

CONFINED MASONRY WORKSHOP HANDBOOK

The Construction and Maintenance of Masonry Buildings in Haiti

MASONRI CHENE MANYEL POU TRAVAY

Konstriksyon ak Reparasyon kay an Masonri an Ayiti

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Craig Totten, P.E., Editor

in collaboration with:

**AIDG
AWB - OREGON
HAITIREWIRED**



TAB MATYE

Kay ki ka reziste Tranblemanntè
Plan yon kay ki ka reziste tranblemanntè

1. Konstriksyon Fondasyon an
2. Bati miray blòk yo
3. Konstri kolòn yo
4. Pou attache deuziem etaj e plafon an
5. Kantite mur ki genyen nan yon kay
ki ka reziste tranblemanntè

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Description of this Translation

This document replaces the original manual (Seminar Handout Revision, April 12, 2010) which was adapted and translated from part of the original document, "Construction and Maintenance of Masonry Houses," edited by Marcial Blondet. There have been a number of changes to the format, the graphics, and the content to better reflect it's intended audience. Some of the changes were also in response to the workshops that took place in April 2010 in hopes of improving the quality and delivery.

This document is adapted from part of the original document, "Construction and Maintenance of Masonry Houses," edited by Marcial Blondet. Changes have been made to represent concrete block construction. © Marcial Blondet © Pontificia Universidad Católica del Perú © SENCICO.

For electronic copies of the handbook and additional information on confined masonry please see www.aidg.org/confinedmasonry.

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Appreciation

This construction book is an example of the on-going efforts to help in the reconstruction of Haiti. It has been prepared as a collaboration between AIDG (Appropriate Infrastructure Development Group), Architects Without Borders - Oregon (AWB) and HaitiRewired, who came together in response to the earthquake in Haiti to help with the reconstruction efforts. The loving hands that have touched this effort include:

Adajah François Codio
Abby Dacey
Melissa Guarin
Peter Haas
Dave Hammond
Susan John

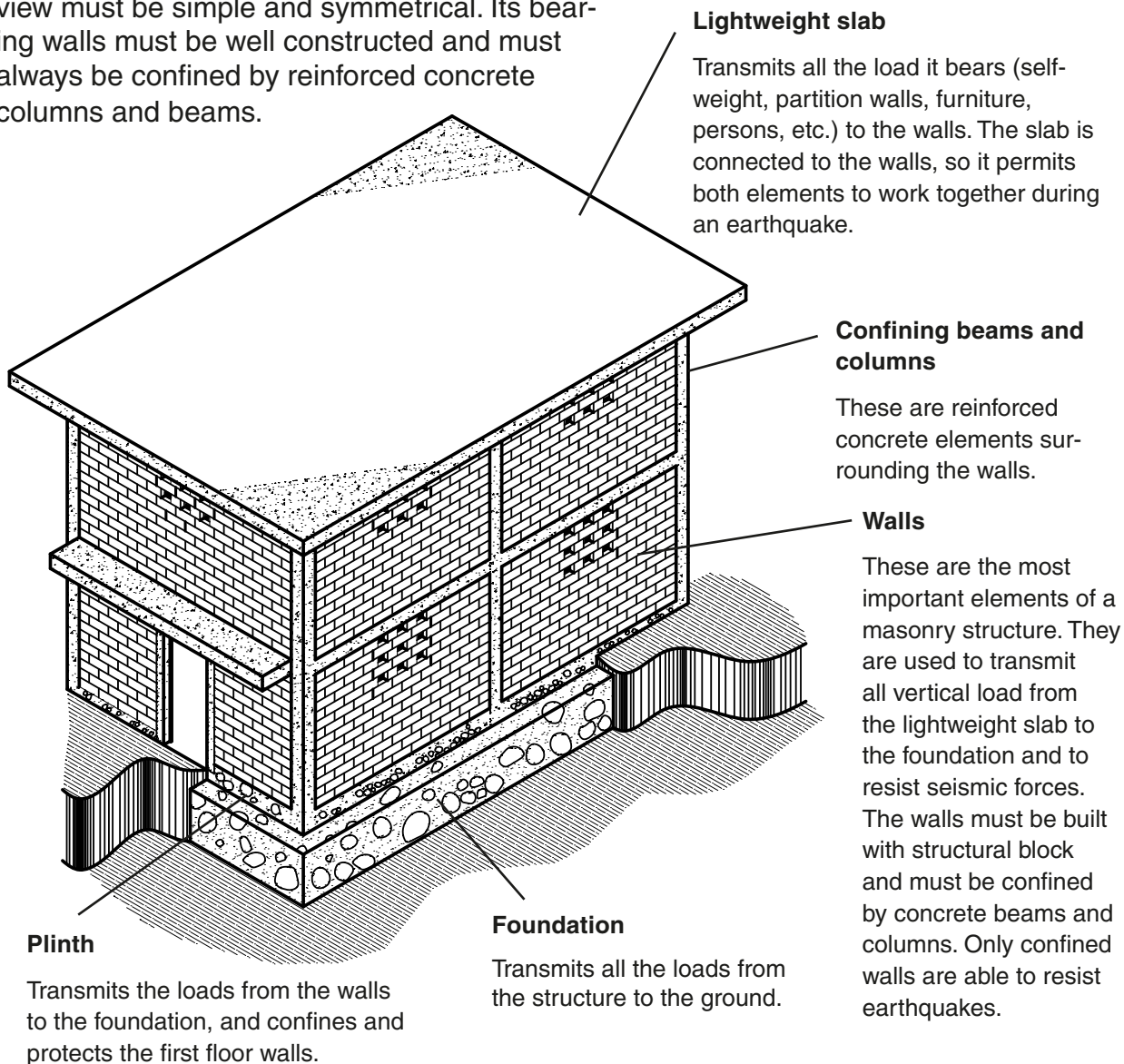
Catherine Laine
Laura Lovett
Jessica Lozier
Taylour McIntosh
Stewart McIntosh
Jan Noethe

Kennett Payne
Caitlin Poliak
Shelly Rolandson
Brian Sisco
Oliver Smith-Callis
Craig Totten

This is a gift to the people of Haiti with the hope that it will help you build back better futures for your families. Let it be a small reflection of the hope of the people of Haiti.

The Earthquake-resistant House

A confined block masonry earthquake-resistant house is designed and constructed so that its walls are able to resist earthquakes. Its plan view must be simple and symmetrical. Its bearing walls must be well constructed and must always be confined by reinforced concrete columns and beams.



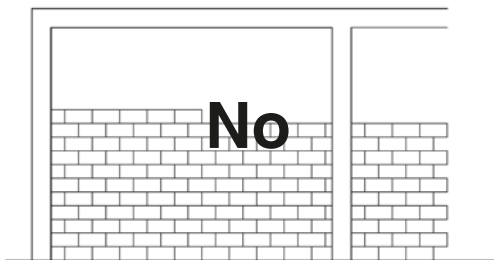
Recommendation:

Walls confined by beams and columns resist earthquakes. If you want your house to be earthquake-resistant, we recommend that it should have the greatest possible quantity of confined walls in both directions. Partition walls, made with lightweight hollow clay tile, should be used only to separate rooms inside the house.

Plans for Earthquake-safe Houses

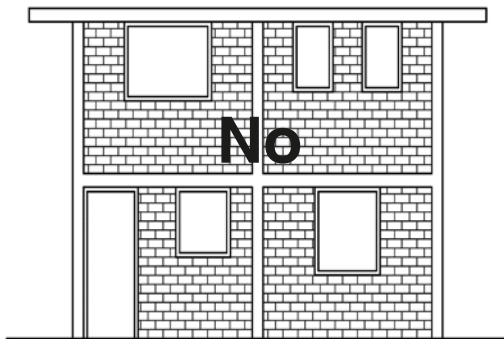
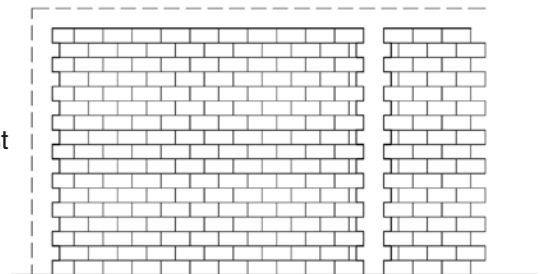


If you want your house to resist earthquakes successfully, your design must have a good shape and an adequate distribution of walls.



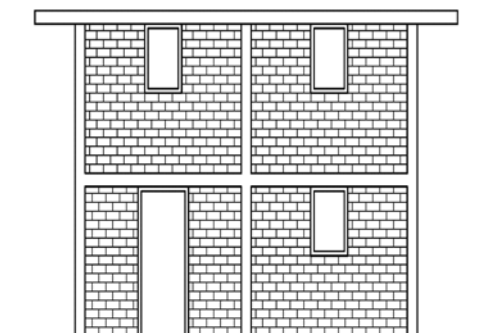
Yes!

Build the block walls first then pour the columns and floors directly against the blocks.



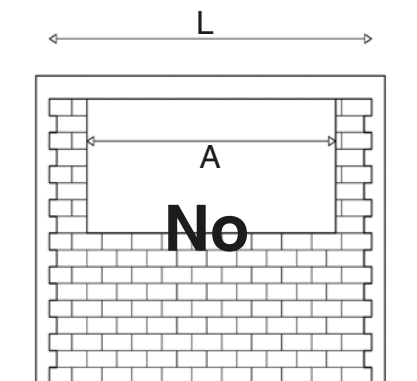
Yes!

Build window and door openings up to the level of the collar beam and locate them in the same position on every floor.



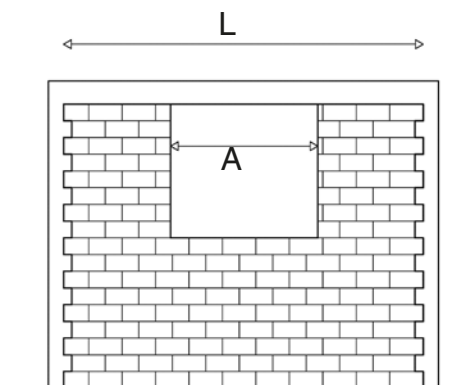
Poor location of window and door openings.

Good location of window and door openings.



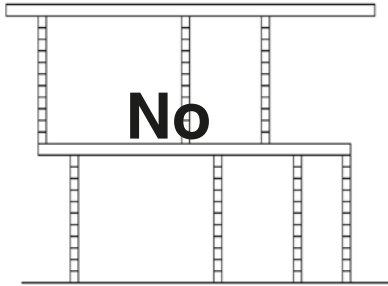
Yes!

Openings weaken the walls. Do not make openings larger than half the length of the wall. (Distance A must be less than half of distance L.)



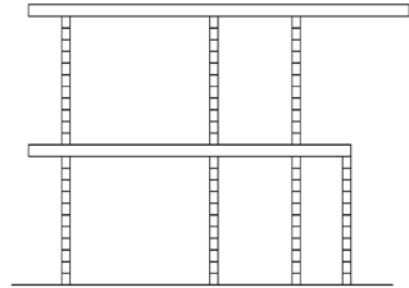
Inadequate opening proportions

Adequate opening proportions



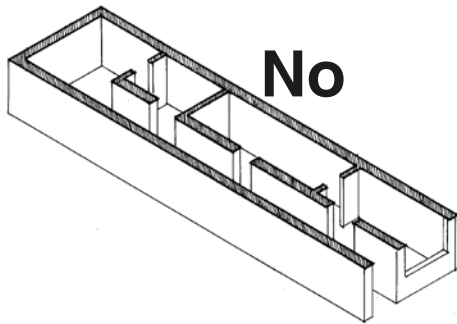
Improperly located walls that do not rest over other walls.

Yes!



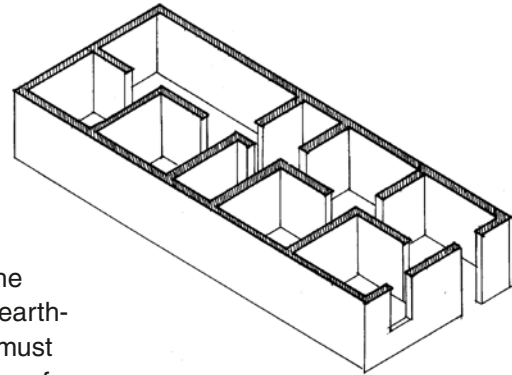
Properly located walls

The adequate location of second floor walls is very important. Always build second floor walls directly over first floor walls.



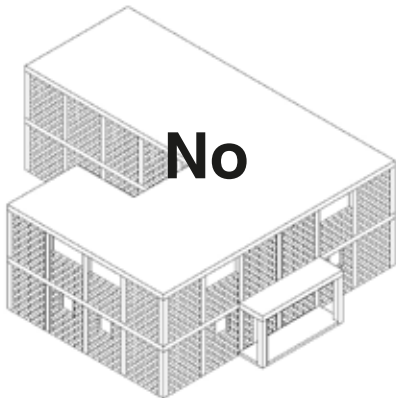
Few confined walls in the short direction of the house.

Yes!



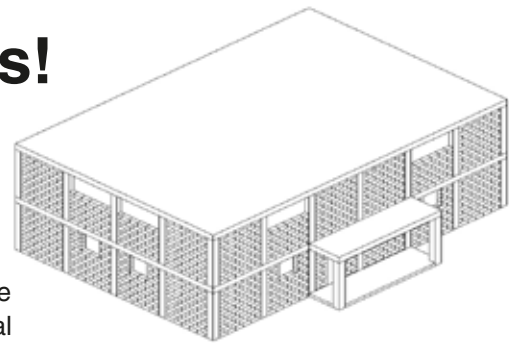
Many confined walls in both directions.

Confined walls are the elements that resist earthquakes. Your house must have a similar number of walls in both directions.



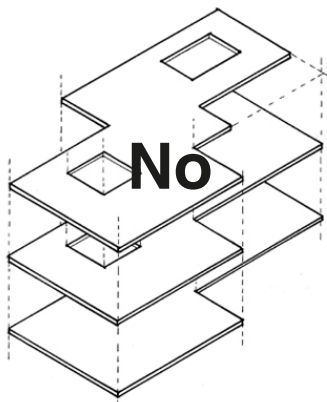
Irregular

Yes!



Symmetrical

The shape of your house has to be as symmetrical as possible, both in plan view as well as elevation. Lightweight slabs must not have too many openings.

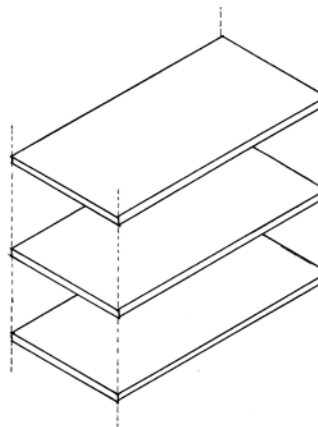


No

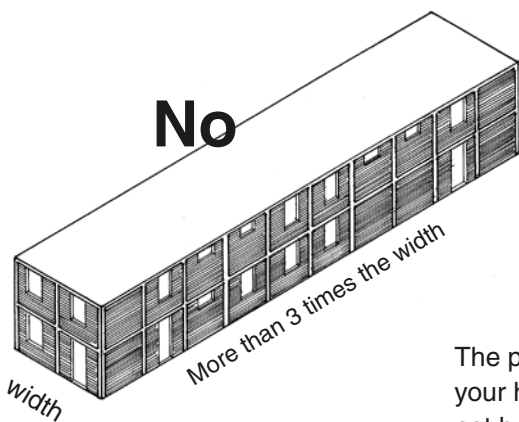
Slabs of different shape on every floor

Yes!

It is important for slabs to be well proportioned and to be the same shape on every floor.



The same shape of slab on every floor

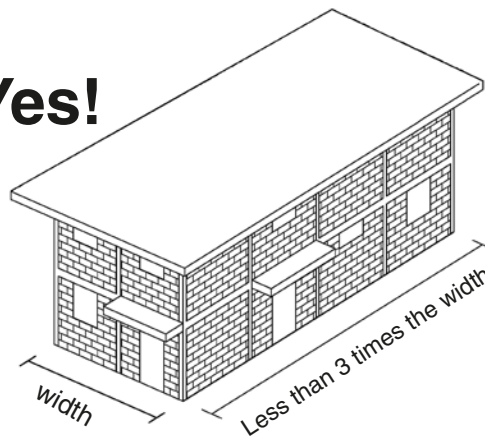


No

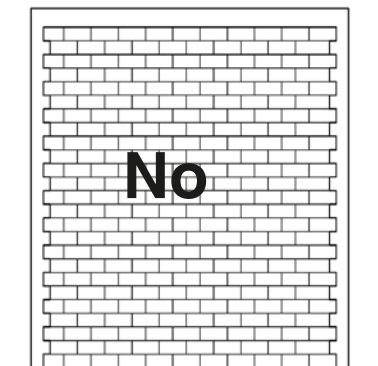
Poorly proportioned plan

Yes!

The plan length of your house should not be greater than 3 times the plan width.



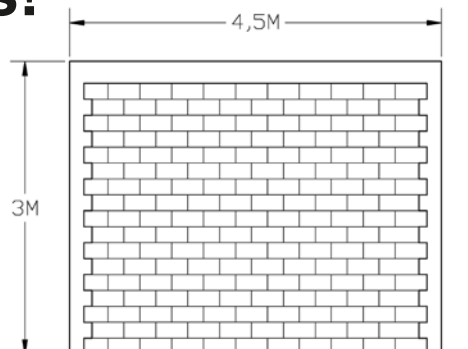
Well proportioned plan



No

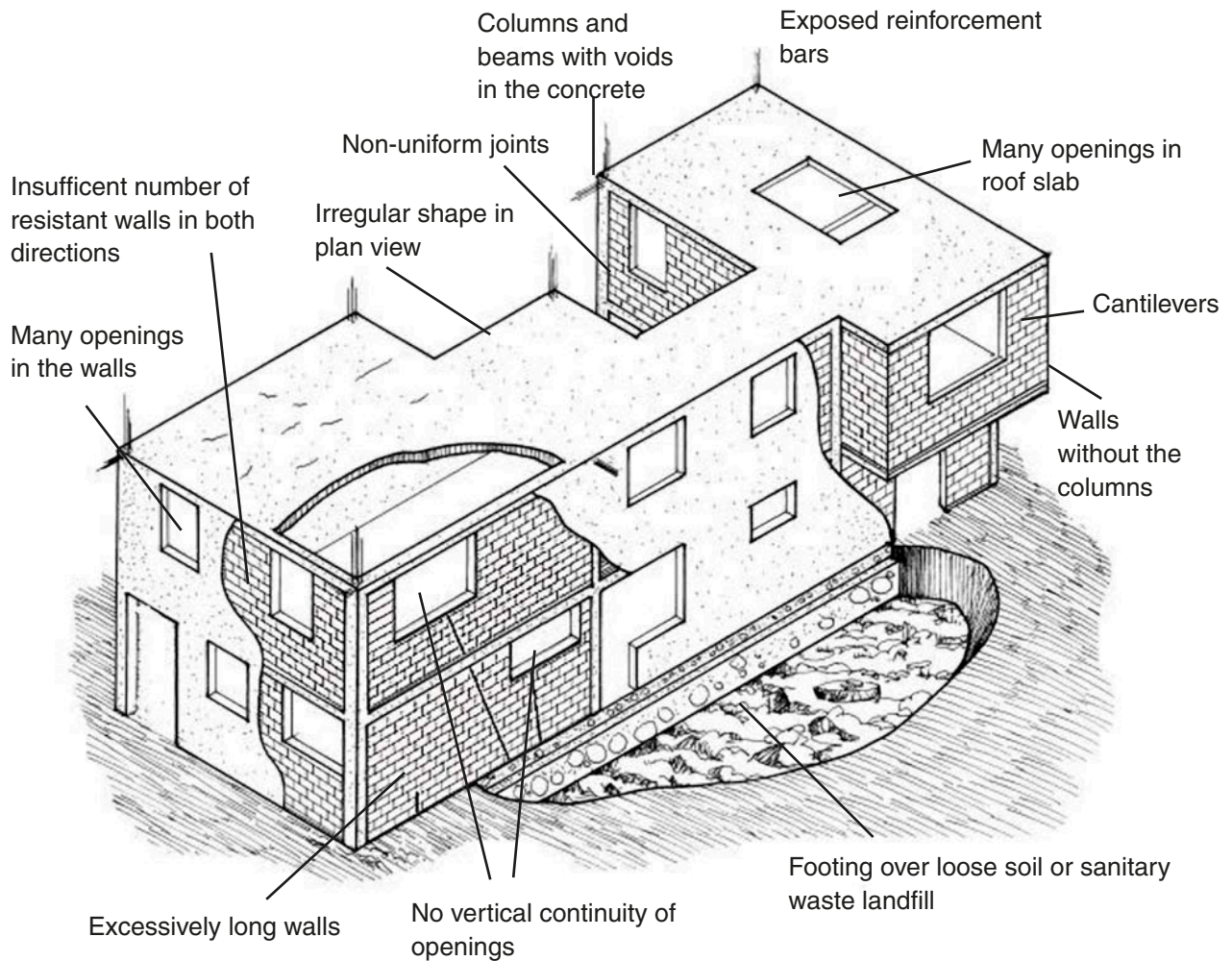
Yes!

Columns must be spaced no more than 4.5 meters apart. The floor heights must be no more than 3 meters.



The Unsafe House

This drawing shows the most common errors in houses that have not been built by professionals. These houses are not safe during earthquakes.

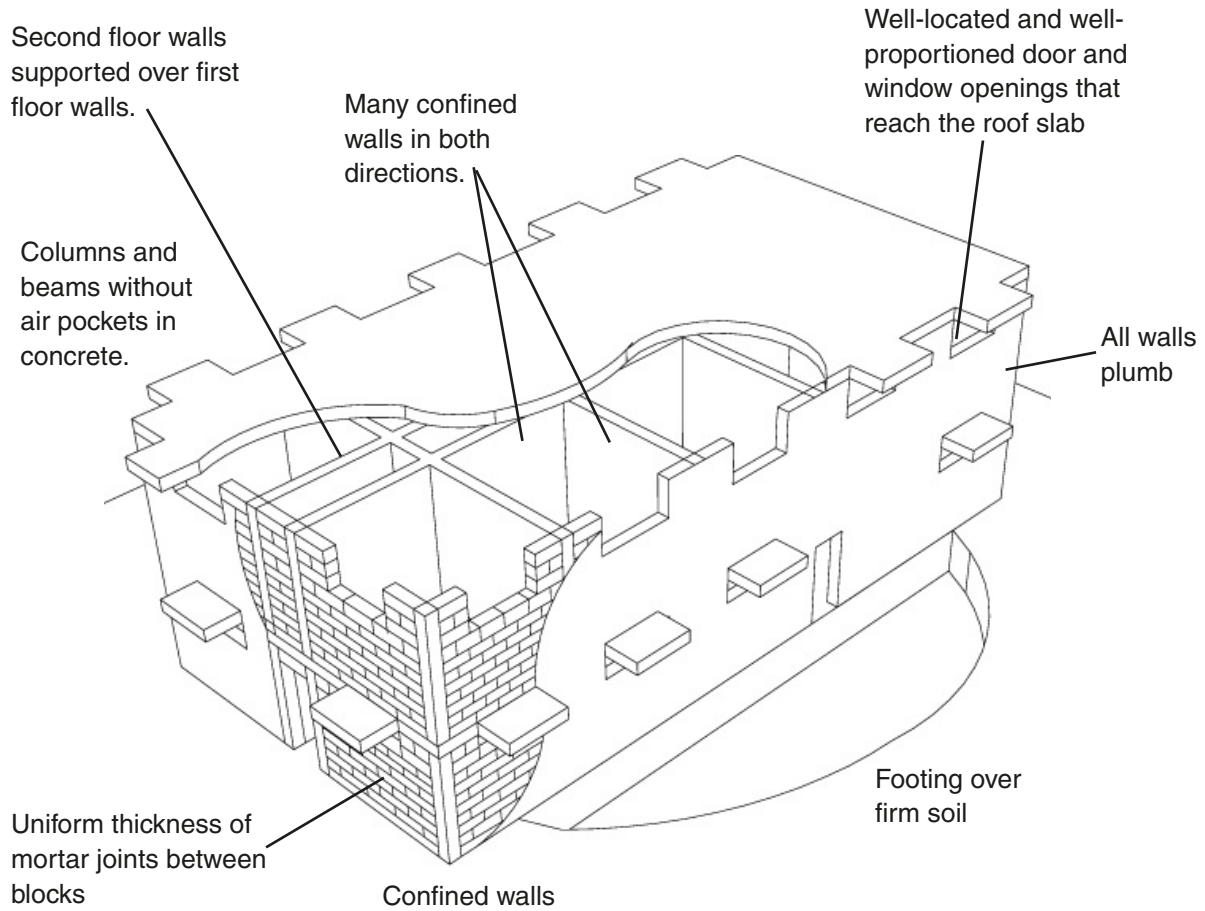


The Safe House

This drawing shows the characteristics of a well-designed, safe house that will resist an earthquake.



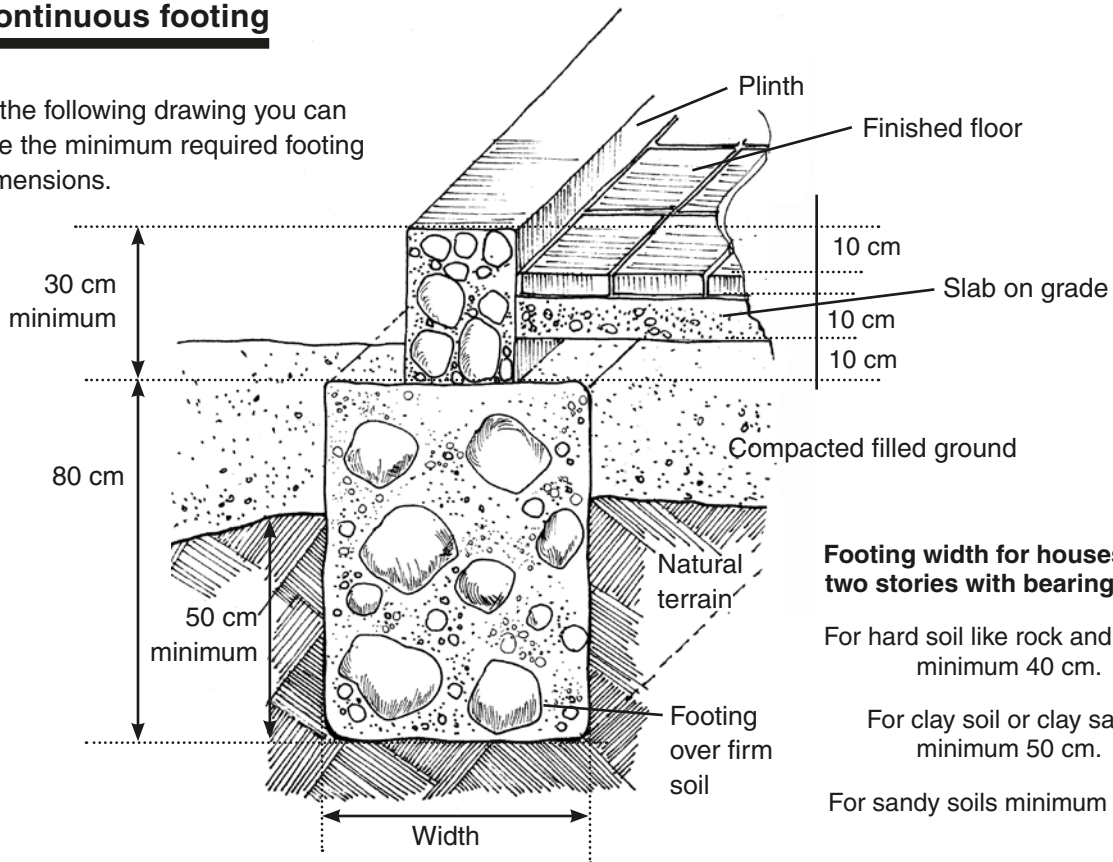
Well-proportioned house



1. Constructing the Foundation

Continuous footing

In the following drawing you can see the minimum required footing dimensions.



Footing width for houses up to two stories with bearing walls:

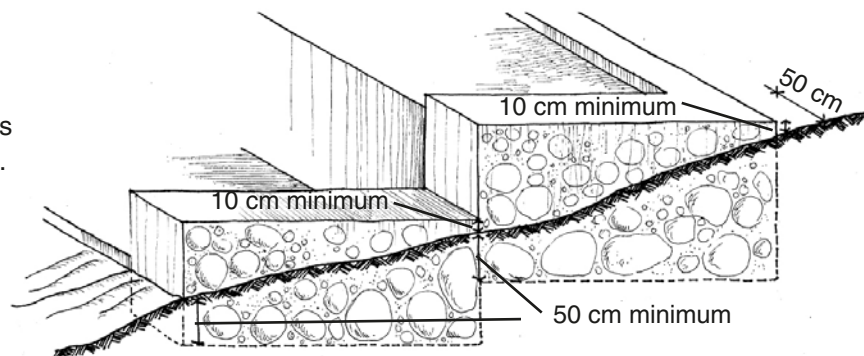
For hard soil like rock and gravel, minimum 40 cm.

For clay soil or clay sand, minimum 50 cm.

For sandy soils minimum 70 cm.

Stepped footing

Construct stepped footings when the terrain is sloped.



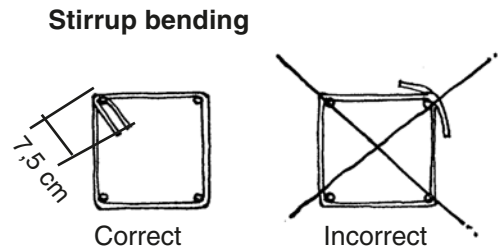
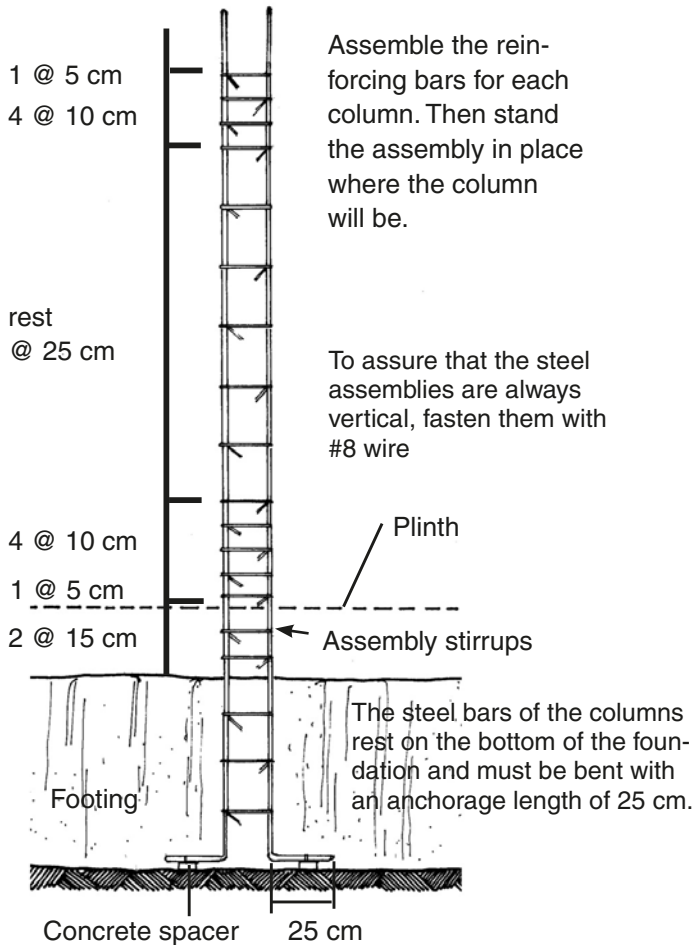
Recommendations

Hard soils such as rock or gravel are the best foundation soils. Gravel is made up of different size stones and coarse compact sands.

Sometimes it is difficult to excavate these soils with a shovel and you have to use a large drill. Find out about the footings of nearby houses. If nearby houses have settled under their weight, then your foundation should be wider and deeper than your neighbors.

Before pouring the footing

Standing column reinforcing bars

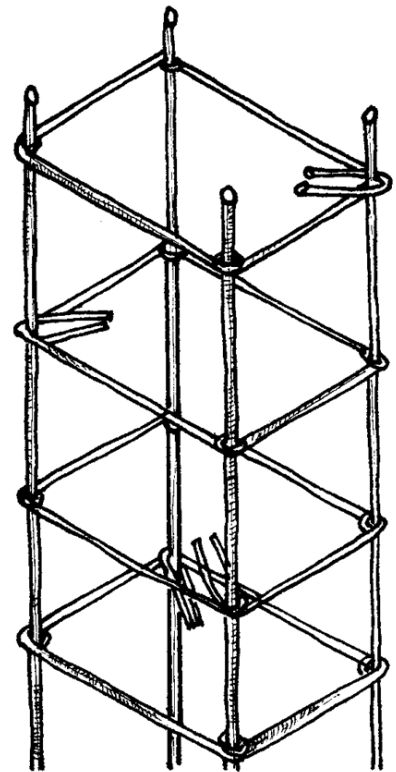


It is very important that the hooks stay in the interior of the column so they work adequately.

Reinforcement

Minimum reinforcement for columns is 4 x 3/8 in. steel bars. Column stirrups are 1/4 in. and have to be placed with the following spacing: 1 @ 5 cm + 4 @ 10 cm + rest at 25 cm on each end. The distance between stirrups is measured starting from the plinth upwards and from the collar beam downwards.





Try to alternate the position of the stirrup's hook so that it is not located in the same corner of the column.



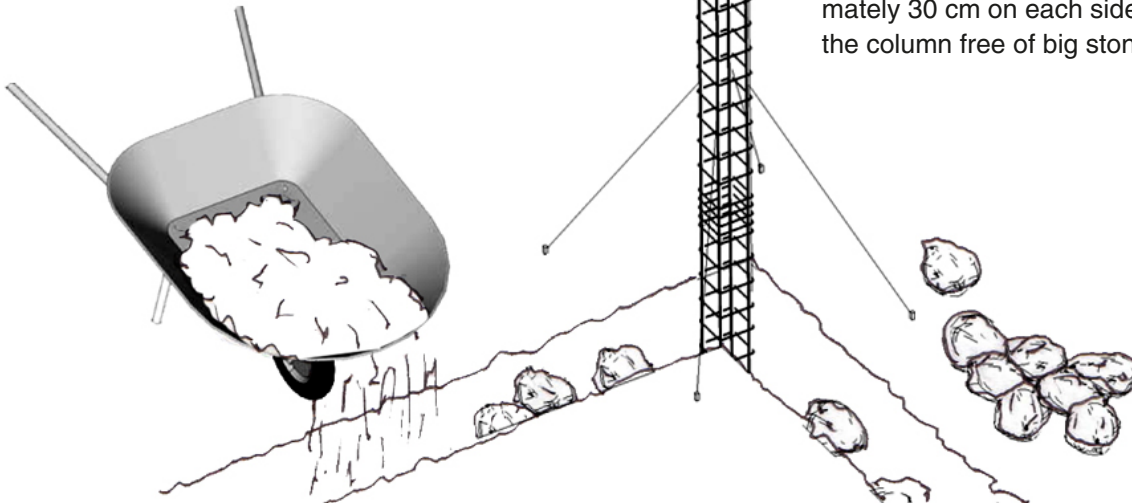
Pouring Concrete for the Foundation

It is better if you rent a small capacity mixer to prepare concrete. This will help control quality and save materials.

Concrete for the foundation
Foundations are made of simple concrete

-  **1** bucket of cement
-  **10** buckets of aggregate
-  **30%** by volume of big stones (maximum size 10 in.)
-  **1-1/2** buckets of water

Pour concrete for the foundation with wheelbarrows. As pouring continues, drop big stones in the foundation trenches.

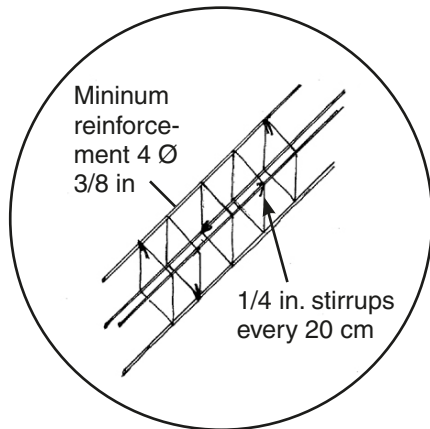


Do not place big stones near the columns. Leave approximately 30 cm on each side of the column free of big stones.

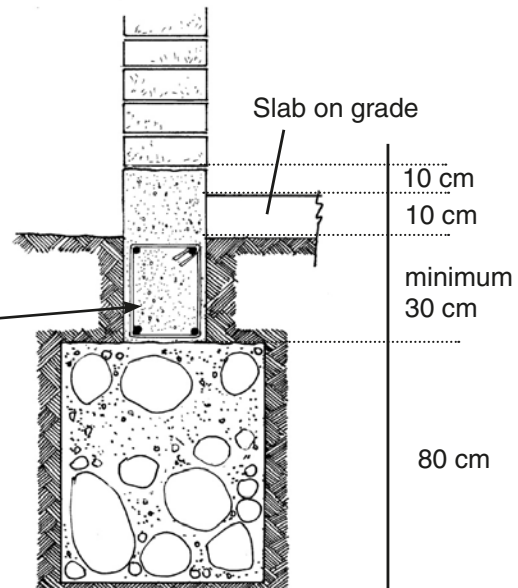
Be careful to ensure that each stone is completely covered by concrete.

Steel reinforcement in the Plinth

If your soil is sandy or clayish, it is better to place steel reinforcement in the plinth.



Plinth beam



Concrete for plinth in firm soil

The plinth does not require steel reinforcement



1 bucket of cement



8 buckets of aggregate



25% by volume of medium size stones (maximum size 4 in.)



1-1/4 buckets of water

Concrete for plinth in loose soil (sand or clay)

Build a reinforced plinth to prevent cracking of the walls due to settlement of the ground soil.



1 bucket of cement



2 buckets of aggregate



4 buckets of crushed stone (maximum size 3/4 in.)



1 bucket of water

2. Building a Block Wall

Making Concrete Masonry Block

1

Screen the aggregate through a 1 cm sieve.



2

The block mix:



1 bucket of cement



8 buckets of aggregate

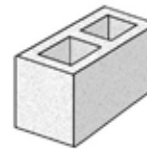


1/2 bucket of water



Blocks must be 15 cm or more thick. Do not use 10 cm or 12 cm block for confined masonry walls.

15 cm



3

Fill mold and compact with a shovel.



4

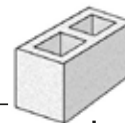
Spray completed blocks with water 3 times per day for 7 days after casting.

5

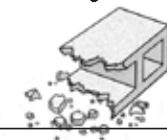
Block "drop test"

Drop each block from about 1.5 m onto a hard surface. If the block breaks, do not use it.

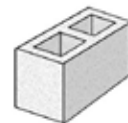
No



1.5 m




Yes!




The Mortar


Mortar Mix



1 bucket of cement



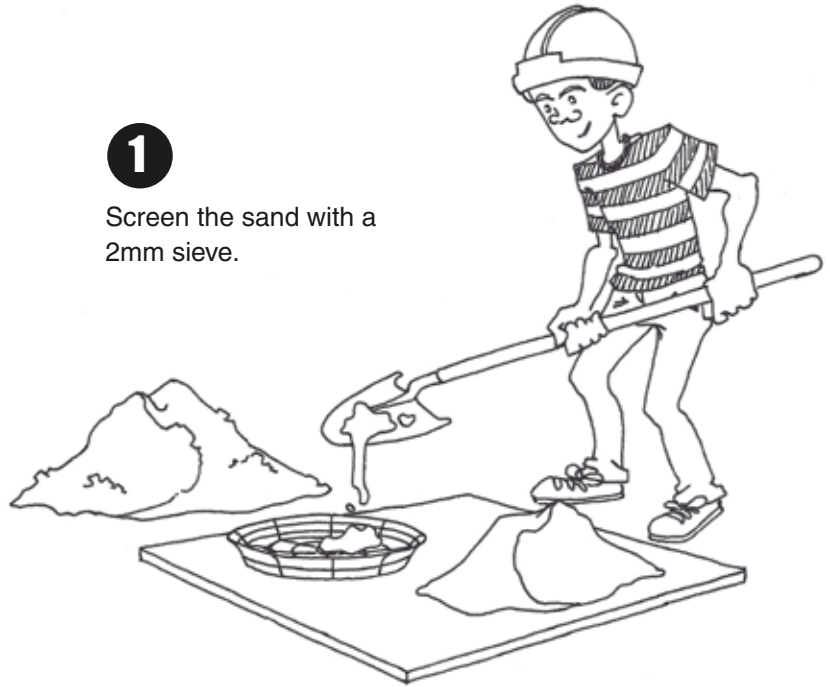
4 buckets of river sand



water

1

Screen the sand with a 2mm sieve.



2

Dry mix the sand and cement.

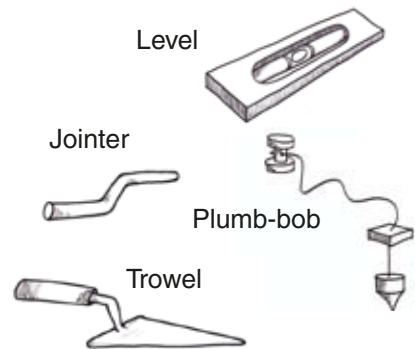


3

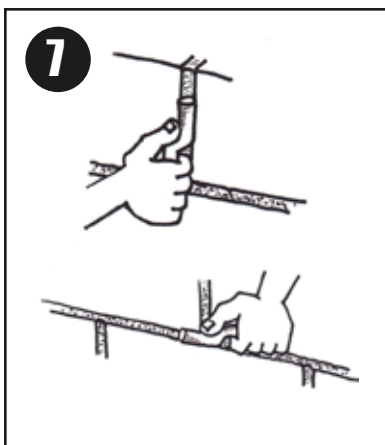
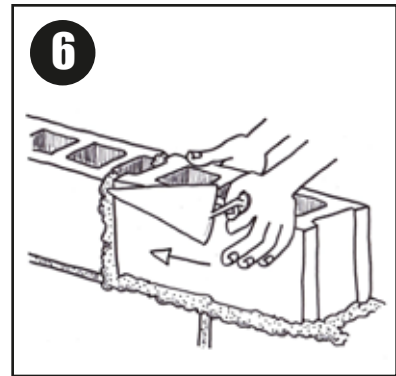
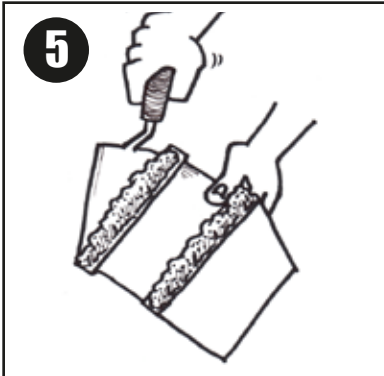
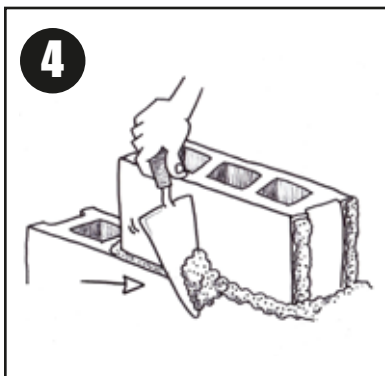
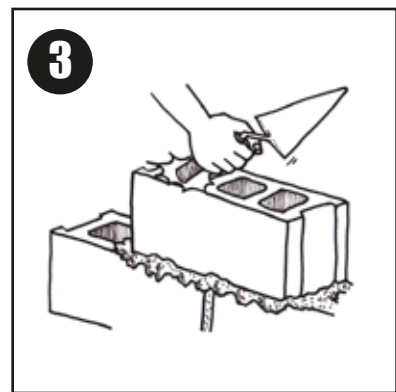
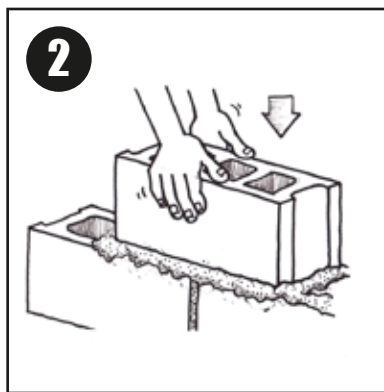
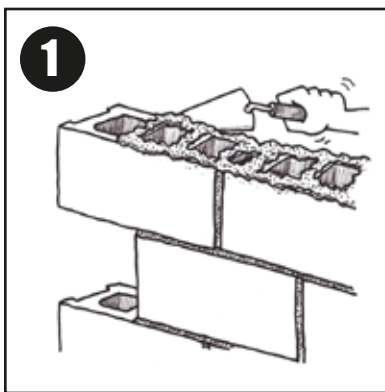
Add water as required to make the mix workable.

Constructing the walls

For the construction of the first course, place mix uniformly over the plinth using a blocklayer's trowel. Set the block over the mix and verify that their edges touch the strings that connect the guide blocks. To set successive layers, alternate blocks so the ends do not line up and fill the vertical joints completely.

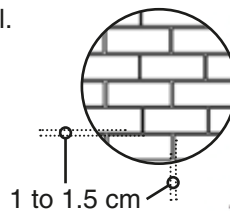


Laying the blocks



Horizontal and vertical joints

Do not make joints more than 1.5 cm thick. Joints that are too thick will weaken the wall.



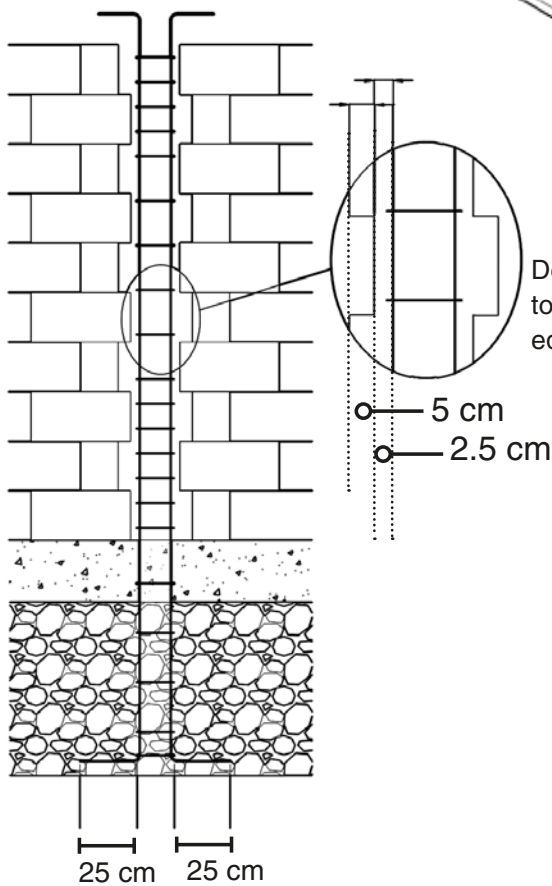
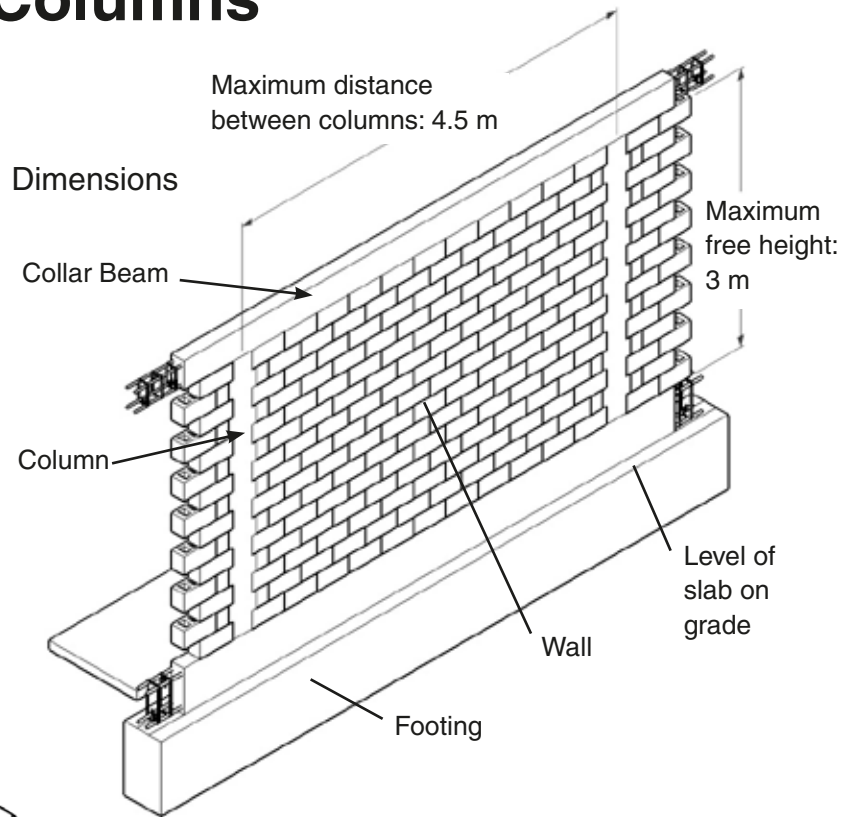
Level Control

Use the plumb-bob on every course to make sure the wall is vertical.

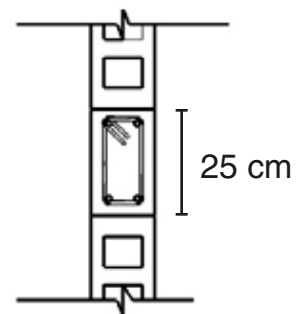
3. Creating the Columns

Column-Wall Connection

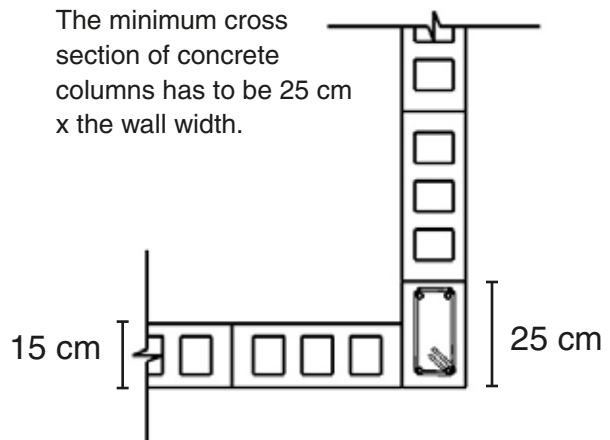
Leave toothed edges at the sides of the wall next to every column to provide adequate confinement for the wall.



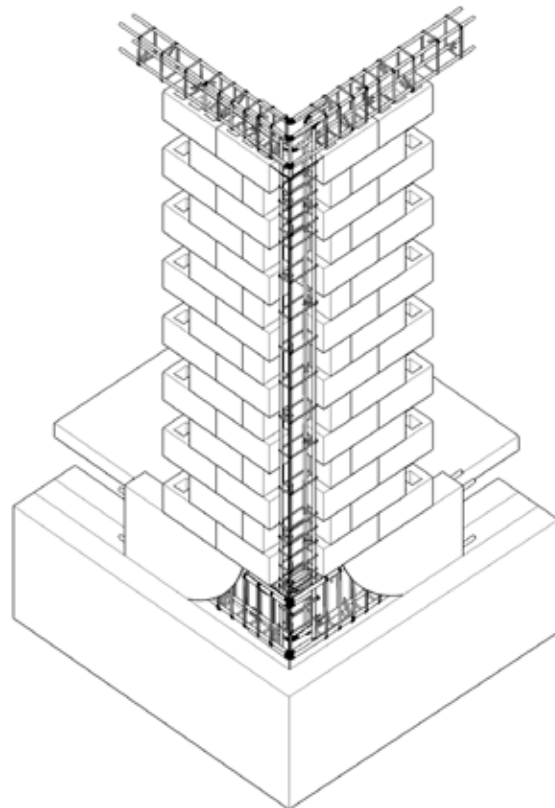
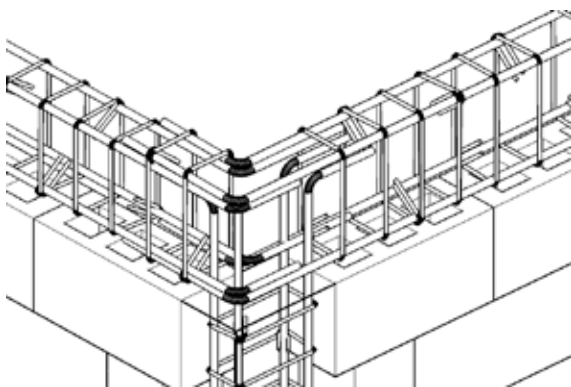
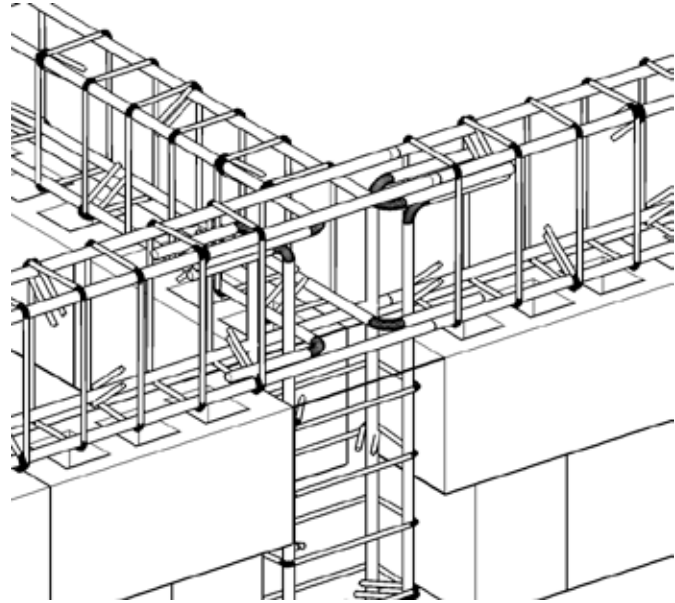
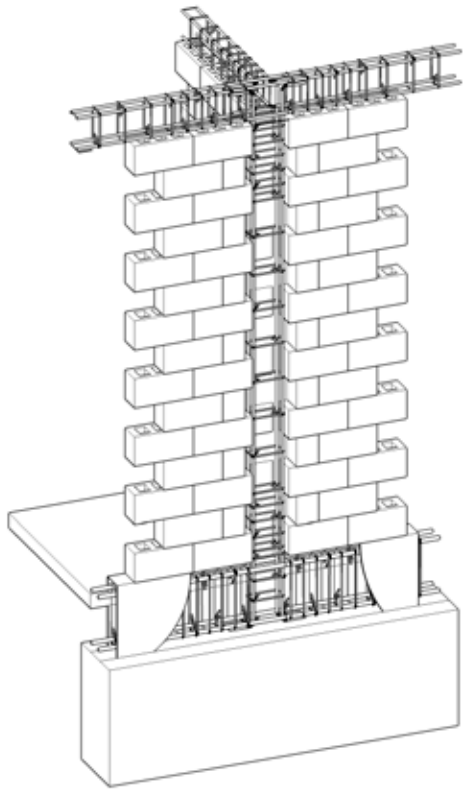
In the foundation and the plinth, do not place big stones near columns.



The minimum cross section of concrete columns has to be 25 cm x the wall width.



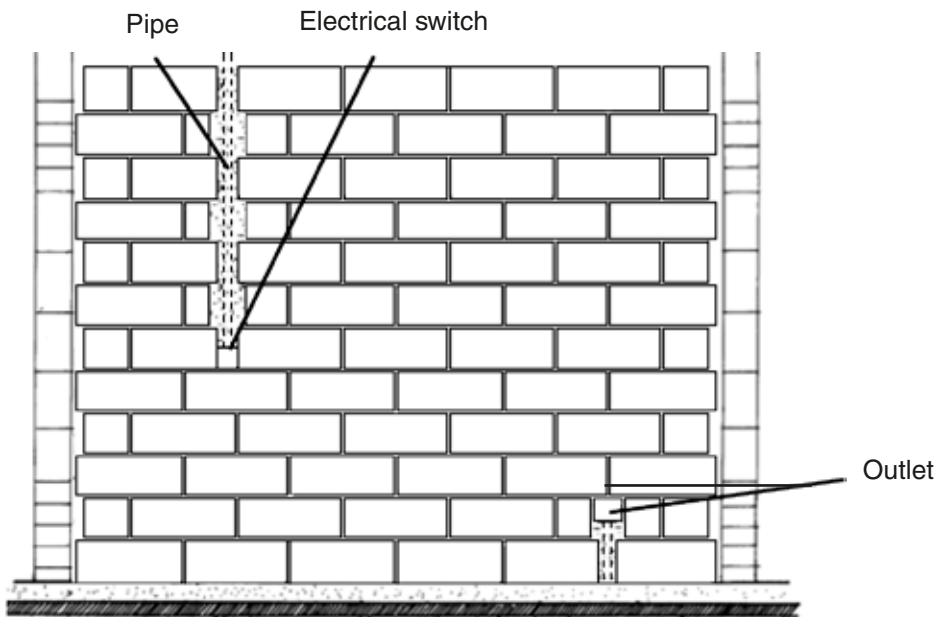
Examples of column and beam reinforcing



Electrical installation in the Walls

Embed electrical conduit inside false columns that are formed between toothed walls without steel and filled with 1:6 concrete.

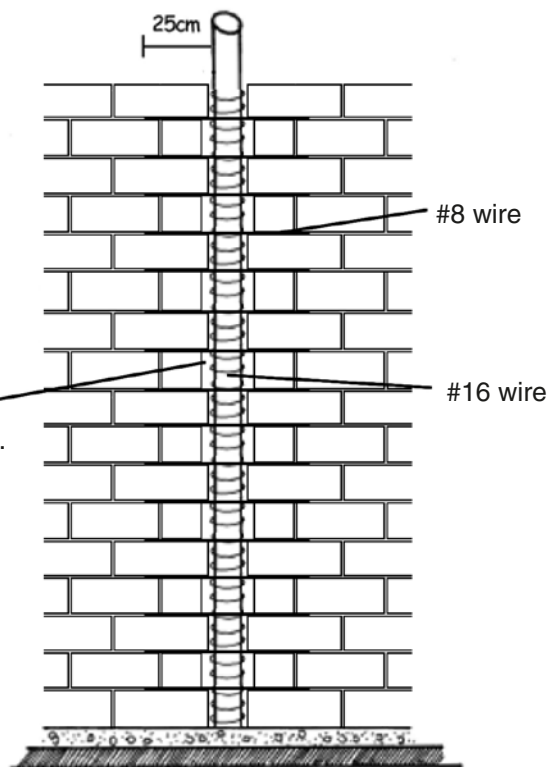
Never weaken the wall by breaking it to place electrical conduits or accessories.



Drain and ventilation pipes

Embed the drain and ventilation pipes inside false columns that are formed between the toothed walls. Place #8 wire every three layers and wrap the pipes with #16 wire.

Fill the false columns with 1:6 fluid concrete.



Pouring Concrete in Confining Columns

Formwork and pouring

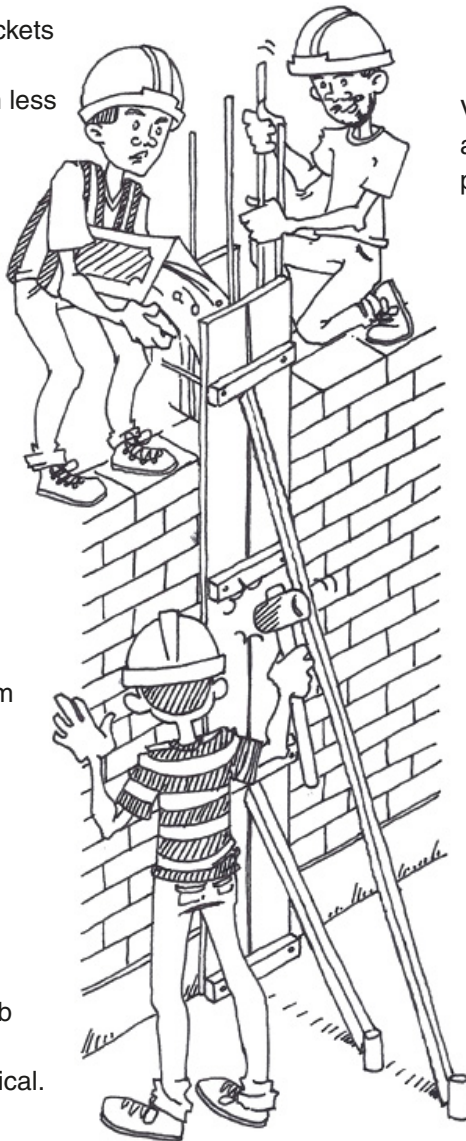
After the walls are built, attach formwork to the walls for the confining columns. It is better if you use a portable concrete mixer to prepare concrete for columns. Use buckets to carry the concrete mix from the mixer to the upper part of the formwork.

To prevent air pockets in columns, use concrete mix with less stone in the first batches.





Vibrate the concrete with a long rod to prevent air pockets.

Lightly hit the form externally with a rubber hammer.

Use a plumb-bob to verify that the formwork is vertical.

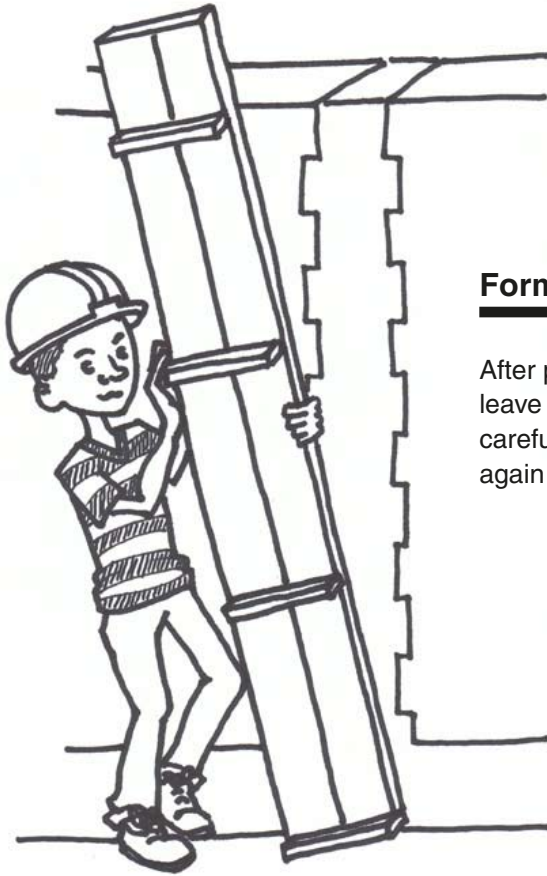


Concrete for columns

	1 bucket of cement
	2 buckets of coarse sand
	4 buckets of crushed stone
	1 bucket of water

Use braces to hold the forms.

3. CREATING THE COLUMNS



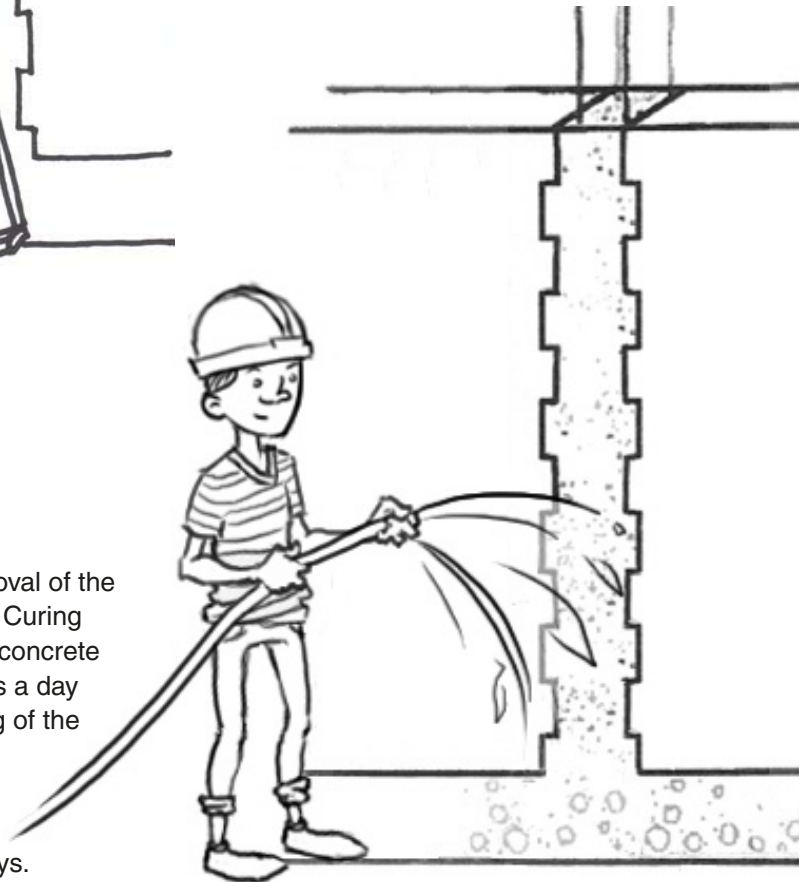
Formwork removal

After pouring concrete into the columns, leave the forms up for 24 hours. Then carefully remove the forms and use them again for other columns.

Curing

Cure concrete after removal of the forms from the columns. Curing consists of watering the concrete elements at least 3 times a day to improve the hardening of the cement.

Cure every concrete element for at least 7 days.



Recommendation

If a column has a large number of voids, immediately break and remove the concrete. Carefully clean the steel bars. Replace the formwork and pour the concrete again.

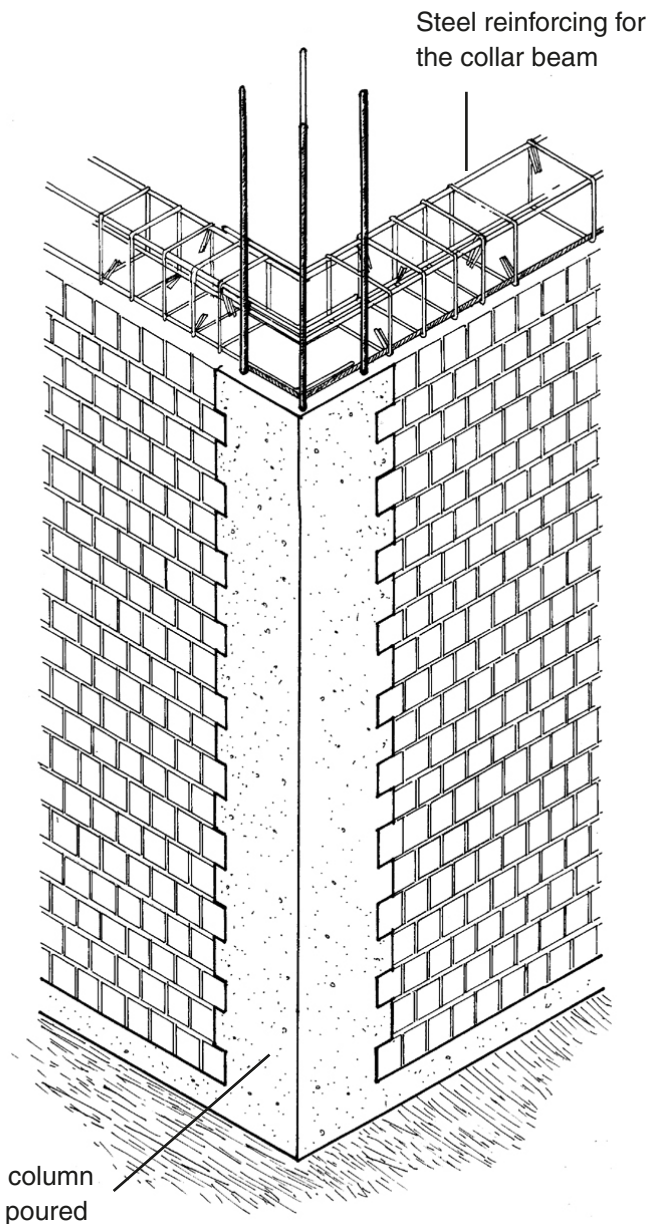
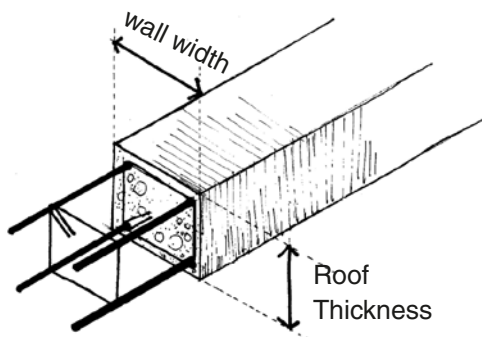
4. Attaching the Second Floor & Roof

Confining Beams: The confining beams of your house are important because they help confine the walls.

Collar Beams: Collar beams are the beams on top of the walls.

Minimum Reinforcement

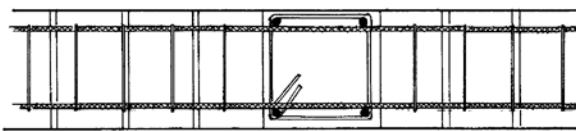
Minimum reinforcement of all beams is: 4 steel bars \varnothing 3/8 in. with \varnothing 1/2 in. stirrups spaced 1 @ 5 cm, 4 @ 10 cm and the rest @ 25 cm from each end.



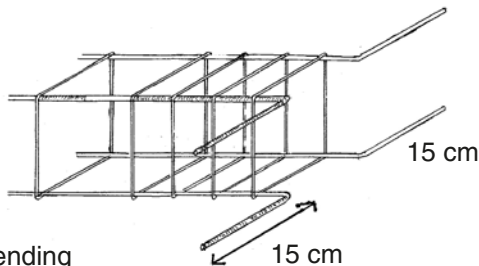
Beam-Column Connections

Carefully place reinforcement bars at beam-column intersections. When you pour concrete in these areas, vibrate the concrete extensively with a rod so that no air pockets form.

Detail of plan view



In case the beam is not continuous, bend the steel bar horizontally.

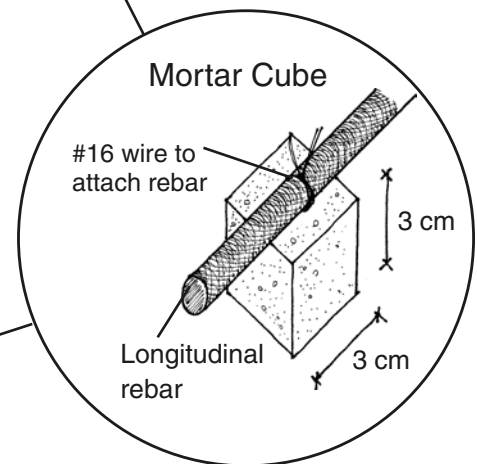
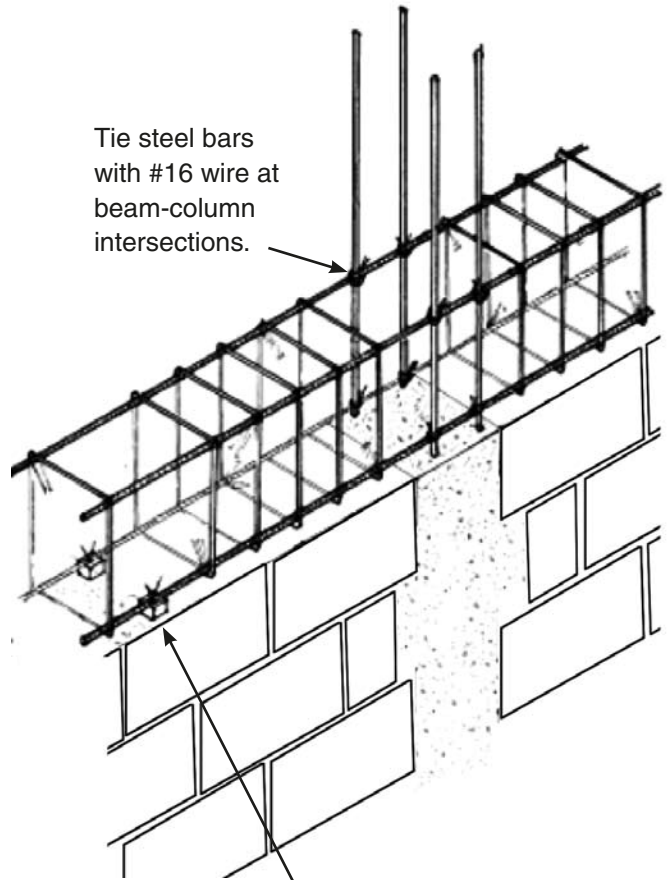
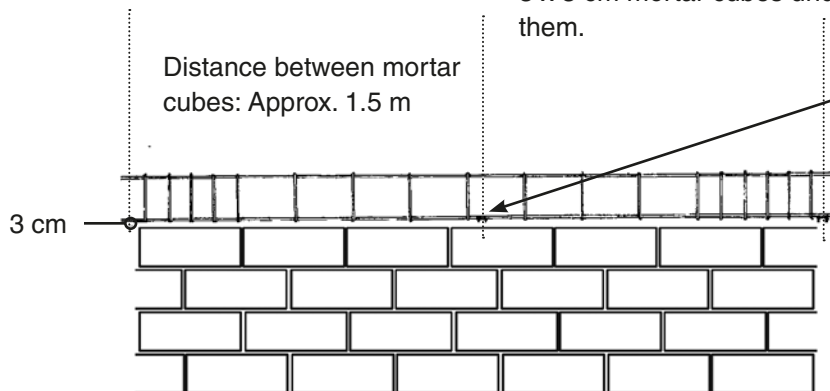


Rebar bending length in beams has to be 15 cm.

Spacers for beams

To keep beam reinforcing bars in a horizontal position, place 3 x 3 cm mortar cubes under them.

Distance between mortar cubes: Approx. 1.5 m



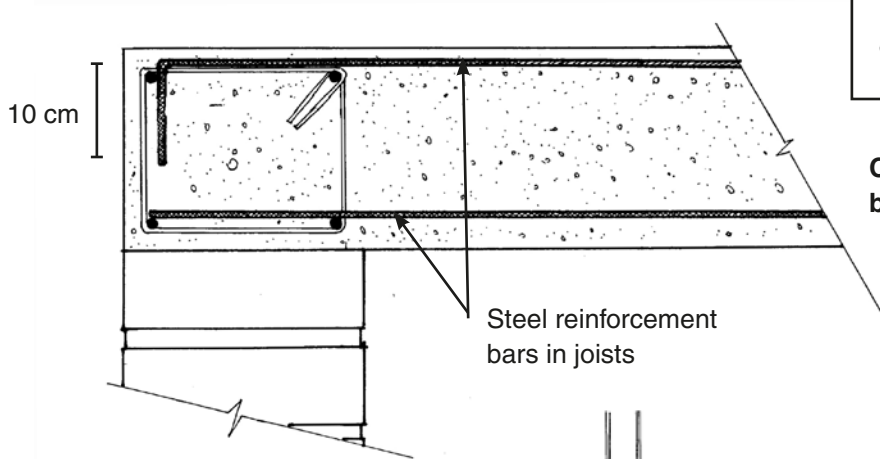
Use equal strength concrete for the mortar and beams (proportion 1:4)

Beam Rebar Assembly





After removing the formwork from the columns, place the steel reinforcement bars of the collar beams on top of the walls.

Pouring of Beams

All beams (collar, deep and flat) and lintels are poured simultaneously with the slabs.

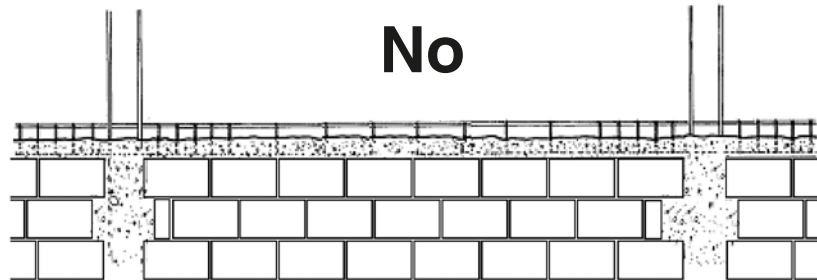


Concrete for beams & slabs

-  **1** bucket of cement
-  **2** buckets of coarse sand
-  **4** buckets of crushed stone (maximum size 3/4 inch)
-  **1** bucket of water

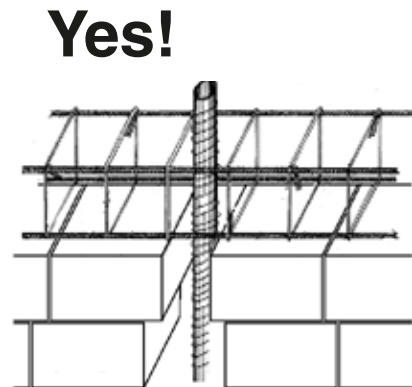
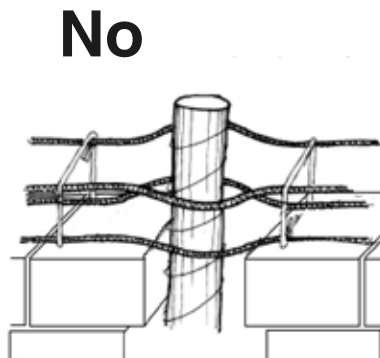
Connection between confining beam and joist rebar

Tie joist upper reinforcement bar to confinement beam reinforcement with #16 wire.



Pipes/Plumbing in beams

Never bend beam rebars to pass drainage pipes.



5. Calculating the Walls needed for an Earthquake-resistant House

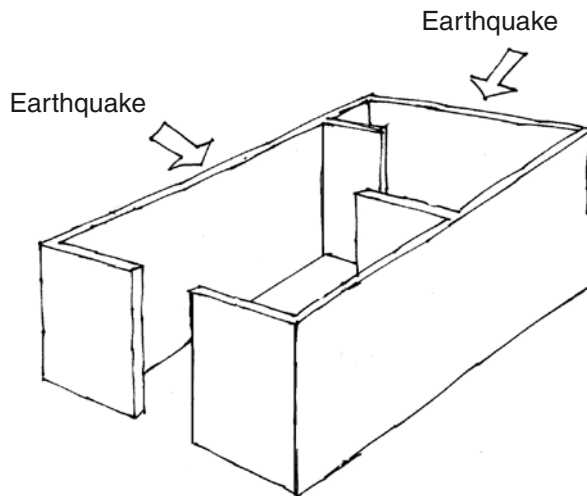
Your house has to have an adequate number of confined walls in both directions in order to resist an earthquake.

How do I calculate how many confined walls I must have in either direction?

The required number of walls depends on the type of soil where you build your house.

Vulnerable House

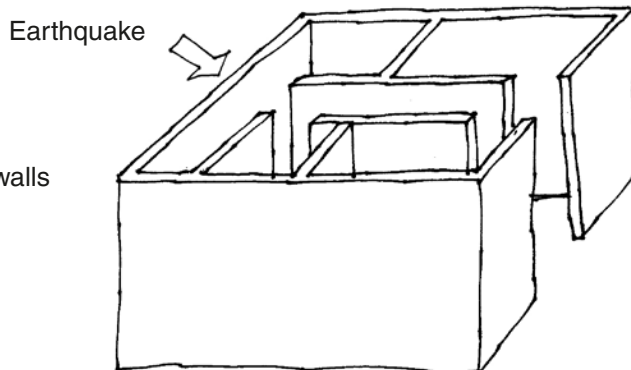
Few confined walls in the direction parallel to the street.



Earthquake

Resistant House

Adequate quantity of confined walls in both directions



Wall Calculations

To calculate the number of walls needed for a house with a maximum of two stories, follow these steps:

1. Classify the soil of the place where you will build your house.
2. Determine minimum wall density needed in each direction, according to your soil type. Use the following table:

Type of Soil	Description	Minimum Wall Density Required (%)
Hard	Rock Gravel	3 %
Intermediate	Hard Clayish Sand	4 %
Soft or Loose	Loose Sand Soft Clay	5 %



3. Calculate the roof area covering each floor in square meters.
4. Calculate the required horizontal area of confined walls for each floor.

$$\text{REQUIRED HORIZONTAL AREA OF CONFINED WALLS IN FIRST FLOOR} = \frac{\text{MINIMUM WALL DENSITY}}{100} \times (\text{ROOF COVERED AREA OF FIRST FLOOR} + \text{ROOF COVERED AREA OF SECOND FLOOR})$$

$$\text{REQUIRED HORIZONTAL AREA OF CONFINED WALLS IN SECOND FLOOR} = \frac{\text{MINIMUM WALL DENSITY}}{100} \times \text{ROOF COVERED AREA OF SECOND FLOOR}$$

5. CALCULATING THE WALLS NEEDED FOR AN EARTHQUAKE-RESISTANT HOUSE

Example

Suppose that your house will be constructed over a compact gravel-coarse sand soil and that it will have 70 m² of roof covering area in the first floor and 50 m² in the second floor. Wall density required for hard soil is 3%.

To calculate the horizontal wall area needed in the first floor, consider the roof covering areas of the first and second floors. That is, the wall area required by the first floor will be:

$$\text{Required Horizontal Area for Floor One} \\ (3/100) \times (70+50\text{m}^2) = (3/100) \times 120\text{m}^2 = 3,60\text{m}^2$$

To calculate the horizontal wall area necessary in the second floor, you only have to consider the roof area covering the second floor. That is, the wall area required for the rest of the second floor will be:

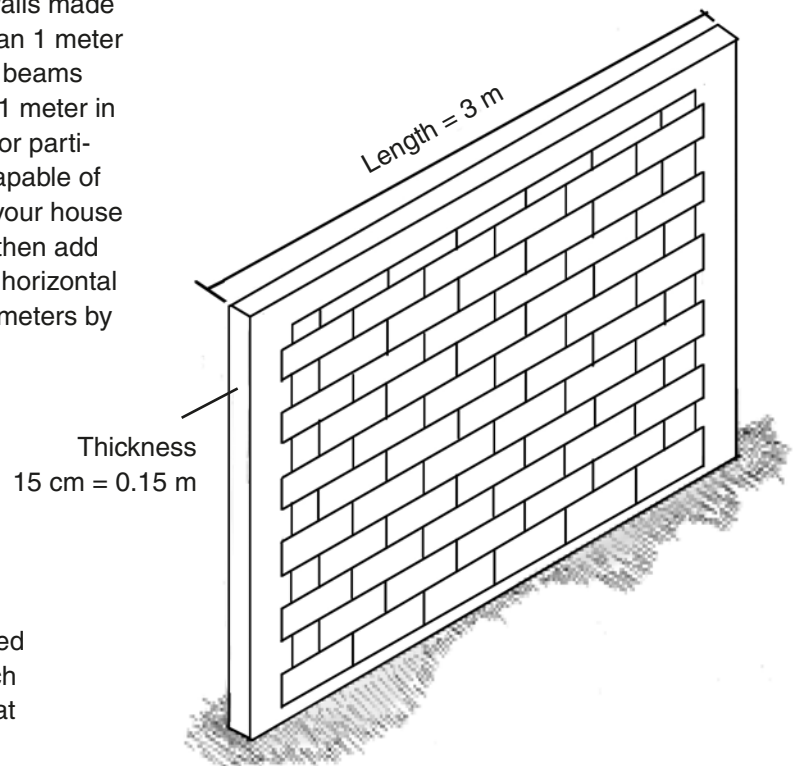
$$\text{Required Horizontal Area for Floor Two} \\ (3/100) \times (50 \text{ m}^2) = 1,5 \text{ m}^2$$

5. Verify that the total horizontal area of confined walls in your house in each direction is greater than the required area. In the elevation only include walls made of structural block whose length is greater than 1 meter and that are confined by reinforced concrete beams and columns. Do not include walls less than 1 meter in length. Also do not include unconfined walls or partition walls because these elements are not capable of resisting earthquakes. For each direction of your house evaluate the area of each confined wall and then add up the areas of all the walls. To calculate the horizontal area of each wall in m² multiply its length in meters by its thickness in meters.

Example

Horizontal wall area
 $3 \text{ m} \times 0.15 \text{ m} = 0.45 \text{ m}^2$

Then verify that the horizontal area of confined walls in every floor of your house and for each direction is greater than the required area that you calculated in the previous step.



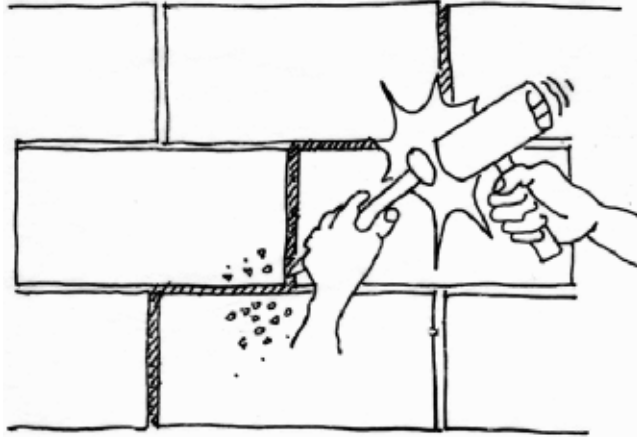
Total horizontal wall area (m²) > required horizontal area (m²)

REPAIR WALL CRACKS

IF ANY WALL HAS DIAGONAL CRACKS NOT MORE THAN 1.5mm THICK AND THE CONCRETE IN THE BEAMS AND COLUMNS IS NOT SEVERLY DAMAGED, YOU CAN REPAIR THE WALL IN THE FOLLOWING WAY:

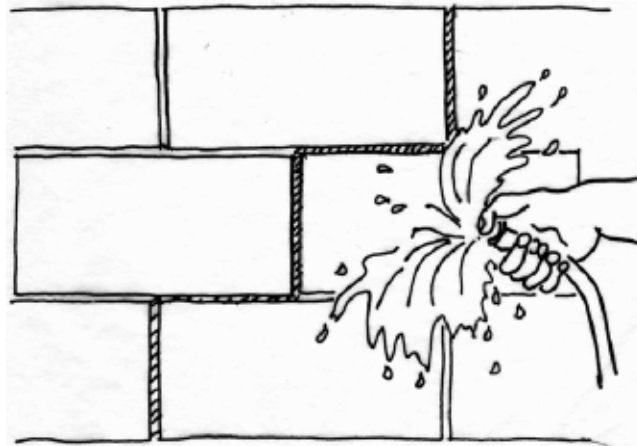
1

REMOVE MORTAR FROM CRACKED JOINTS AND ELIMINATE ALL LOOSE MATERIAL. TRY NOT TO HIT NEARBY BLOCKS.



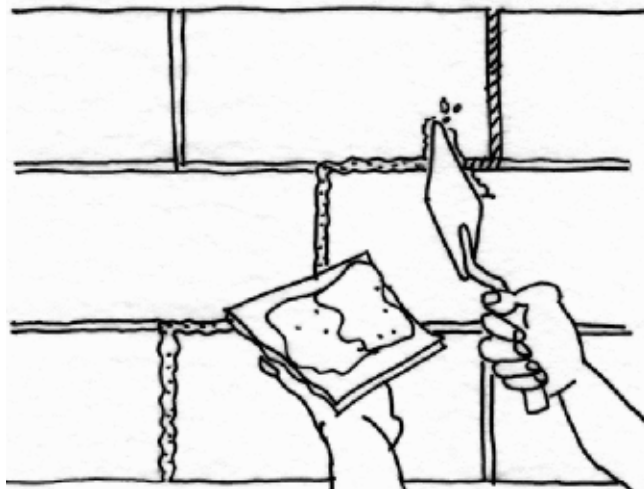
2

CLEAN CRACKED JOINTS THOROUGHLY WITH PRESSURIZED WATER. LET WATER DRAIN DURING 15 MINUTES.



3

REFILL THE JOINT WITH NEW 1:4 (CEMENT:SAND) MORTAR. APPLY AND COMPACT THE MORTAR UNTIL YOU COMPLETELY FILL THE JOINT.

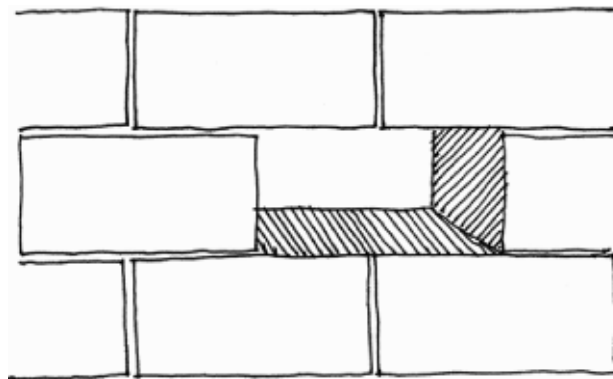
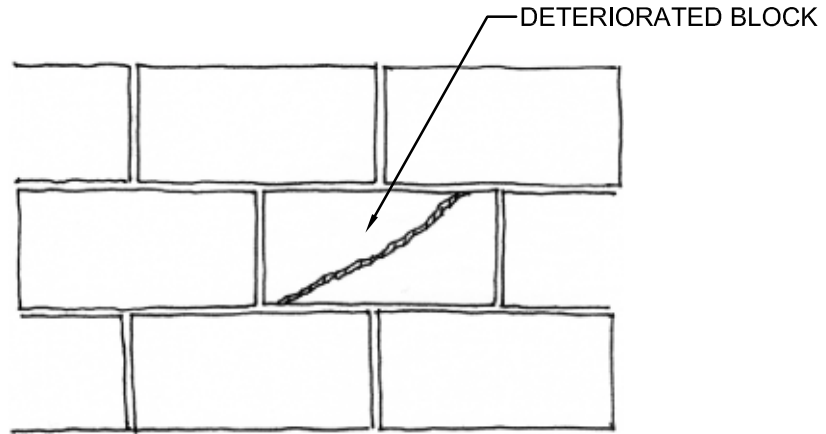


REPLACEMENT OF DAMAGED BLOCKS

IF ANY WALL HAS BROKEN OR DETERIORATED BLOCKS,
YOU CAN REPLACE THEM IN THE FOLLOWING WAY:

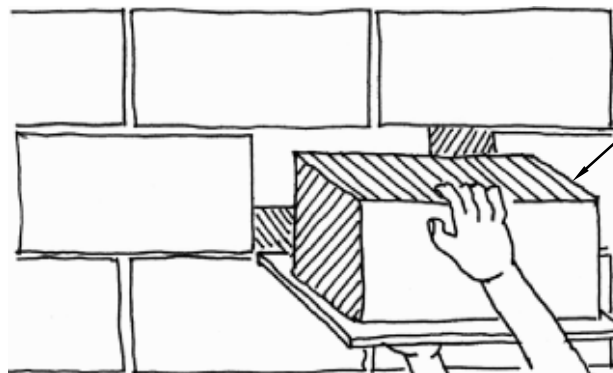
1

CAREFULLY REMOVE THE DAMAGED BLOCK. CLEAN UP THE MORTAR THAT REMAINS IN THE HOLE.



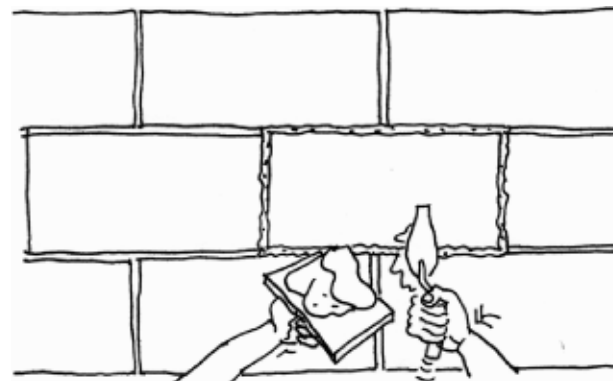
2

GET A NEW GOOD QUALITY BLOCK TO REPLACE THE REMOVED BLOCK.



3

THOROUGHLY WET THE BLOCKS IN THE WALL AND ADJACENT TO THE NEW BLOCK AND PLACE NEW 1:4 (CEMENT:SAND) MORTAR ALONG THE EDGES OF THE HOLE. CAREFULLY PLACE THE NEW BLOCK. TO FINISH, FILL ANY REMAINING SPACES AROUND THE NEW BLOCK WITH MORTAR.

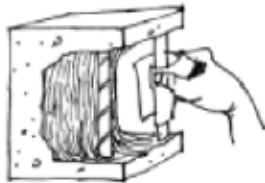
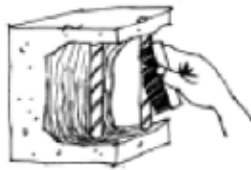


REPAIR OF COLUMNS WITH POOR CONCRETE



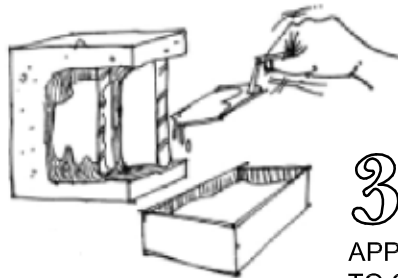
1

CAREFULLY BREAK ALL
DETERIATED CONCRETE
UNTIL YOU GET A ROUGH
UNDAMAGED SURFACE.



2

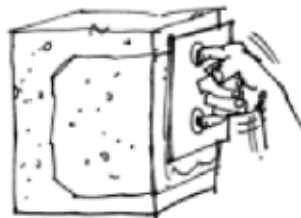
THOROUGHLY CLEAN THE
RUSTED BAR WITH A STEEL
BRUSH. TO ELIMINATE
RESIDUES SOFTLY
SANDPAPER THE STEEL.



3

APPLY CEMENT PASTE
TO OLD CONCRETE SO
THAT NEW CONCRETE
WILL EASILY ADHERE.

4



COMPLETELY FILL THE HOLE LEFT
BY THE REMOVED CONCRETE
WITH 1:4 (CEMENT:SAND) MORTAR.
CAREFULLY ALLIGN THE SURFACE
OF THE NEW CONCRETE WITH THE
EXISTING SURFACE. CURE THE
NEW CONCRETE FOR 7 DAYS
WATERING IT EVERY 8 HOURS.