Guide book
for building earthquake-resistant houses in confined masonry

NON-COUNTRY SPECIFIC VERSION
Guide book
for building earthquake-resistant houses in confined masonry

Guide book for technical training for earthquake-resistant construction of one to two-storey buildings in confined masonry

GUIDE BOOK FOR BUILDERS
masons - steel trades - carpenters

COMPETENCE CENTER FOR RECONSTRUCTION - CCR

SWISS AGENCY FOR DEVELOPMENT AND COOPERATION HUMANITARIAN AID - SDC/HA

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This version of the Guide is non-country specific, and is the result of the compilation of international building codes and construction practices.

You might find other versions of the Guide, made specifically for certain countries and adapted to their construction codes, building materials characteristics and local building cultures. For this reason, some information may vary among versions, such as mixing proportions, dimensions, tools, etc.

SDC declines any responsibility regarding the translation and technical content of the other context-specific adapted versions.
This Guide is intended for the training of professional masons in confined masonry. It can be used as a building guide at construction sites or as a training resource. It is presented in a simple manner and explains in a step-by-step sequence how to build a one or two-storey confined masonry house.

The Guide was developed for masons working in developing countries. The recommendations are intended to be conservative (on the safe side) and to ensure life safety of the occupants of the house.

This Guide needs to be adapted in consideration of the type and quality of locally available materials and local capacities. The technical recommendations contained in the Guide should be in compliance with local construction codes and other regulations (when available).

Illustrations included in the Guide may be adapted to suit the local culture and perceptions and to ensure good acceptance. The text may be translated into a local language that the masons are able to read and understand.

While the authors have tried to be as accurate as possible, they, the organizations they are affiliated with, and the sponsoring organizations cannot be held responsible for any construction, or any misinterpretations, that might be based on the material presented in the Guide.
THE MASON’S WORLD
Mason's tools - 1

Guide book  tape measure  straight edge  level

pencil  plumb line  string  nail  chalk line

aluminium screed  machete  screen (05, 03)

trowel  float  hammer  chisel  club hammer
Mason’s tools - 2

- bucket
- mixing box
- big brush
- cone for slump test
- transparent water hose 10 -20 m
- pickaxe
- shovel
- long handled cold chisel
- rammer
- grinder
- needle vibrator
- concrete mixer
- wheelbarrow
- vibrating block/brick press
Formwork tools

- Guide book
- Tape measure
- Straight edge
- Level
- Pencil
- Plumb line
- String
- Nail
- Hammer
- Chisel
- Crowbar
- Axe
- Saw
- Plane
Steel reinforcement tools

- Guide book
- Tape measure
- Straight edge
- Level
- Pencil
- Chalk
- Plumb line
- String
- Nail
- Wire twister or pincer
- Pliers
- Tin snips
- Hammer
- Chisel
- Plastic pipes of different diameters
- Hacksaw
- Rebar bender
- Chain bolt cutter
Quality of materials

The quality of materials is essential to ensure safe construction.

**Water:**
clean and non-salty

**Blocks & bricks:** (ch. 9)
minimal size and strength

**Sand:**
river sand, washed and dry

**Cement:**
portland cement, new and dry bags

**Gravel:**
crushed or round, from hard rock and clean, well-graded, max size 18-20 mm

**Steel bars:**
standard size, ribbed steel, grade 60 new and not corroded
Storage of building materials on site

Store cement bags away from the sun and protected from humidity. Do not place on the ground!

Store wood and steel bars in a dry environment. Do not place on the ground!
Protection on the construction site

Do not forget that health and security concerns everybody, starting with oneself.

If people are injured on a construction site, wash the wound with clean water and soap and go to a doctor.
CONFINED MASONRY FOR TWO-STOREY HOUSES
What is confined masonry?

Confined masonry is a construction technique where walls are built before the reinforced concrete elements. In confined masonry, the walls carry the weight. The tie-columns ensure that the walls don’t fall apart.

The concrete elements work like a chain around the masonry walls, preventing them from collapsing during an earthquake.

In confined masonry, these concrete “chains” are called tie-columns and tie-beams.
Confining elements (ties)

Confining the walls is like holding a pile of books together with a string: they can still move but they will not fall apart.

Horizontal ties (tie-beam) and vertical ties (tie-column).

Only tie-columns is not good enough.

Only tie-beams is not good enough.
A strong house

All walls and openings should be confined to ensure stability during an earthquake.

Confining elements in red: (chap. 6-8)
tie-column and tie-beams (plinth beam and ring beam)

Anchoring bands & opening reinforcement in grey: (chap. 11)
seismic bands (lintel & sill bands) and vertical reinforcement
Shape of the house

YES, THIS IS CORRECT!

Maximum ratio 1 to 3.

Each facade must have at least one tied wall without openings = shear walls.

NO, THIS IS NOT CORRECT!

Openings are too big.

Free standing wall without any tie.
Shear walls - 1

Shear walls are walls without openings, which follow these two rules:

Rule 1: the wall must be confined on all four sides with reinforced concrete elements.

Rule 2: the length of a shear wall must be minimum 2/3 of its height.
Shear walls - 2

Shear walls are walls without windows or with a small window outside of the diagonals of the wall.

Opening is too big:
not a shear wall!

Opening is small and outside the diagonals:
it is a shear wall!
Size of openings

In walls that are not shear walls, the width of the openings should not exceed half of the length of the wall.

Note: for larger openings, consult an experienced engineer.

Rule: \( b \) smaller than \( a/2 \)

Correct: \( b \) smaller than \( a/2 \)

Incorrect: \( b \) bigger than \( a/2 \)
Seismic gap

Avoid complex shapes by creating seismic gaps.

Complex shape: WEAK, will break

NO

Simple shape: STRONGER

YES

Recommended: joints of 45-60 cm

27
Vertical continuity of walls

Walls must be placed continuously one on top of the other, from the ground to the roof!

- **YES**
- **NO**

- Cantilevered
- Large openings are dangerous
- No vertical continuity between the upper and the lower wall.
ADEQUATE LOCATION
Site selection - 1

Keep enough distance on each side of the house.

Don’t build on fresh embankments.

Don’t build on embankments.

Don’t build on stilts.

Don’t build too close to a cliff.

Building near high buildings can be dangerous (objects falling). Ask an engineer.
Site selection - 2

Don't build at the bottom of a canyon.

Don't build near a river.

Don't build near the ocean (due to tsunami hazard).

Don't build on fresh embankments.
Building on a slope

**YES**
Build between retaining walls.

**NO**
Don’t build against a retaining wall.

**NO**
Don’t build on top of a retaining wall.
Layout

Place the batter boards 1 m outside the trenches.

Drive in nails in order to pull strings.

It is a rectangle:
- if diagonals are of the same length, and
- if the opposite sides are of the same length ($A=A'$, $B=B'$)
Tracing a right angle (3 : 4 : 5)

Proportion rule:

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 cm</td>
<td>40 cm</td>
<td>50 cm</td>
<td></td>
</tr>
<tr>
<td>60 cm</td>
<td>80 cm</td>
<td>100 cm</td>
<td></td>
</tr>
<tr>
<td>90 cm</td>
<td>120 cm</td>
<td>150 cm</td>
<td></td>
</tr>
<tr>
<td>1.5 m</td>
<td>2 m</td>
<td>2.5 m</td>
<td></td>
</tr>
<tr>
<td>2.1 m</td>
<td>2.8 m</td>
<td>3.5 m</td>
<td></td>
</tr>
<tr>
<td>3 m</td>
<td>4 m</td>
<td>5 m</td>
<td></td>
</tr>
<tr>
<td>3 ft</td>
<td>4 ft</td>
<td>5 ft</td>
<td></td>
</tr>
<tr>
<td>6 ft</td>
<td>8 ft</td>
<td>10 ft</td>
<td></td>
</tr>
<tr>
<td>9 ft</td>
<td>12 ft</td>
<td>15 ft</td>
<td></td>
</tr>
</tbody>
</table>
Site preparation

Remove the topsoil and the excavated material, and place them in different heaps, away from the excavated area.

Check whether the ground is level by using a transparent hose filled with water.
STONE FOUNDATION
Excavation

Dig until you find firm soil.

Soil test:

1. Drop the steel bar. If it remains standing, the soil is too soft. If the steel bar falls down, the soil is hard.

2. Place a concrete cube of 3x3x3 cm (can be a spacer) at the bottom of the excavation. Have a person stand on top of it. If the cube sinks in, the soil is too soft. If not, then the soil is hard.

Place the soil you have dug up to a minimum of 60 cm away from the trenches, to avoid its falling back into the excavation.
Stone Foundation

Dig until you find firm soil, and then build the foundation with the proper width.

Foundation height:
Minimum 50 cm height (under the topsoil), until you find firm soil.

Foundation width:
- hard soil: 40 cm
- rammed soil: 50-60 cm
- soft soil: 70 cm
Foundation dimensions

Foundations must reach min. 50 cm into firm ground (under topsoil).

**Hard soil**:
- width: 40 cm
- height: min. 50 cm
  (lean concrete: 5 cm)

**Rammed soil**:
- width: 50 cm
- height: min. 50 cm
  (strip footing: 15 cm)
  (lean concrete: 5 cm)

**Soft soil**:
- strip footing width: 70 cm
- foundation width: 50 cm
- height: min. 50 cm
  (strip footing: 15 cm)
  (lean concrete: 5 cm)
Stepped foundations

If you build on a slope, the foundation must be stepped, keeping the bottom of the trench always horizontal.

Avoid building parallel to the slope.
Stone masonry foundation

Always use running foundations in confined masonry.

Place all the stones in a horizontal position.

Do not place the stones in a vertical position.

Place through-stones:
Horizontally: at least every 1 m
Vertically: at least every 50 cm
Cyclopean concrete foundation

Use concrete with a 1:2:4 mix (cement:sand:gravel) with 60% of concrete and 40% of stones.

1. First pour the concrete in layers of 10 - 30 cm.

2. Then in each layer of fresh concrete place the stones with the 40% - 60% rule

Note: It is very important to pour the concrete before placing the stones, to avoid creating empty pockets under the stones.

If the strip footing is larger than the foundation: instead of formwork, it is possible to place stones on each side, without mortar, before pouring the cyclopean concrete.
Reinforced concrete strip footing

A strip footing must be used for soft soil conditions. It is also recommended for other soil conditions.

![Diagram of reinforced concrete strip footing]

- **Rebar**: 12 mm
- **Stirrups**: 10 mm @ 15 cm
- **Spacers**: 3-5 cm
- **Min. Distance**: 10 cm

Width 50 cm => 4 rebars
Width 70 cm => 5 rebars

Before pouring the concrete, make sure the reinforcement is perfectly vertical.

Leave space around the reinforcement for the concrete.

min. 10 cm
Curing and ground floor

Always interrupt foundation work on a sloped and stepped line.

Cure the foundation walls: every day, for the three first days.

Build a “drainage bed” with round stones, to prevent humidity from coming up from the ground.

- **Plinth beam**
- **Flashing**
- **Foundation wall**
- **Strip footing**
- **Compacted soil**
- **Lean concrete**
- **Small round stones without mortar**
- **Big round stones placed vertically, without mortar**

5 cm
5-7 cm
15-20 cm

Every day, for the three first days.
Placing sewage pipes

The pipes must go through the foundation, under the plinth beam.

Place a larger diameter tube first, and place the final pipes inside.

Never use empty cement bags to create a passage for the pipes.

Do not go through the plinth beam.
Reinforced Concrete Ties
Types of steel rebars

Always use ribbed steel. Do not use second hand rebars.

For confined masonry Grade 60 should be used. Always use standard rebars (not sub-standard).

Rebar diameter (metric and imperial systems):

<table>
<thead>
<tr>
<th>metric</th>
<th>imperial</th>
<th>inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 mm</td>
<td>#4</td>
<td>1/2”</td>
</tr>
<tr>
<td>10 mm</td>
<td>#3</td>
<td>3/8”</td>
</tr>
<tr>
<td>8 mm</td>
<td>- no equivalent -</td>
<td>-</td>
</tr>
<tr>
<td>6 mm</td>
<td>#2</td>
<td>1/4”</td>
</tr>
</tbody>
</table>

Recommended diameters for vertical and horizontal ties:

stirrups: min. Ø 6 mm better Ø 8 mm
rebars: min. Ø 10 mm better Ø 12 mm
Stirrups

Bend stirrup ends at 45° to make proper hooks.

If stirrups are not bent at 45°, they will open during an earthquake.

Stirrups for ties (columns and beams):

Stirrups for seismic bands and opening reinforcements:
Stirrup spacing

H (max. 3 m)

H/6

plinth beam

50

Important:
Check that stirrups are with stirrups of min. 6 mm (better 8 mm)

min. 6 mm diameter
and not sub-standard.

PSRUWDQW

Check that stirrups are min. 6 mm diameter and not sub-standard.

with stirrups of min. 6 mm (better 8 mm)

50

first @ 5 cm

5 @ 10 cm

rest @ 20 cm

5 @ 10 cm

first @ 5 cm

5 @ 10 cm

rest @ 20 cm

50

tie-column

tie-beam

seismic band

first @ 5 cm

5 @ 10 cm

rest @ 20 cm

5 @ 10 cm

H (max. 3 m)

plinth beam

H/6

H/6
It is necessary to alternate position of stirrup hooks.

Alternate stirrup positions
Lap length

The concrete keeps the rebars together like tight fists: the more fists we have (longer overlap) the stronger the connection!

Tie wires only hold the rebars in place. They don’t add strength to the connections.

**Lap length**: (overlapping)

\[ 50 \times \varnothing \]

(50 times the diameter)

for 10 mm rebar = 50 cm
for 12 mm rebar = 60 cm
Tie-beam: L-connection

Rebars must cross like the fingers of a hand.

Connection with straight bars.

Put an additional rebar around the outer corner.

Extend bent bars from the inside to the outside.

Connection from inside to inside.
Tie-beam : T-connection

Always extend bent bars from the inside to the outside.

Connection with straight bars.

Connection around the inner corner.
Tie-beam: X-connection

**YES**
- All main tie rebars are interrupted

**NO**
- Bent bars around the inner corner
- Interrupted bars without connection

Connection straight bars in both directions and lapped with main tie rebars

50 Ø
Connections with continuous rebars

Solution for T-connection:

YES

continuous bars

bent connection bars

Solution for X-connection:

YES

continuous bars in both directions.

connection straight bars lapped with main tie rebars in one direction ...

... and continuous bars in the other.

50 Ø
Tie-beam to Tie-column connection

If a second storey will be constructed in the future, leave 90 cm high free vertical rebars.

In the last storey, bend the vertical rebars toward the tie-beam and into the strirrups.
Protection of free rebars

Allowed only on top of the first floor.

Protect free rebars with lean concrete.

Exposed free rebar will rust and cannot be reused.

These small columns can be useful to fix a guardrail on to them.

protected free rebars

exposed free rebars
FORMWORK
Formwork for tie-columns - 1

Wall thickness 20 cm,
Column dimension 20x20 cm:

Place a 25 mm board under the formwork panel.

15 cm thick wall,
with a 20x20 cm column:
Columns of the same width as a 15 cm wall must measure min. 25 cm, to allow the vibrating needle to enter.

15 cm thick wall,
with a 15x25 cm column:

Columns of the same width as a 15 cm wall must measure min. 25 cm, to allow the vibrating needle to enter.
Formwork for tie-columns - 2

Formwork held with tie wire

**Warning**: wait until the masonry and the mortar have hardened before placing this type of formwork. Otherwise the tie wire will move the bricks or blocks.

Formwork held with bracings and stakes.
Formwork for tie-beams

Use wooden planks to connect the formwork.

Don't use tie-wire to maintain distance.

Formwork must be well fastened.

Wooden planks provide more accuracy and stability than tie-wire.

Formwork must be well braced!
Spacers are very important: they ensure that the rebars remain in the right place and are well covered by concrete.

Don't use stones to fix the rebars, use spacers with wire loops instead!

Spacers - how to make them

wire loops
mould for spacers
Spacers - how to use them

Add spacers on all sides to avoid rebars touching the formwork.

Placing the spacers:
- every 50 cm
- alternate their position
- on the most external rebars (stirrups on confining elements)

reinforced concrete slab
joist and pan slab

tie-column
tie-beams
Concrete mix (1 : 2 : 3)

The most common and preferred mix is = 1 : 2 : 3

1 part cement

3 parts gravel (round and max. 18-20mm diameter)

2 parts clean sand (washed and dry)

3/4 part clean water

Table of various concrete mixes (by volume):

<table>
<thead>
<tr>
<th>Use</th>
<th>cement</th>
<th>sand</th>
<th>gravel</th>
<th>mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>cyclopean foundation</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>200 kg/m³</td>
</tr>
<tr>
<td>tie columns &amp; beams</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>250 kg/m³</td>
</tr>
<tr>
<td>free columns &amp; beams</td>
<td>1.5</td>
<td>2</td>
<td>3</td>
<td>350 kg/m³</td>
</tr>
<tr>
<td>lean concrete</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Note:
A concrete of 250 kg/m³ contains 250 kg of cement per cubic metre of concrete.
Mixing concrete

Mixing the concrete by hand:

1. Make a pile with the gravel, the sand and the cement but without water.

2. Mix the pile without water and move it twice with a shovel.

3. Add the water only now and mix again.

Mixing with a concrete mixer:

1. Add 1/2 water and cement, mix 1 minute.
2. Add aggregate, mix 1 minute.
3. Add rest of water slowly, mix 3-4 min.

Always use the concrete within 1 hour after mixing.
Concrete test

QUICK TEST:
Take a handful of concrete. If the concrete leaks through your fingers, it is too wet!

Concrete must be used in less than 1 hour.
Never “refresh” dried concrete by adding water.
Don’t mix too much concrete at a time.
Use a standard Abrams steel cone:

1. Fill cone in 3 equal layers.
2. Tamp down each layer 25 times with a rod (rebar).
3. Lift the cone vertically and place next to the slump.

Slump test

SLUMP TEST PROCEDURE:

1. Fill cone in 3 equal layers.
2. Tamp down each layer 25 times with a rod (rebar).
3. Lift the cone vertically and place next to the slump.

Explaination of the results:

<table>
<thead>
<tr>
<th>Workability</th>
<th>mm</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low</td>
<td>0-30</td>
<td>Very dry mix: for street works only.</td>
</tr>
<tr>
<td>low</td>
<td>30-50</td>
<td>Foundations with few reinforcement.</td>
</tr>
<tr>
<td>medium</td>
<td>50-100</td>
<td>Compacted and vibrated concrete.</td>
</tr>
<tr>
<td>high</td>
<td>100-130</td>
<td>Parts with many reinforcements and/or thin structural elements.</td>
</tr>
</tbody>
</table>
Pouring concrete

Pour concrete in layers of 30 - 50 cm and compact it with a rod (rebar) and a hammer to avoid air pockets, or better: use a needle vibrator if available.

Never add water to make the concrete more liquid to “flow down better”.

Roughen up the top surface of the plinth beam to increase bonding of the mortar of the wall.
Compacting with a needle vibrator

The concrete has to be compacted to remove air pockets, the needle vibrator will cause the air to move upwards.

1. Insert the needle vertically until it enters 10 cm into the previous layer.

2. Leave it 10 to 20 seconds for standard concrete. Not more or the concrete will desegregate! With very fluid concrete (not recommended) vibrate 5 to 10 seconds.

3. Lift the needle slowly (the air moves up 2.5 to 7.2 cm per second).

4. The concrete will not be vibrated by solely touching the rebars with the needle.

5. Do not use the needle to move the concrete sideways.

Progress regularly in one direction, keeping in mind that the range of the needle is 8-10 times its diameter.
Curing the concrete

Concrete must not “dry”, otherwise it will be weak. 
Concrete needs water to harden!

After pouring concrete, cure the concrete by wetting the formwork 3 times a day for 3 days. Remove formwork only after three days.

After the formwork is removed, cure the concrete for 7 more days, and cover it with plastic sheets.
Ensure good quality concrete

Protect the free steel reinforcements by casting a small column with lean concrete.

Protect exposed rebars from rusting by rapidly covering them with an enriched mortar (with more cement).

Cavities caused by air pockets due to poor compaction and when removing a vibrating needle too fast.
BRICKS & BLOCKS
Which clay bricks to use

Best brick:
solid burnt clay brick.

Bad brick:
vertical holes more than
50% of surface area.

Good brick:
vertical holes less than
50% of surface area.

Bad brick:
with horizontal holes
(cannot carry weight).

Solid bricks are better than multiperforated ones.

min. 11 cm
(recommended 15 cm or more)

With less than 12.5 cm bricks build double layer walls!

Note: we recommend to use 10 MPa bricks.
Brick test

Visual test:

Bricks need to be:

1. regular in form
2. uniform colour
3. not warped
4. no visible flaws or lumps

Physical test:

1. Bricks cannot be easily scratched by a knife.

2. Resists the “3 point test”:
   Person standing on a brick spanning between two other bricks.

3. Bricks must give a ringing sound when struck against each other.
Which concrete blocks to use

Use heavy blocks and never light blocks.

Best block: 15-20 cm thick, solid block.

Satisfactory block: 18-20 cm thick, with 3 holes.

Good block: 15-20 cm thick, with 4 holes.

Blocks with 2 holes are too weak for confined masonry. 20 cm and only top quality!

- wall thickness: min 25 cm
- voids surface: less than 50%
- web thickness: minimum 25mm

Note: we recommend to use 10 MPa blocks.
Block test

Test blocks before buying them!

Drop 5 blocks from 1.5 m height on hard surface (concrete surface).

Acceptable quality: (1 or less broken)

Bad quality: don’t buy! (more than 1 broken)

Check if blocks were cured in the shade!

Stored in the shade: good.

Blocks which dry in the sun: very bad!

Stored under plastic sheets: good!
Concrete mix for blocks (1 : 4 : 3)

1 part cement
4 parts clean sand
3 parts gravel (5-10mm)
3/4 part clean water

Sand should be crushed, washed and dried.
Do not use sea or beach sand!

1. Make a pile with the gravel, the sand and the cement but without water!
2. Mix the pile without water and move it twice with a shovel.
3. Add water and mix again.

Add water only at the end.
Making the blocks

Wait 18 days before using the blocks!

Fill the molds with the mixture. Compact the mix by hitting the mold with a shovel and a hammer.

If possible use a vibrating machine.

Cover the blocks with plastic sheets immediately!

Store the blocks in the shade for 10 days.

Cure the blocks 3 times a day for a minimum of 7 days and cover with plastic sheets.
MASONRY WALLS
Cement mortar mix (1:4)

1 part cement

4 parts clean sand (washed and dry)

3/4 part clean water

1. Make a pile with the sand and the cement but without water!

2. Mix the pile without water and move it twice with a shovel.

3. Add the water and mix again.

For walls 15 cm or less thick use a 1:3 mix ratio.

Add water only at the end.
Cement-lime mortar

Cement-Lime mortar has lower compressive strength than simple cement mortar, but offers a better workability, higher elasticity, and it is more economical!

Recommended mix: 1 : 1/2 : 4.5

Mix first without water, add water only at the end.
Masonry walls height

Two rules to respect:

1. The height of the wall should be smaller than 22 x the block or brick’s width (A).

2. The maximum height (H) of any wall type is 3 m (or consult an experienced civil engineer for higher constructions).

\[ H = \text{max. } 3 \text{ m} \]

\[ H = \text{max. } 22 \times A \]

wall thickness

12.5 cm

max. 275 cm

max. 300 cm

wall thickness

15 cm / 20 cm / 24 cm
Masonry bonds

**YES**

1/3 to 1/2 of block/brick

**Solid wall = Running bond**

vertical joints are not continuous.

**Weak wall = Stack bond**

vertical joints are continuous.

**NO**

If using bricks less than 12.5 cm wide, build double layer brick walls, with either the English or the Flemish bond pattern:

**English bond pattern**

**Flemish bond pattern**

In both cases the length must be twice the width.
If the toothing is bigger than 7 cm, the concrete cannot properly penetrate and fill the voids.

If it is smaller than 4 cm, the toothing is useless, and will not ensure good anchoring of the masonry wall.
Preparing the masonry units

Dried blocks and bricks will absorb the water from the mortar. Therefore it is important to water the masonry units before using them.

There are various ways to moisten them. Be careful not to wet them too much.

Soak the blocks in water for a while.

Water them with a brush before use.

Water all blocks together.

Water them well, half an hour before using them.
Use a plank as a guide to ensure the wall is in plumb and straight. (5x10 cm plank).

Stack blocks one course at a time.

Cure the concrete with water before laying the blocks.

Important: fill vertical joints with mortar.

Place blocks with their holes downwards.

Joints: 10 - 15 mm = the width of the pinky finger!
Good masonry practice - 2

Don’t build more than 120 cm high of masonry per day.

100 to 120 cm
(5 to 6 blocks)
(10 to 13 bricks)

Protect the wall in warm weather:
mortar must not dry out in the sun.

Keep walls moist by pouring water on them 3 times a day for 7 days and/or by covering them with a plastic sheet for 7 days.
Integrating pipes and tubes

Place pipes in block holes.
Place pipes in service duct.
Don't place pipes in walls or in ties.

Never break the wall to place pipes.
The best way to place the electric tubes is to fix them onto the plastering.
Leave space in the masonry for the electric pipes, that can be later filled with mortar.
Cover seismic gaps

Seismic gaps are needed to prevent independent walls in a building from colliding during an earthquake and therefore affect the whole building stability.

Seismic gaps can be covered with bricks or blocks placed over the gaps and fixed with mortar.

How to cover the gap in the slab.
SEISMIC REINFORCEMENT
Seismic bands

Place a seismic band below and above every opening. Don’t go higher than 6 courses of blocks, don’t exceed 1.20m.

example with 2 seismic bands

example with 1 seismic band
Seismic band details

Roughen up the top surface of the bands to increase bonding of the masonry mortar.

Spacers must be fixed onto the stirrups, not onto the rebars.

Seismic band:
Height (bricks): 7.5 cm
Height (blocks): 10 cm
2 rebars: 10 mm
Stirrups: 6 mm @ 15 cm

2 rebars Ø 10 mm
use spacers
stirrups @ 15cm
Ø 6 mm or Ø 8 mm

7.5 - 10 cm

Spacers must be fixed onto the stirrups, not onto the rebars.
Connect seismic band to tie-column

In case of overlap in the tie-column: respect minimum lap length.

Hook seismic bands reinforcement and lap with tie-column reinforcement.
Opening reinforcement

All openings must be framed with vertical reinforcements and seismic bands or tie-beams.

Reinforcements for walls with 2 seismic bands: see p. 100-102.

Reinforcements for walls with 1 seismic band: see p. 103.
Door reinforcement

Case with 2 seismic bands:

Hook the door vertical reinforcement and lap 30cm with the plinth beam and upper seismic band (lintel), under the stirrups. Do the same with the lower band (sill) in the vertical band.
Small window reinforcement

Case with 2 seismic bands:
For windows smaller than 90 cm.

Hook the window vertical reinforcement and lap 30 cm with the seismic band reinforcement, inside the stirrups.
Large window reinforcement

Case with 2 seismic bands:
For windows wider than 90 cm.

- **window lintel**: min. 15 cm high
- **support**: 30 cm
- **seismic bands**
- **seismic band** (lintel band)
- **stirrups at 15 cm spacing**
- **vertical window reinforcement**
- **formwork**

For windows wider than 90 cm, a window lintel is required. The lintel should be at least 15 cm high. A support of 30 cm is also needed. Seismic bands are placed at the specified locations, and stirrups are added at 15 cm spacing. There is also vertical window reinforcement and formwork included in the design.
Openings up to the tie-beam

Case with 1 seismic band:

Hook the vertical reinforcements and lap 30 cm with the tie-beam and seismic band reinforcements, inside the stirrups.

Hook the vertical reinforcements and lap 30 cm with the tie and plinth beam reinforcements, inside the stirrups.
Vertical reinforcement

This is an alternative solution with vertical reinforcements. **We do not recommend it**, as it is more complicated to build and walls without opening will have poorer seismic reinforcement.

Place a vertical band on each side of every opening. Add a horizontal reinforcement band below and above all openings.
Vertical reinforcement: door

Hook the door vertical reinforcement rebars and lap 30cm with the tie and plinth beam rebars, under the stirrups. Do the same with the lintel band in the vertical band.
Vertical reinforcement: window 1

For windows smaller than 90 cm.

- **tie-beam**
- **window**
- **horizontal reinforcement**
- **plinth-beam**
- **window vertical reinforcement**

Hook the window vertical reinforcements and lap 30 cm with the tie and plinth beam reinforcements, inside the stirrups.

Do the same with the horizontal reinforcement and the vertical bands.
Vertical reinforcement: window 2

For windows wider than 90 cm.

- tie-beam
- plinth-beam
- window horizontal reinforcement
- window vertical reinforcement
- stirrups at 15 cm spacing
- window lintel reinforced seismic band
- formwork

- 90-150 cm
- min. 15 cm
- 30 cm
- 30 cm
Shear wall reinforcement - 1

In some cases, the need for openings makes it impossible to make shear walls in each facade.

Correct, shear wall
Not correct, shear wall missing

In such cases, shear walls can be created by adding tie-columns next to the openings (4 rebars instead of 2, from plinth-beam to ring-beam).

By doing so, the vertical opening reinforcements become tie-columns.
Shear wall reinforcement - 2

Vertical opening reinforcements (2 rebars) can be turned into tie-columns, using 4 rebars connected with the tie-beam.

Opening reinforcements with 2 rebars

Tie-columns with 4 rebars

Reinforcements are turned into tie-columns, by using 4 rebars.
Hollow block slabs

Unidirectional slab

In a unidirectional slab, the primary reinforcement spans only in one direction: the shorter one.

Bidirectional slab

In a bidirectional slab, the primary reinforcement spans in two directions simultaneously. This type of slab is used for square-like spaces.
Unidirectional slab - 1

Primary reinforcement

Primary rebars are placed in the shorter direction (span).

Secondary reinforcement

Secondary rebars are placed on top of and perpendicular to the primary rebars.
Unidirectional slab - 2

Primary reinforcement (Ø 12 mm)

To ensure good anchoring, it is important to insert the hooked slab rebars deep into the bond beam.

YES

NO

primary rebars
spacer
hook

bond beam
block wall
Secondary reinforcement (Ø 10 mm)

Secondary rebars must be placed, using spacers, in the middle of the concrete covering the hollow blocks.

Yes NO

Ø 10 mm @ 50 cm

Ø 12 mm
Bidirectional slab - 1

Primary reinforcement

The rebar's diameter depends on the span:
Span 0-3 m: Ø 10 mm every 40-50 cm
Span 3-4.5 m: Ø 12 mm every 40-50 cm

Primary lower rebars are placed in the spaces in between blocks.

The rebar ends are hooked in the tie-beam.
Bidirectional slab - 2

Primary upper rebars

The upper reinforcement consists of short hooked rebars placed in the last third of the slab.

The hooks must be inserted deeply in the tie-beam reinforcement.
Hollow block slab: formwork

**GOOD FORMWORK**

- 2 to 2.5 cm thick wood planks or plywood
- 5 x 10 cm minimum
- 8 x 10 cm maximum
- Plank
- Max 90 cm
- Counter brace
- Max 75 cm

**BAD FORMWORK**

- Inclined post
- Irregular post
- Don’t place posts on blocks.
- Don’t use patched up posts.
Hollow block slab: placing pipes

Avoid horizontal tubes: use vertical technical ducts next to wet spaces (kitchen, bathroom).

Drill through hollow blocks.

Pass pipes through the hollow blocks and cross only one concrete beam. Reinforce joist with additional rebars.

Don't drill through a concrete beam.

Don't cross more than one concrete beam.
Hollow block slab: before concreting

Test watertightness of the pipes before pouring concrete, by filling them with water and waiting 4 hours to ensure pipe connections are still watertight.

Water the formwork before pouring concrete.
Hollow block slab: concreting

It is essential to maintain the slab humid during the first 1-2 weeks. The easiest way to cure the slab is to create ponds with sands or mud and fill them with water for a minimum of 7 days.

Use a vibrating needle to compact the concrete and avoid air pockets.
Full concrete slab - 1

Full concrete slabs are made without hollow blocks. Place lower rebars on spacers across the shortest direction (span). Place upper rebars perpendicularly on the lower ones and hook both deep into the tie-beam reinforcement.

For span up to 3m:

- tie-beam
- hook
- rebars
- formwork
- spacer
- lower rebar

For span bigger than to 3m:

- 1/6 of span
- span $L > 3m$

Hook options:

- NO
- YES
- YES
- YES
- YES
- span $L < 3m$
- span $L > 3m$
The weight will cause the slab to deform. To avoid cracks from appearing, rebars must be placed on the exterior side of the curves.

Additional upper reinforcement in continuous slabs:

L/3 \[\rightarrow\] L/3 \[\rightarrow\] L/3 \[\rightarrow\] L/3 \[\rightarrow\] max. 60 cm

Place upper reinforcement on chairs and create a water drip:
Full concrete slab - 3

Reinforcement of full concrete slabs:
min. rebars steel grade : grade 60

<table>
<thead>
<tr>
<th>span L</th>
<th>slab thickness</th>
<th>primary reinforcement</th>
<th>secondary reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 3,0m</td>
<td>15cm</td>
<td>Ø 10mm @ 12cm</td>
<td>Ø 8mm @ 15cm</td>
</tr>
<tr>
<td>3,0m-3,6m</td>
<td>18cm</td>
<td>Ø 12mm @ 15cm</td>
<td>Ø 8mm @ 20cm</td>
</tr>
<tr>
<td>3,6m-4,2m</td>
<td>20cm</td>
<td>Ø 12mm @ 15cm</td>
<td>Ø 8mm @ 20cm</td>
</tr>
<tr>
<td>4,2m-4,5m</td>
<td>22cm</td>
<td>Ø 12mm @ 15cm</td>
<td>Ø 8mm @ 20cm</td>
</tr>
</tbody>
</table>

Curing the concrete is essential. Create ponds with sand or mud and fill them with water for 7 to 14 days.
LIGHT ROOF
Roof shape

4 hipped roofs are particularly suitable for areas prone to strong winds and cyclones.

1 hipped roofs do not resist strong winds well.
Concrete tie on top of the gable wall.
Roof structure - trusses

Don't build trusses with boards: there is not enough room for the required nails. Moreover the boards will split due to the nails. Preferably use screws instead of nails.

Use plywood boards to leave enough room for the nails ...

... or metal plates and perforated steel straps.

Timber connections:
Put at least 3 nails in each direction.

Nail length should be equal to the thickness of the united timber elements.
Cyclones

Keep verandas independent from the main roof: so that if the wind tears it off, the main roof stays in place.

Closed gable wall.

Opened gable wall. Main roof extending over veranda.
Fastening of the veranda framing

- straps
- bracing
- solid fastening (steel plates & brackets)
- plinth < 40 cm
Fastening of the roof structure

Solidly fasten the anchors or straps to the wood framing.

Close the spaces between trusses with a plank or a screen to avoid insects.
Bracing

Bracing: wood planks nailed to the trusses.
FUTURE EXTENSIONS
Preparation

Open all corners, all rebar connections.

Build a new solid foundation for the new room.
Add anchor bars

Place the hooks around the vertical rebars: one on top and one under each stirrup.
Place reinforcement

Connect each corner the same way!

Place the 10 mm hooks and then place both the plinth beam and the tie-columns reinforcement.

Connect the new plinth beam to the existing one with the hooks around the existing reinforcements.

Add a vertical 2-bars reinforcement next to each existing tie-column to confine the new wall.

Place the 10 mm hooks and then place both the plinth beam and the tie-columns reinforcement.

New plinth-beams

Vertical reinforcements 2 rebars

Connect each corner the same way!

New tie-columns 4 rebars
Extension of the structure - 1

Pour concrete for the plinth-beam and fill completely the opened corners (phase 1).

Build the masonry walls first until the seismic band (phase 2) and only after pour the concrete for the tie-columns and vertical reinforcements (phase 3).
Extension of the structure - 2

The walls and tie-elements for future extensions should align with the existing structure (existing tie-elements).

Build the seismic bands at the same height as in the existing building (min. every 1.2 m).
RETAINING WALLS
Where to build with retaining walls

A retaining wall doesn't support a house. A retaining wall only holds back the ground!

Don't build your house too close to a retaining wall.

Don't build your house on top of a retaining wall.

Don't build your house against a retaining wall.
Rule 1 - Wall footing

Height: depends on the type of soil.
(bottom of wall to firm soil)

- rock: 30 cm
- hard soil: 30 cm - 60 cm
- medium soil: 60 cm
- soft soil: 60 cm - 90 cm
- freezing soil: 60 cm - 90 cm
Rule 2 - Slope of the wall (5:1)

Slope 5:1
Every time you go up 5 cm, move back 1 cm.
Every time you go up 1 meter, move back 20 cm.
Rule 3 - Dimensions of the wall

![Diagram]

**Height above ground (H):**

- \( H \text{ max} = 2.50 \text{ m} \)

**Top (C):**

- \( \text{min} \ 50\text{cm} \)
- \( 50 \text{ cm} : H \leq 150 \text{ cm} \)
- \( 55 \text{ cm} : H > 150 < 250 \text{ cm} \)
- \( 60 \text{ cm} : H \geq 250 \text{ cm} \)

**Total height (A):**

- \( A = H + B \)
- \( \rightarrow B = 30-90 \text{ cm} \)

**Wall base width (D) calculation:**

The base of the wall (D) equals the total height (A) divided by 5, plus the top’s width (C):

\[ D = \frac{A}{5} + C \]

<table>
<thead>
<tr>
<th>H</th>
<th>C</th>
<th>B</th>
<th>A</th>
<th>D</th>
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<tbody>
<tr>
<td>100</td>
<td>50</td>
<td>30-80</td>
<td>130-190</td>
<td>75-90</td>
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<td>125</td>
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<td>230-290</td>
<td>100-115</td>
</tr>
<tr>
<td>250</td>
<td>60</td>
<td>30-80</td>
<td>280-340</td>
<td>115-130</td>
</tr>
</tbody>
</table>
Rule 4 - Placing the stones

Place the stones on their flat faces and tilt them towards the back.

Place the stones at right angles to the wall's external face.

Don't place the stones in a vertical position!

Don't place the stones at grade!
Rule 5 - Through-stones (or bands)

- Wall without through-stones nor concrete ties.

Diagram showing through-stones in cap beam, middle ties, and base beam bands.
Rule 6 - Drainage

YES

- Drainage pipes
- Drainage bed: gravel and stones. Width = 30 cm.
- Place a drainage pipe every 1.50 m. (vertically and horizontally)

NO

- Wall with no drainage pipes and no drainage bed.
Retaining wall - Confining elements

If there is no other solution than building on a retaining wall, then use these recommendations.

Tie-columns
Every 3 - 4.50 m

Tie-beams
Must go all around the foundation.
Every 1 m height
Add one at the top.

If possible: avoid building the house on retaining walls!
Gabion walls - 1

Gabion walls are made of galvanized wire mesh cages filled with stones.

The stones must be placed by hand, in an interlocking manner. Don't just dump them!

There are various ways to pile the cages. All of them are valid.

Method 1: stepped face

1.5 m

2 m

min. 50 cm, until firm soil

2.5 m
Gabion walls - 2

**Method 2:**
flat vertical face

- Fill with soil by layers of 50 cm and compact everytime
- Slope of the wall 5:1

**Method 3:**
flat inclined face

- Height: 1.5 m, 2 m, 2.5 m
CONSTRUCTION DRAWINGS
Reading plans

A plan represents a house, seen from above, as if it was cut at window height.

Door symbol: indicates the direction of opening of the door.

House plan (seen from the top).
If you vertically cut the house on the line AA\' ...

... this is what you will see!

the same window: seen from above,

and seen from the side

Section AA\'

Plan
Plan dimensions

The sum of all partial dimensions must result in the total dimension.
Section dimensions

Total dimensions

Partial dimensions

+ 2.9m

+- 0.00
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This Guide was originally developed by the Competence Center for Reconstruction of the Swiss Agency for Development and Cooperation (SDC) after the devastating January 2010 Haiti earthquake.

It was developed as a resource for the mason training programme related to confined masonry construction practice, which was launched as a response to the urgent need to establish an earthquake-resistant construction practice in Haïti. Its main purpose was to improve construction practices in areas where housing construction occurs without technical input.

This guide was used at construction sites and as a resource material for mason training programmes. It offered simple but essential advice on building safer houses using the confined masonry construction technology.

This version of the Guide was adapted by SDC together with members of the Confined Masonry Network of the Earthquake Engineering Research Institute (EERI) for use in various countries and regions of the world.

It is hoped that this resource that was first developed in Haiti will be useful in other countries facing the same challenges. The users may include local governmental and non-governmental organizations, international humanitarian and development agencies, and most importantly skilled and unskilled masons around the world.

Non-country specific version, revised June 2018