Guide book for building earthquake-resistant houses in confined masonry

Swiss Agency for Development and Cooperation SDC
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

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HUMANITARIAN AID - SDC/HA

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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 which the masons are able to read and understand.

While the authors have tried to be as accurate as possible, they cannot be held responsible for construction that might be based on the material presented in this guide. The authors and their organizations disclaim any and all responsibility for the accuracy of any of the material included 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
- cone for slump test
- big brush
- transparent water hose 10-20 m
- pickaxe
- shovel
- 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!
Construction site protection

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
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 NO

Only tie-beams NO

YES

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

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

**Confining elements**: (chapters 6-8)
tie-column and tie-beams (plinth beam and ring beam)

**Anchoring bands and opening reinforcement**: (chapter 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

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!
Seismic gap

Avoid complex shapes by creating seismic gaps.

Simple shape: BETTER

Complex shape: WORSE

Minimum 10 cm (better 45-60 cm)
Vertical continuity of walls

Walls must be placed continuously one on top of the other. From ground to the roof!

Cantilevered

The opening is too large.

No vertical continuity between the upper and the lower wall.
FINDING AN ADEQUATE LOCATION
Site selection: where to build

Don't build at the foot of a cliff.
Don't build on stilts.
Don't build on fresh embankments.
Don't build too close to a cliff.

Keep enough distance on each side of the house.

Don't build on embankments.
Don't build on stilts.
Don't build at the foot of a cliff.
Flood related hazards

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).
Building on a slope

Build between retaining walls.

Don't build against a retaining wall.

Don't build on top of a retaining wall.
Site preparation

Remove the topsoil and the excavated material, and place it in 2 (or more) different heaps, away from the excavated area.

Check whether the ground is level by using a transparent hose filled with water.
Tracing a right angle (3 : 4 : 5)

<table>
<thead>
<tr>
<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>
</tr>
<tr>
<td>60 cm</td>
<td>80 cm</td>
<td>100 cm</td>
</tr>
<tr>
<td>90 cm</td>
<td>120 cm</td>
<td>150 cm</td>
</tr>
<tr>
<td>1.5 m</td>
<td>2 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>2.1 m</td>
<td>2.8 m</td>
<td>3.5 m</td>
</tr>
<tr>
<td>3 m</td>
<td>4 m</td>
<td>5 m</td>
</tr>
<tr>
<td>3 ft</td>
<td>4 ft</td>
<td>5 ft</td>
</tr>
<tr>
<td>6 ft</td>
<td>8 ft</td>
<td>10 ft</td>
</tr>
<tr>
<td>9 ft</td>
<td>12 ft</td>
<td>15 ft</td>
</tr>
</tbody>
</table>
Place the batter boards 1 m outside the trenches.

Drive in nails in order to pull strings.

Marking strings

It is a rectangle if each diagonal is of the same length.

Layout
STONE FOUNDATION
Excavation

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.

WARNING: dig until you find firm soil and then build the foundation with the proper width !!!

Foundation height:
- hard soil: min 30 cm
- rammed soil: min 50 cm
- soft soil: min 80 cm

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

**Hard soil**
- height: 30-50 cm
- width: 40 cm
- strip footing: 40 cm

**Rammed soil**
- height: 50-80 cm
- width: 50 cm
- strip footing: 50 cm

**Soft soil**
- height: min 80 cm
- width: 70 cm
- strip footing: 70 cm

**Warning**!
- height above the ground: maximum 20 cm!
Special foundations

If the part above ground is higher than 20 cm, then the foundation acts as a retaining wall.
Do not exceed 40 cm above the ground!

The external face of the foundation wall must be inclined!

Avoid building in a flood-prone area!

Foundation height:
- Rammed soil: min 50 cm
- Soft soil: min 80 cm

Foundation width:
- Rammed soil: min 60 cm
- Soft soil: min 70 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 construction

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

Place through-stones in section:

Place through-stones in plan:
Reinforced concrete strip footing

A strip footing is a must for soft soil conditions! It is also recommended for other soil conditions.

Strip footing:
Width 40 cm = 4 rebars
Width 50 cm = 4 rebars
Width 70 cm = 5 rebars

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

Leave a space around the reinforcement for the concrete.
Curing and ground floor

Cure the foundation walls!
Wet every day, for the three first days!

Always interrupt foundation work on a sloped line.

Build a "drainage bed" to avoid moisture coming in!

- plinth beam
- flashing
- foundation wall
- strip footing
- "drainage bed"
- 7-10 cm lean concrete
- 15-20 cm small stones on top of big stones
- good compacted soil
Placing sewage pipes

**YES**

Bigger pipe

Smaller pipe

For tolerance, leave a hole larger than the sewage pipe, using a larger diameter pipe. Don't use empty cement bags!

The pipe must go through the foundation, under the plinth beam!

**NO**

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

Use ribbed steel for all rebars. Only stirrups can be made of smooth steel.

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

Strength indication are written on the rebar:

- Country of origin
- Producer
- Grade
- Diameter

Do not use second hand rebars!
Steel bar diameters

For rebars:

- YES
- NO

For stirrups:

- YES

Rebars diameters (imperial and metric):

<table>
<thead>
<tr>
<th>imperial</th>
<th>inch</th>
<th>metric</th>
<th>rebars</th>
<th>stirrups</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>3/4 in.</td>
<td>19 mm</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>#5</td>
<td>5/8 in.</td>
<td>16 mm</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>#4</td>
<td>1/2 in.</td>
<td>12 mm</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>#3</td>
<td>3/8 in.</td>
<td>10 mm</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>-</td>
<td>1/3 in.</td>
<td>8 mm</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>#2</td>
<td>1/4 in.</td>
<td>6 mm</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>

Rebar dimensions for vertical and horizontal ties:

- stirrups: min Ø 6 mm, better Ø 8 mm
- rebar: min Ø 10 mm, better Ø 12 mm
Stirrups

Bend stirrup ends at 45°!

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

Possible stirrup types:
It is necessary to alternate position of stirrup hooks!!
Rules for stirrup spacing:

1. At the top and bottom of each tie-column and ends of tie-beams place the first stirrup at 5 cm spacing, then place stirrups at 10 cm spacing over a length of $H/6$ (better 60cm).

2. Place stirrups at 20 cm spacing elsewhere.
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 : T-connection

Always:
extend hooked bars from the inside to the outside!

Lap length:
(overlapping)
50 x Ø
(50 times the diameter)

for 10 mm rebar = 50 cm
for 12 mm rebar = 60 cm

Connection with straight bars.

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

Rebars must cross like the fingers of a hand!

Connection with straight bars.

Hooked bars from inside to inside.

Put an additional rebar around the outer corner.

Extend hooked bars from the inside to the outside!
Tie-beam to Tie-column connection

If the wall continues, add vertical rebars with an $50 \, \varnothing$ overlapp.

If the wall ends here, bend the vertical rebars into the tie-beam.

One-storey building

Two-storey building
Protection of rebar ends

Protect rebar ends with lean concrete.

Exposed rebar ends will rust and cannot be reused.

Protected rebar ends.

Exposed rebar ends.
Formwork for Ties

**Block walls:**

- 20cm wall thickness: place formwork boards on both sides.

- 15cm wall thickness: place a 1 inch board under the formwork board.

**Brick walls:**

- 15-24cm wall thickness: place formwork boards on both sides.

- 15cm wall thickness: place a 1 inch board under the formwork board.

Sizes of tie-columns and tie-beams:
20 x 20 cm recommended / 15 x 20 cm minimum!
Vertical formwork

Vertical formwork at upper floor level:

- Wooden scantling
- Tie wire
- Nails for tie wire
- Shuttering
- Ø 8 mm rebars built in tie-beam

Vertical formwork at ground floor level:

Formwork must be well braced!
Horizontal formwork

Use wood planks to connect formwork.

Formwork must be well fastened!

To be able to reuse the formwork, use small nailed planks. Do not use 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 instead!
Spacers - 2

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

Alternate the position of the spacers around the stirrups!

tie-column

reinforced concrete slab  joist and pan slab
CONCRETE
Concrete mix (1 : 2 : 3)

- 1 part cement
- 3 parts gravel (max. 18mm)
- 2 parts clean sand (washed and dry)
- 3/4 part clean water

Table of various concrete mixes (by volume):

<table>
<thead>
<tr>
<th>Cement</th>
<th>Sand</th>
<th>Gravel</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>minimum</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>preferred</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Preferred mix = (1 : 2 : 3) = 250 kg/m³!

Note:
Concrete should have a minimum amount of 300 kg of cement per cubic metre. The values taken into account in this manual are lower (min. 200 kg/m³), to allow for a concrete not made properly by untrained workforce.
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 and mix again. Add the water only at the end!

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 90 min 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 90 min.
Never “refresh” dried concrete by adding water!
Don’t mix too much concrete at a time!
Slump test

Use a standard 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.

Result: the difference between slump and cone should be less than 12.5 cm!
Pouring concrete : Tie-Columns

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

Use a stick (or rebar) and a hammer to help the concrete flow down, to compact it and avoid air pockets. Use a mechanical vibrator if one is available!
Pouring concrete: Tie-Beams

Use a stick (or rebar) and a hammer to help the concrete flow down, to compact it and avoid air pockets. Use a mechanical vibrator if one is available!

Roughen up the top surface of the plinth beam to increase bonding of the mortar for the wall.
Curing the concrete elements

**Concrete needs water to harden!**

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

After formwork is removed, cure the concrete for 7 days, and cover it with plastic sheets.
Exposed rebars will rust!

Poor compaction: the concrete is weakened!
Which clay bricks to use

Best brick: solid burnt clay brick with frogs.

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

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

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

Solid bricks are better than multiperforated ones!

Vertical holes should be less than 50% of the horizontal surface area!

Note: we recommend to use 10MPa bricks.

min 11 cm (recommended 12.5-15cm)
Brick test

Visual test:
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

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

Satisfactory block:
15-20 cm thick, with 3 holes.

Only if excellent quality!
20 cm thick, with 2 holes.

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

Test blocks before buying them!

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

Acceptable quality: (less than 1 broken)

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

Check if blocks were cured in the shade!

Stored in the shade: good.

Stored under plastic sheets: good!

Blocks that dry in the sun: very bad!
Concrete mix for blocks (1:4:3)

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!

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

Add water only at the end!
Making the blocks

Wait 8 days before using the blocks!

Fill the molds with the mixture.

To compact the concrete, hit 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.

Cure the blocks 3 times a day for minimum 7 days and cover with plastic sheets.
MASONRY WALLS
Cement mortar mix (1 : 5)

Mix the mortar:

1 part cement
5 parts clean sand (washed and dry)
3/4 part clean water

Add the water only at the end!

Use 1:3 mix ratio for 15cm or less wall thickness!

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.
Cement-lime mortars

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

Recommended mortar mix proportions:

<table>
<thead>
<tr>
<th>Cement</th>
<th>Lime</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>y</td>
<td>z</td>
</tr>
<tr>
<td>preferred</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>minimum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Mix the mortar:

\[ \text{X parts cement} + \text{Y parts lime} + \text{Z parts clean sand} + \frac{3}{4} \text{ part clean water} \]
Masonry walls height

The Width of masonry unit defines the wall height.

<table>
<thead>
<tr>
<th>Material</th>
<th>Height Formula</th>
<th>Max Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricks</td>
<td>$H = 25 \times W$</td>
<td>$H \leq 275 \text{ cm}$</td>
</tr>
<tr>
<td>Blocks</td>
<td>$H = 22 \times W$</td>
<td>$H \leq 300 \text{ cm}$</td>
</tr>
</tbody>
</table>

**Height = maximum 3m**!
Masonry bonds

**Solid wall = Running bond**
- vertical joints are not continuous.

**Weak wall = Stack bond**
- vertical joints are continuous.

1/3 to 1/2 of block/brick
Tooothing

Toothing: min 5cm / max 13cm

Distance from blocks or bricks: minimum 3 cm! (same length as last bone of thumb).

Tooothing 1/3-1/4 of a block: (max 1/2 of brick length) GOOD!

Tooothing 1/2 of a block: (> 1/2 of brick length) TOO BIG!

YES

NO
Toothing options

**Clay bricks (23-24 cm):**
- 50% running bond (half of a brick)
- Toothing = max 12 cm

**Concrete blocks (40 cm):**
- 50% running bond (half of a block)
  - Break 1/3 of last block!
  - Toothing = min 5 cm

**Concrete blocks (40 cm):**
- 33% running bond (1/3 - 2/3 of a block)
  - Toothing = max 13 cm
Dowels

Although toothing is the optimal method, the use of dowels can be an alternative.

Dowels are 6mm rebars

Place dowels:
- 50 cm within the bed joints of the wall
- place in pairs every 2 layers of blocks every 4 layers of bricks

Note:
Dowels should be covered with enough mortar to protect them properly. Test if dowels can be placed properly!
Preparing the masonry units

Soak the blocks in water for a while...

... or ...

... water them with a brush before use.

... or ...

... water all blocks together.
**Good masonry practice - 1**

Use a plank as guide to ensure the wall is in plumb and straight.

**Stack blocks one course at a time!**

Cure the concrete with water before laying the blocks.

**Important**: fill vertical joints with mortar!

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

Don't build more then 6 courses of masonry per day!
And then add a seismic band if needed.

100 to 120 cm (5 to 6 blocks)

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

Keep wall 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.
SEISMIC REINFORCEMENT
Vertical reinforcement (V)

Place a vertical band on each side of every opening!
Add a horizontal reinforcement band above all openings!
Horizontal reinforcement (H)

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

Place vertical reinforcement on each side of every opening.

Vertical bands are "half tie-columns" : add two rebars.

Vertical bands : (for openings)
Width : 10 cm
2 Rebars : 10 mm
Stirrups : 6 mm (@ 15cm)

If a wall between openings functions as shear wall, the vertical reinforcement is identical to a tie-column : add four rebars!

Vertical bands:
Width : 10 cm
2 Rebars : 10 mm
Stirrups : 6 mm (@ 15cm)

Min 2m / Max 4.50m
**Adding horizontal bands**

Add horizontal bands to the walls if:
- the quality of materials and construction is not ensured
- if the Height is smaller than 1.5 times the Length

**Rule:**

\[ H < 1.5 \times L \]

**YES**

- H smaller than 1.5 x L
- No seismic band

**NO**

- H bigger than 1.5 x L
- With seismic band
Sill band and lintel band

Seismic bands:
- Height (bricks) 7.5 cm
- Heights (blocks) 10 cm
- 2 Rebars: 10 mm
- Stirrups: 6 mm @15 cm

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

Place a stirrup every 15 cm!
Connect seismic band to tie-column

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

**Rule:**

\[ b \text{ smaller than } a/2 \]

Correct: \( b \text{ smaller than } a/2 \)

Incorrect: \( b \text{ bigger than } a/2 \)
Door reinforcement (V)

Hook the door vertical reinforcement rebars and lap 30cm with the tie-beam rebars, under the stirrups. Do the same with lintel band and the vertical bands.
Small window reinforcement (V)

For windows smaller than 90 cm.

Hook the window vertical reinforcement and lap 30 cm with the tie-beams reinforcement, inside the stirrups.

Do the same with the horizontal reinforcement and the vertical bands.
Large window reinforcement (V)

For windows larger than 90 cm.

- Tie-beam
- Window lintel
- Min 15 cm
- 30 cm
- Vertical window band
- Window horizontal reinforcement
- Plinth beam

Stirrups at 15 cm spacing

- Window lintel: reinforced seismic band.
- Min 15 cm
- Window vertical band
- Formwork
Small window reinforcement (H)

For windows smaller than 90 cm.

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

For windows larger than 90 cm.

- **Lintel band**: 30 cm width, min 15 cm down, max 1.2 m.
- **Seismic band**: 30 cm, min 15 cm.
- **Sill band**: Vertical window reinforcement.
- **Vertical window reinforcement**: Stirrups at 15 cm spacing.
- **Formwork**: Reinforced seismic band.
SLAB
Placing of slab reinforcement

Placement of primary rebars.

Step 1

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

Placement of secondary rebars.

Step 2

Secondary rebars are placed on top of and perpendicular to the primary rebars.
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

BAD FORMWORK

- Inclined post
- Irregular post
- Don't place posts on blocks.
- Don't use patched up posts.

Counter brace
Plank
Max 90 cm
Max 75 cm
Max 75 cm
To ensure a good connection, it is important to insert the hooked slab rebars deep into the bond beam.
Hollow block slab: secondary rebars

Secondary rebar must be placed in the middle of the concrete covering the hollow blocks with spacers.

YES

NO
Hollow block slab: positioning pipes 1

- Hollow blocks
- Concrete
- Pipe in hollow blocks

- Drill through hollow blocks!
- Pass pipes through the hollow blocks and cross concrete only in one spot. Reinforce joist with additional rebars.

- Don't drill through concrete!
- Don't cross concrete all the way!
Hollow block slab: positioning pipes 2

- **YES** Place pipes in block holes.
- **YES** Place pipes in service duct.
- **NO** Don't place pipes in walls or in ties!

Test watertightness of the pipes before pouring concrete by filling them with water.
Hollow block slab: pouring concrete

Water the formwork before pouring concrete.

Use a stick (or rebar) and a hammer to compact the concrete and avoid air pockets.
Full concrete slab

Curing the concrete: create ponds with sand or mud and fill them with water for a week.
LIGHT ROOF
Roof shape

- Good
  - YES
- Better
  - YES
- Better
  - YES
- Not so good
  - AVOID
Gable wall

Concrete tie on top of the gable wall.

YES

YES
Roof structure - Trusses

AVOID

Building with planks:

AVOID
(not enough room for nails)

Building with solid timber:

GOOD

Building with plywood gusset:

BETTER!

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

Nails length should be

twice the thickness
of the timber!
Cyclones

Keep verandas independent from main roof: cyclones may tear off the verandas.

Closed gable wall.

Opened gable wall.

Main roof becoming veranda.

If a veranda is part of the main roof, then a cyclone could tear off the whole roof.
Fastening of the veranda framing

- straps
- solid fastening
- bracing
- 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.

Max. 3.0 m

Max. 4.5 m
FUTURE EXTENSIONS
Preparation

Open all corners, all rebar connections.

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

Add hooks: 10 mm rebar.

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

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

Place the 10 mm hooks and then place both the ring beams (tie-beams) and the tie-columns.

Connect each corner the same way!
Extension of the structure

Pour concrete for the plinth beam and fill completely the opened corners.

Build the masonry walls first and only after pour the concrete for the tie columns.

The walls and tie-elements for future extensions should align with the existing structure (existing tie-elements).
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: bottom of wall to firm soil!

- hard soil: 30 cm
- rammed soil: 30 cm - 60 cm
- soft soil: 60 cm - 90 cm

YES

NO
Rule 2 - Slope of the wall (5 : 1)

Slope 1:5
Every time you go up 5 cm, move back 1 cm!
Every time you go up 1 meter, move back 20 cm!

<table>
<thead>
<tr>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>125</td>
<td>25</td>
</tr>
<tr>
<td>150</td>
<td>30</td>
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<tr>
<td>175</td>
<td>35</td>
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<tr>
<td>200</td>
<td>40</td>
</tr>
<tr>
<td>250</td>
<td>50</td>
</tr>
</tbody>
</table>
Rule 3 - Dimensions of the wall

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):

\[ D = A/5 + C \]

<table>
<thead>
<tr>
<th>H</th>
<th>C</th>
<th>B</th>
<th>A</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>50</td>
<td>30-80</td>
<td>130-180</td>
<td>75-85</td>
</tr>
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<td>125</td>
<td>50</td>
<td>30-80</td>
<td>155-205</td>
<td>80-90</td>
</tr>
<tr>
<td>150</td>
<td>50</td>
<td>30-80</td>
<td>180-230</td>
<td>85-95</td>
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<tr>
<td>175</td>
<td>55</td>
<td>30-80</td>
<td>205-255</td>
<td>95-100</td>
</tr>
<tr>
<td>200</td>
<td>55</td>
<td>30-80</td>
<td>230-280</td>
<td>100-110</td>
</tr>
<tr>
<td>250</td>
<td>60</td>
<td>30-80</td>
<td>280-330</td>
<td>115-125</td>
</tr>
</tbody>
</table>

Height above ground (H):
\( H \text{ max} = 2.50 \text{ m} \)

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

Total height (A):
\( A = H + B \)
\( \rightarrow B = 30-80 \text{ cm} \)
Rule 4 - Placing the stones

Don’t place the stones in vertical position!

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

Don’t place the stones at right angles to the wall’s external face.

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

Wall without through-stones nor concrete ties.

YES YES

NO
Rule 6 - Drainage

**YES**

- Drainage pipes
- Drainage bed: gravel and stones.
- Width 30 cm!

**NO**

- Wall with no drainage pipes and no drainage bed.

Place a drainage pipe every 1.50 m!
(vertically and horizontally)
Retaining wall - Confining elements

These recommendations are for building a house on retaining walls: only if there is no other solution!

**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 !!!
CONSTRUCTION DRAWINGS
Reading plans

To draw a plan, cut the house at the window height.

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

House plan (seen from the top).
Reading sections

If you vertically cut the house on this line ...

... this is what you will see!

same window
Plan dimensions

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

Total dimensions

Partial dimensions

+ 2.9m

+/− 0.00

150

290

40

90

120

60

20

145
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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.

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