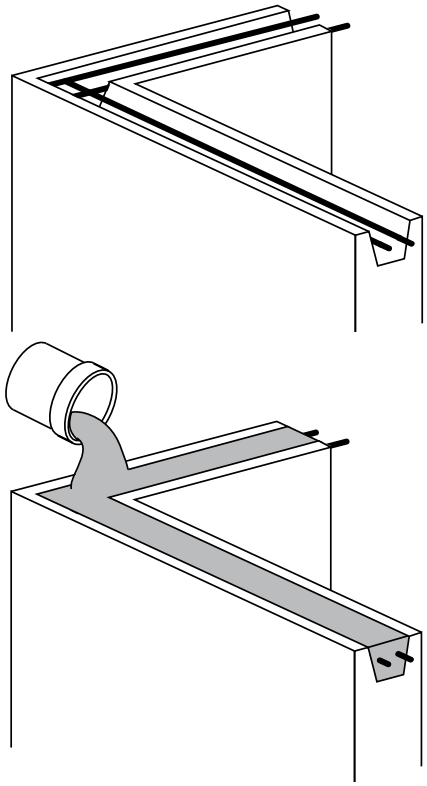
3.5.2 Pea gravel grout proportions: 1 part cement + 2 parts sand + 2 parts pea gravel + water

Make sure the ingredients are mixed to a thorough consistency. Add water so that the grout is liquid enough to flow into all the cavities of a block wall.

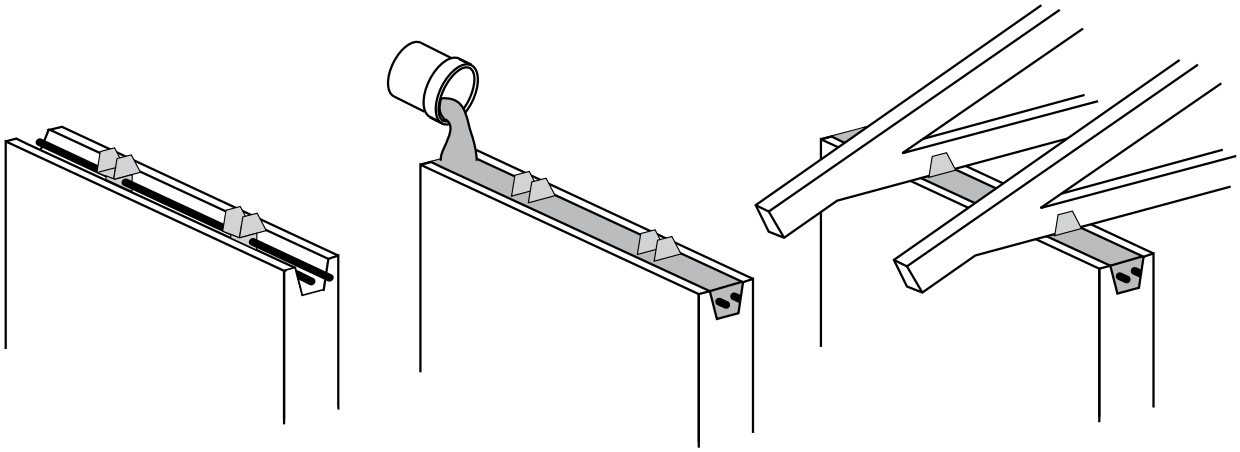
3.6 Bond Beams

The tops of walls must be tied together by a continuous ring or bond beam. Bond beams ensure the walls are contained and remain a solid whole in extreme events.





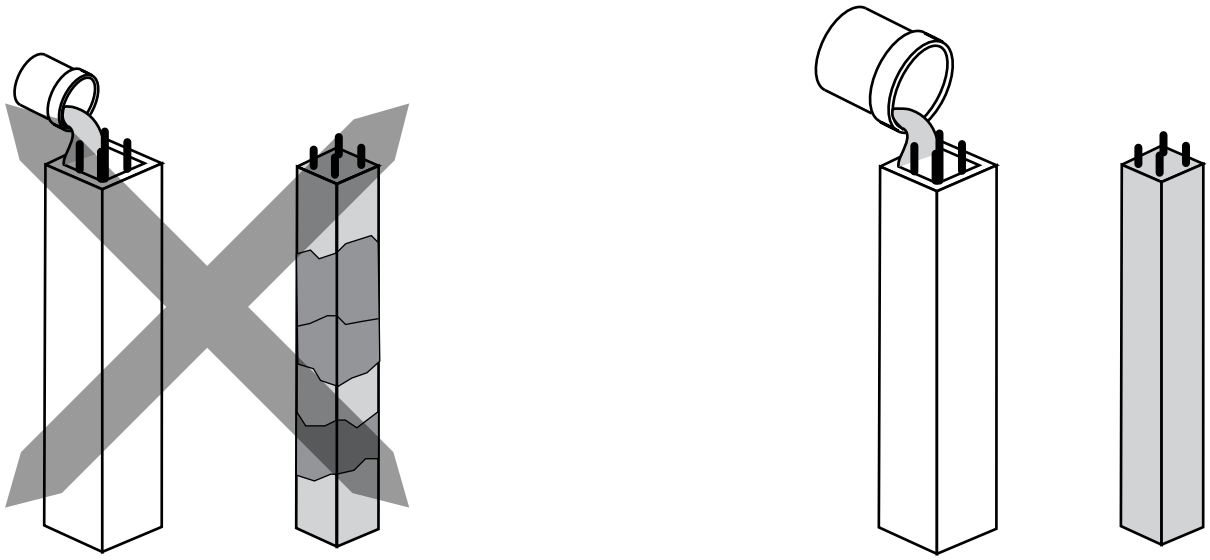
3.6.1 A bond beam is often cast inside a U-shaped concrete block and reinforced with rebar, or it could also be made of reinforced site-cast concrete into a wooden formwork. Rebar in the beam must be well protected by the concrete covering it, including when using U-block.



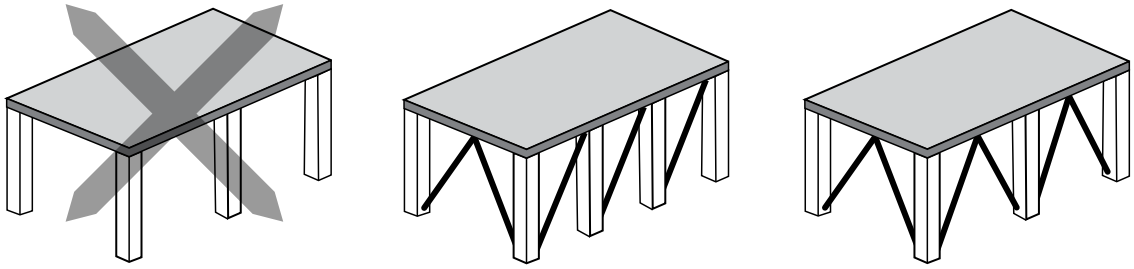
3.6.2 The bond beam must be securely fastened to the walls and floor or roof. In the event of a wood frame roof, roof joists or trusses must be well anchored to the bond beam.

3.7 Columns

Columns have a lot of useful functions, including serving as piers for buildings in areas at risk of flooding. They are also good for creating covered outdoor spaces, or covered arcades in front of buildings. However, structural failure often happens in concrete columns because they were poured in stages instead of at one time. If there is not enough concrete to finish an entire column, it should not be made.



3.7.1 Columns should be made in one single pour.



3.7.2 Always brace columns to withstand lateral forces.

3.7.3 Size columns to at least 25 cm (10 in) on a side. Reinforce vertically with horizontal ties, as shown.

3.7.4 Trees are a great alternative to building a covered outdoor space.

IV. ADDITIONAL RESOURCES

The following is a partial list of web resources we consulted to create this guide. They may be of use to you when seeking information of greater detail.

http://www.eeri.org/site/
The Earthquake Engineering Research Institute is a national, nonprofit, technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. EERI members include researchers, practicing professionals, educators, government officials, and building code regulators.

http://architectureforhumanity.org/
Architecture for Humanity is a nonprofit design services firm founded in 1999. We are building a more sustainable future through the power of professional design. To get in touch with our team in Haiti please contact San Francisco based Program Manager Frederika Zipp (frederikazipp@architectureforhumanity.org) and Haiti based Regional Program Manager Eric Cesal (ericcesal@architectureforhumanity.org).

http://openarchitecturenetwork.org/
The Open Architecture Network is an online, open source community dedicated to improving living conditions through innovative and sustainable design. Here designers of all persuasions can:

- *Share their ideas, designs and plans*
- *View and review designs posted by others*
- *Collaborate with each other, people in other professions and community leaders to address specific design challenges*
- *Manage design projects from concept to implementation*
- *Communicate easily amongst team members*
- *Protect their intellectual property rights using the Creative Commons "some rights reserved" licensing system and be shielded from unwarranted liability*
- *Build a more sustainable future*

Images courtesy of Pragmatic Construction (3.6.1)

Profound thanks as well to our translators–Isabelle, Yasmine, Louis, Crisenger, Vanessa, Yanick and Dominique.