Guide book for building earthquake-resistant houses in confined masonry

Schweizerische Eidgenossenschaft
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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

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

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE
EERI

Schweizerische Eidgenossenschaft
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Swiss Agency for Development and Cooperation SDC

Revised version, August 2015

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Revised version, August 2015

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INTRODUCTION

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.

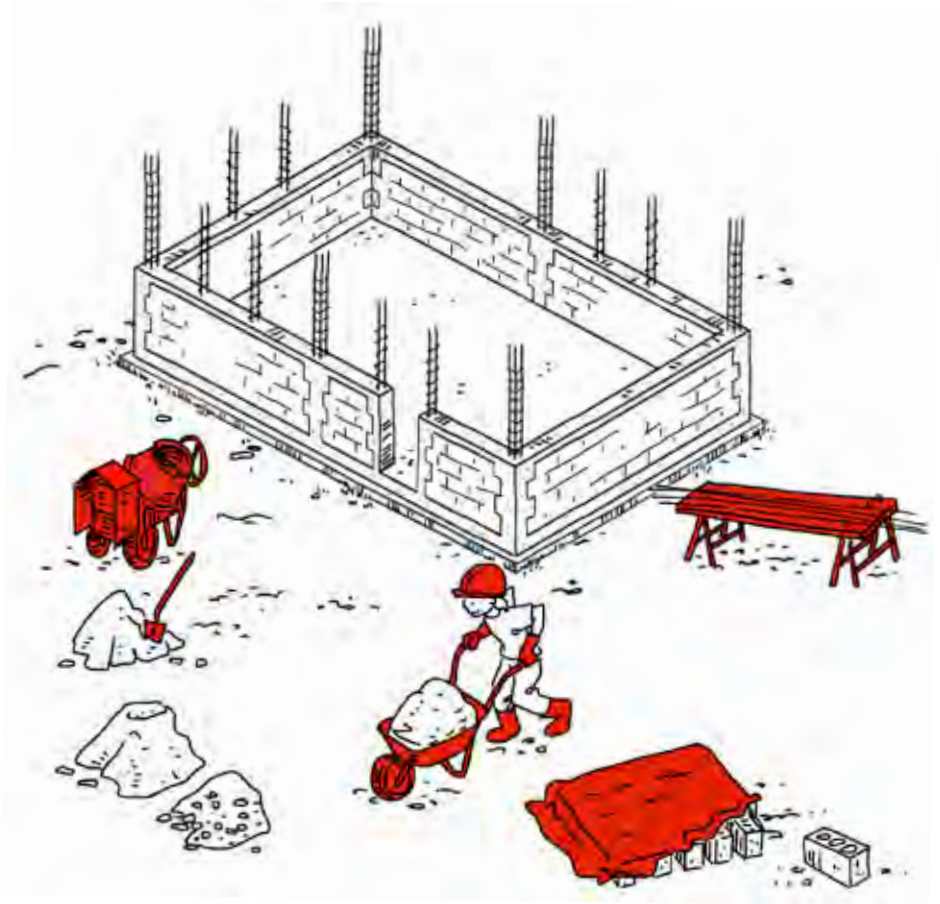
The Guide was developed for masons working in developing countries. The recommendations are intended to be conservative (on the safe side) and to ensure life safety of the occupants of the house.

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

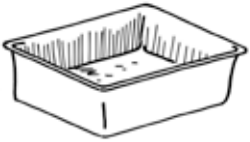
hammer

chisel

club hammer

Mason's tools 2

bucket



mixing box

cone for slump test

big brush

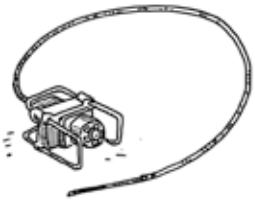
transparent water hose 10 -20 m

pickaxe

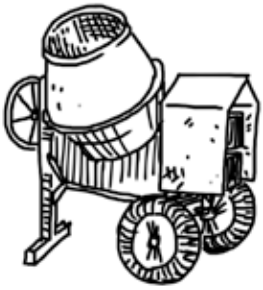
shovel

rammer

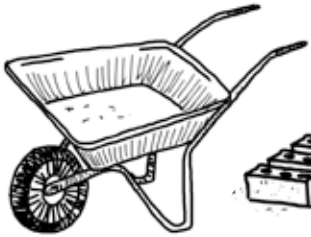
grinder



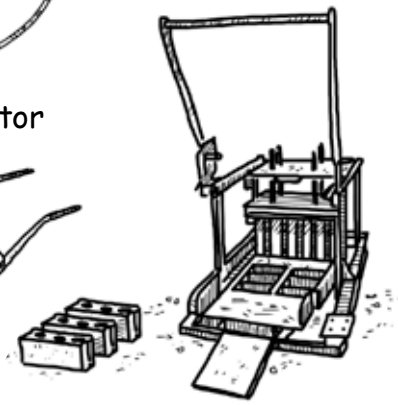
needle vibrator



concrete mixer



wheelbarrow



vibrating block/brick press

Formwork tools

guide book

tape measure

straight edge

level

pencil

plumb line

string

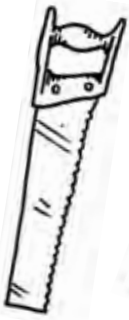
nail

hammer

chisel

crowbar

axe



saw

plane

Steel reinforcement tools

guide book

tape measure

straight edge

level

pencil

chalk

plumb line

string nail

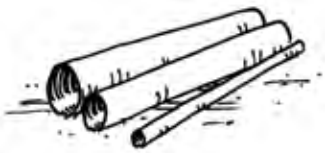
wire twister or pincer

pliers

tin snips

hammer

chisel



plastic pipes of different diameters

hacksaw

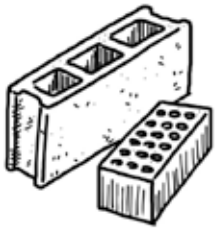
rebar bender

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

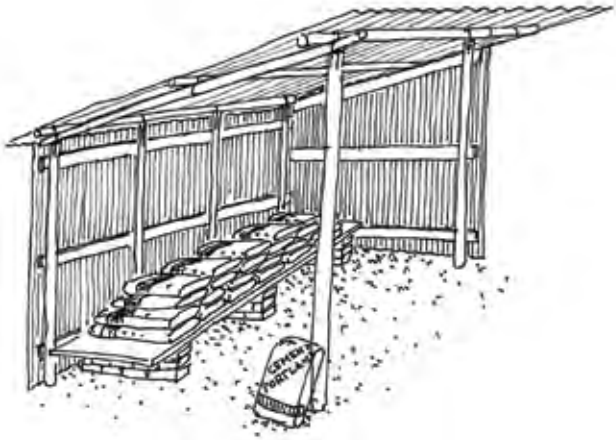
Sand :
river sand,
washed and dry

Cement :
portland cement,
new and dry bags

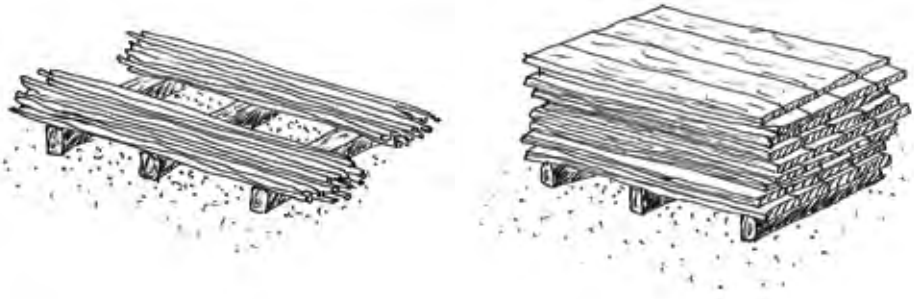
Gravel :
crushed or round,
from hard rock and clean,
well-graded, max size 18-20 mm

Steel bars :
standard size,
ribbed steel, grade 60
new and not corroded

Storage of building materials on site



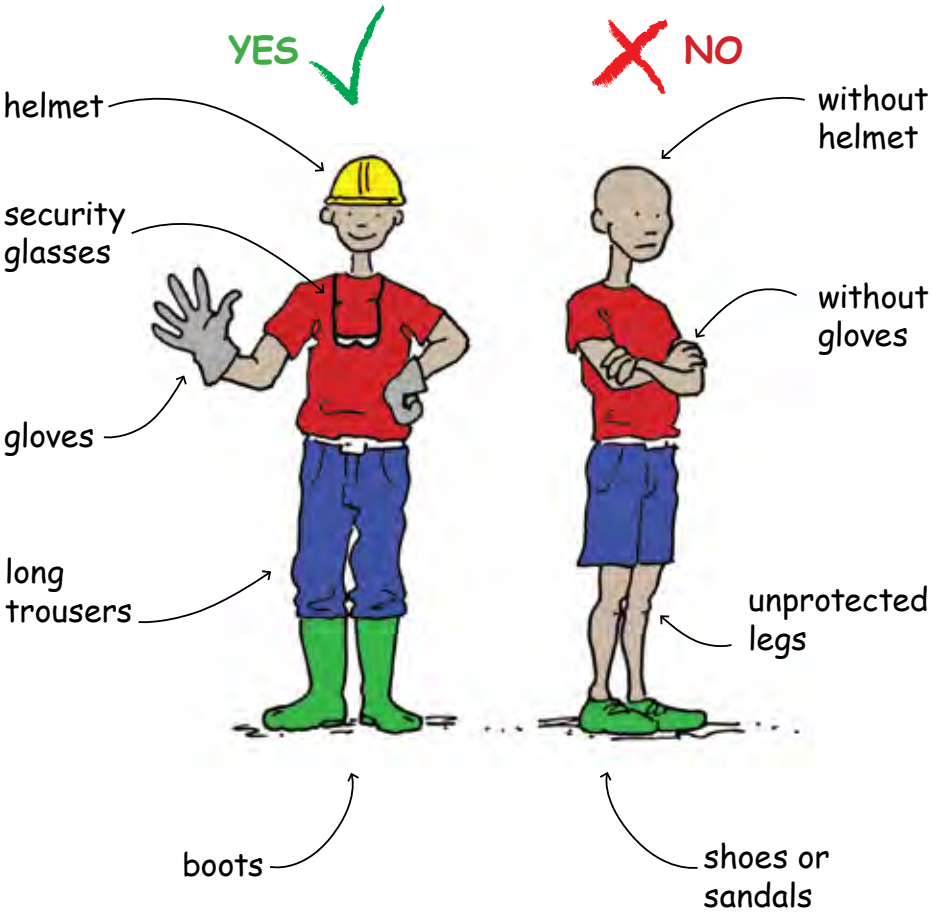
Store cement bags away from the sun
and protected from humidity.
Do not place on the ground !



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

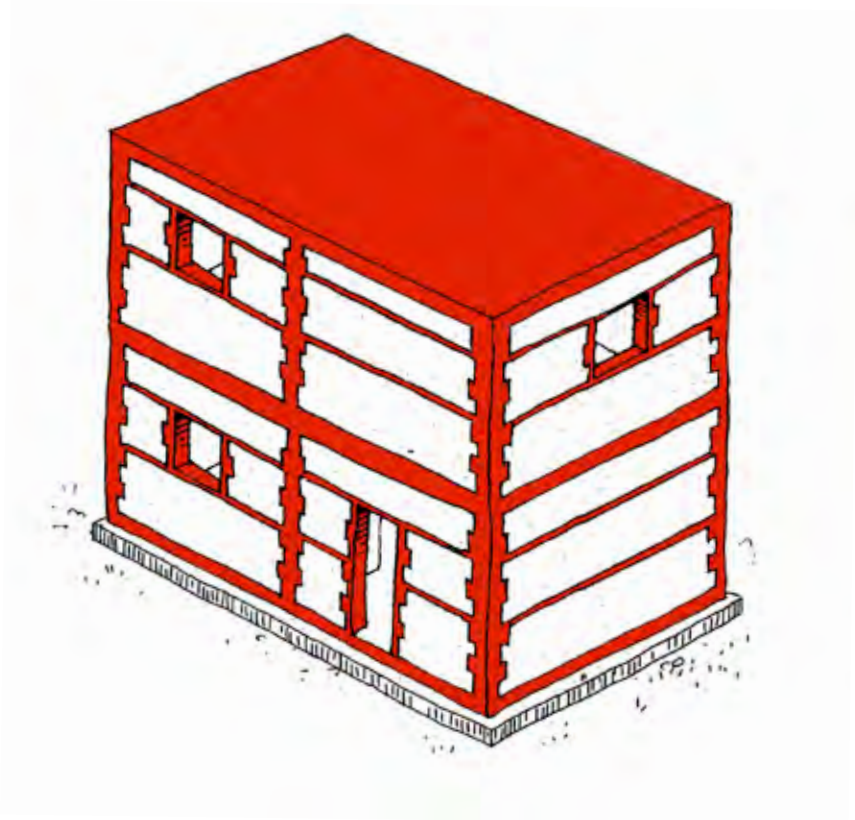
Construction site protection

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 !

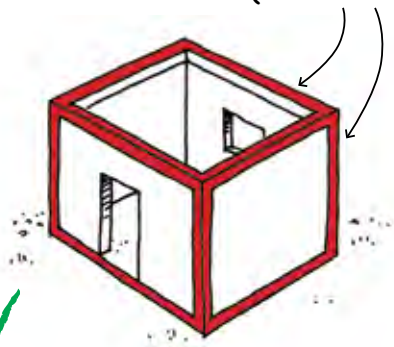
CONFINED MASONRY FOR TWO-STOREY HOUSES



Confining elements (ties)

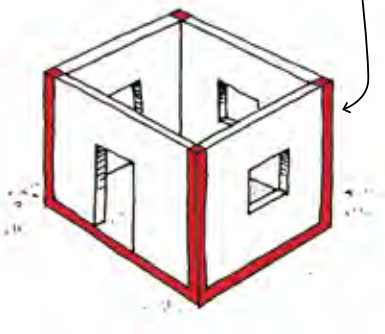
Confining the walls is like holding a pile of books together with a string: they can still move but they will not fall apart.

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

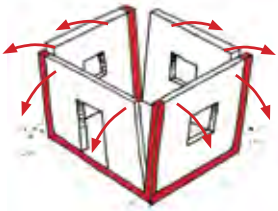


YES

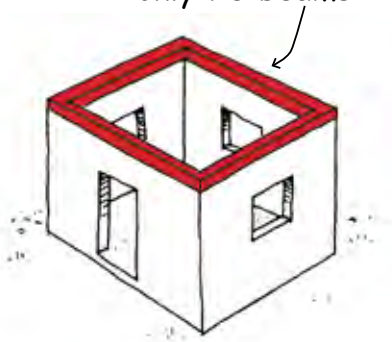
only tie-columns



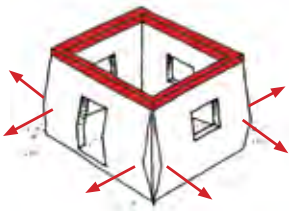
NO



only tie-beams



NO

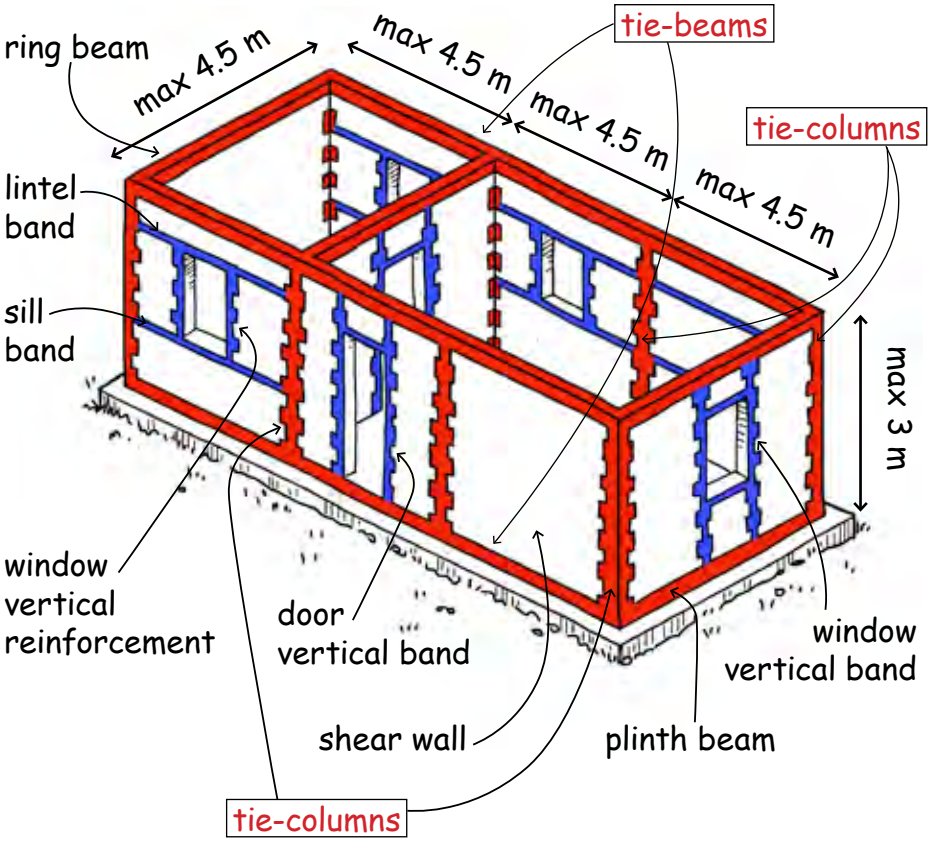


A strong house

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

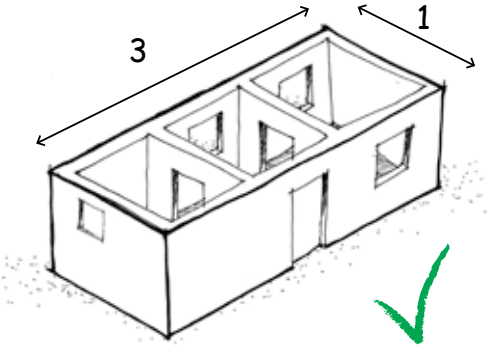
Confining elements : (chapters 6-8)
tie-column and tie-beams (plinth beam and ring beam)

Anchoring bands and opening reinforcement : (chapter 11)
seismic bands (lintel & sill bands) and vertical reinforcement

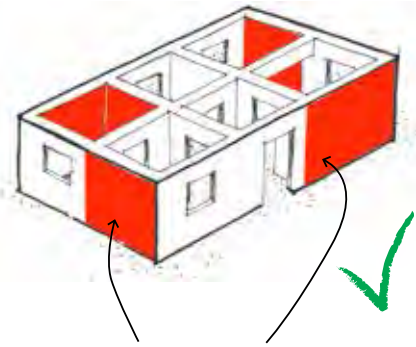


Shape of the house

YES, THIS IS CORRECT !

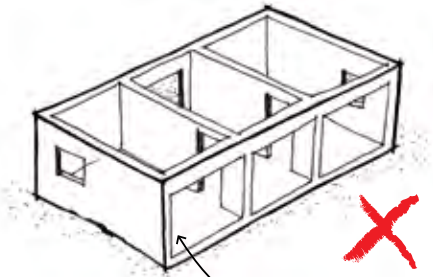


Maximum ratio 1 to 3.

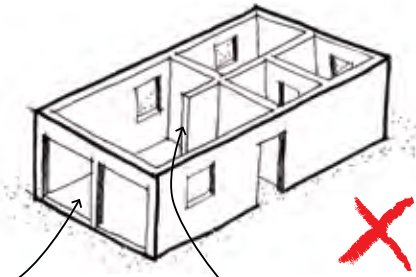


Each facade must have at least one tied wall without openings = shear walls.

NO, THIS IS NOT CORRECT !



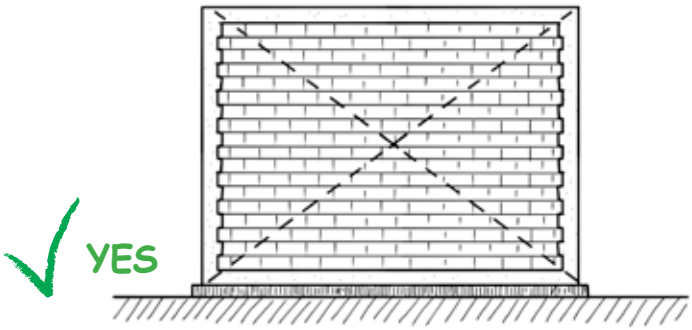
Openings are too big.



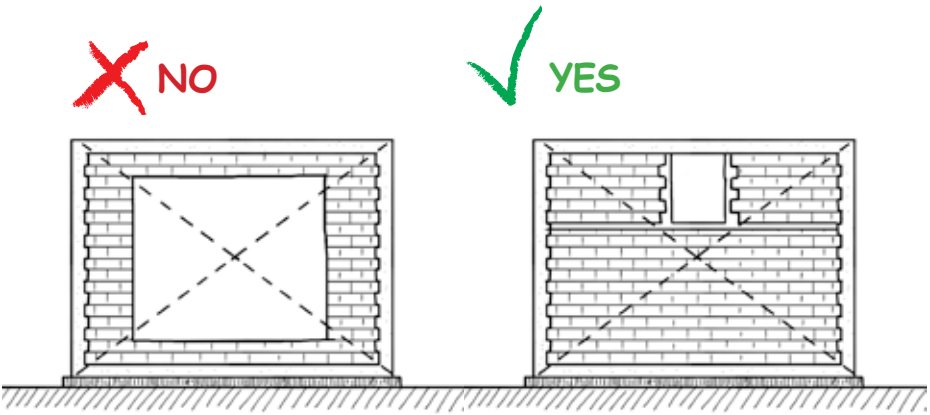
Free standing wall without any tie.

Shear walls

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



Full shear wall



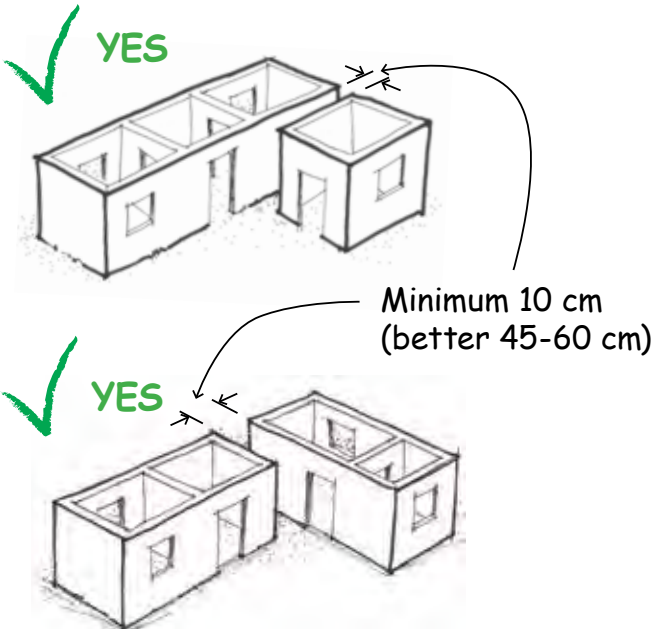
Opening is too big:
Not a shear wall !

Opening is small and
outside the diagonals:
It is a shear wall !

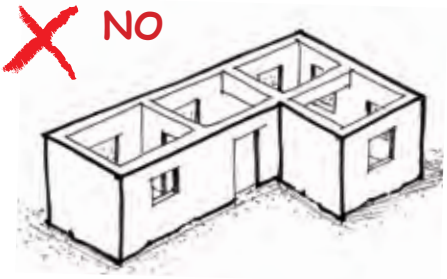
Seismic gap

Avoid complex shapes by creating seismic gaps.

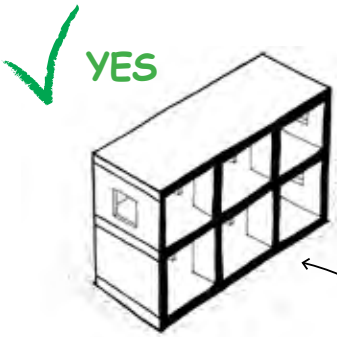
Simple shape : BETTER

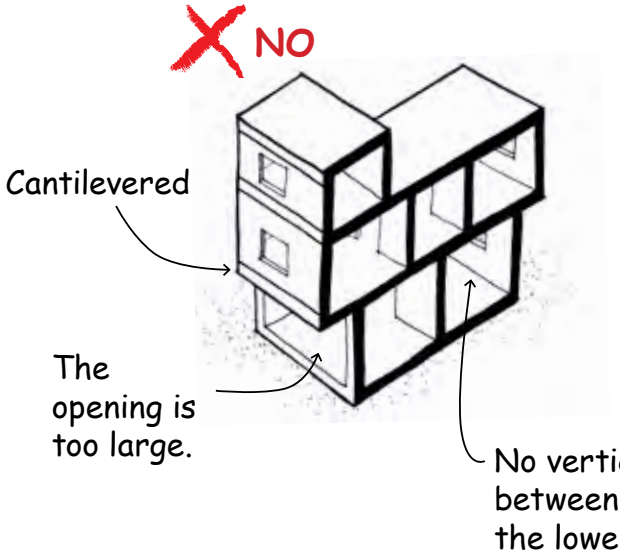


Complex shape : WORSE



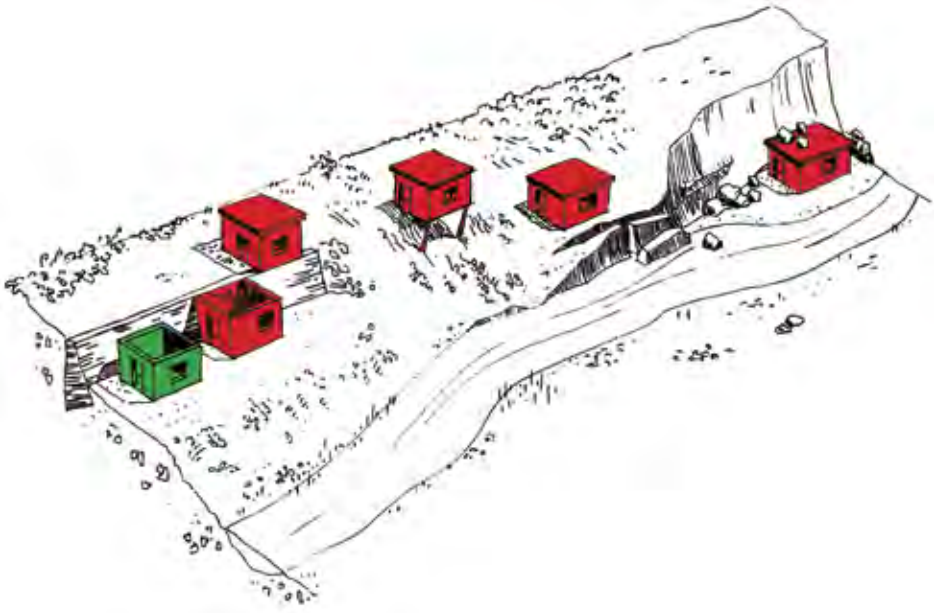
Vertical continuity of walls





FINDING AN ADEQUATE LOCATION

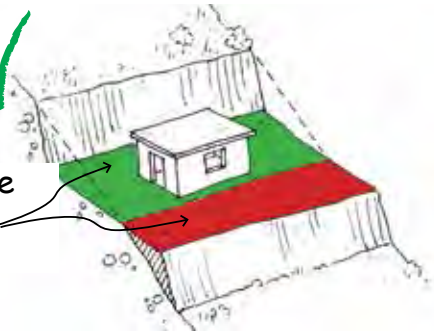
3



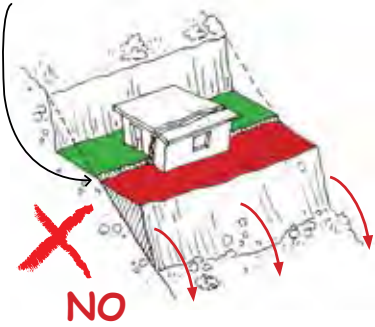
Site selection: where to build

YES

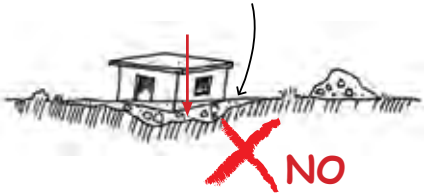
Keep enough distance on each side of the house.



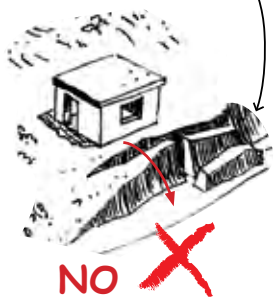
Don't build on embankments.



Don't build on fresh embankments.



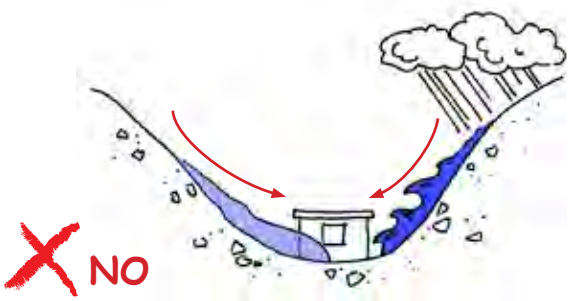
Don't build too close to a cliff.



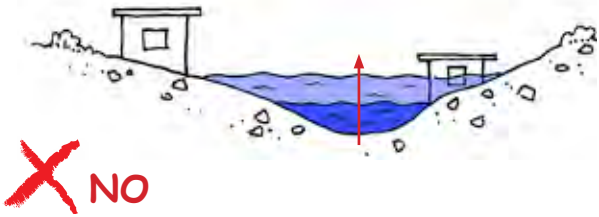
Don't build on stilts.

Don't build at the foot of a cliff.

Flood related hazards



Don't build at the bottom of a canyon.

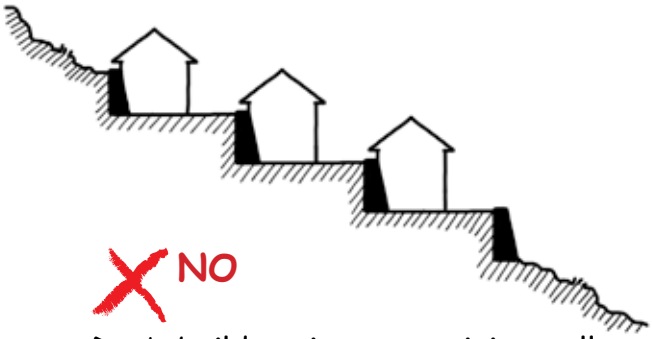


Don't build near a river.

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

Building on a slope

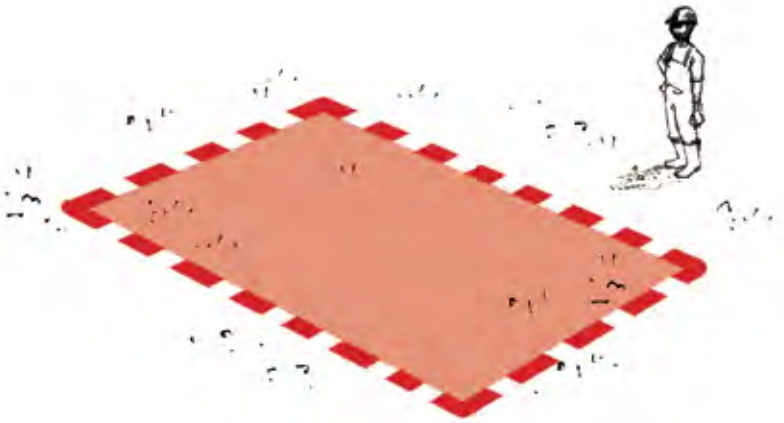
Build between retaining walls.



Don't build against a retaining wall.

Don't build on top of a retaining wall.

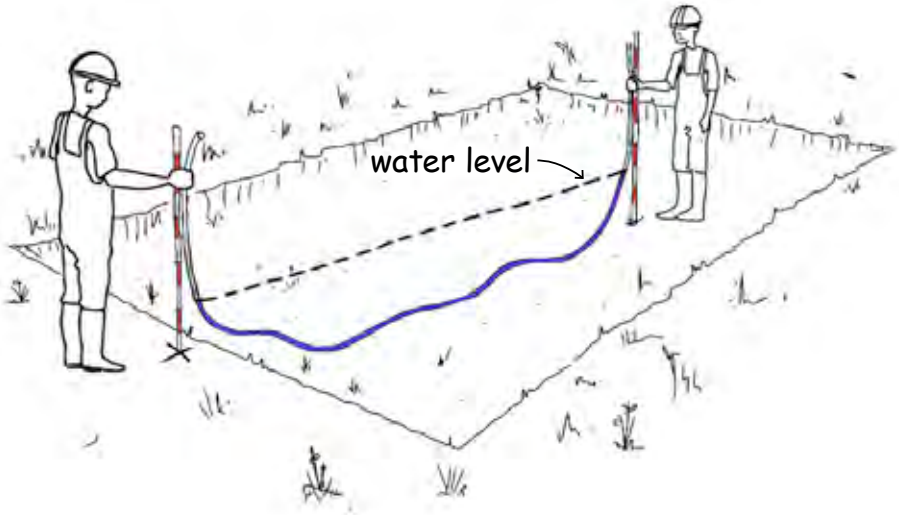
LAYOUT



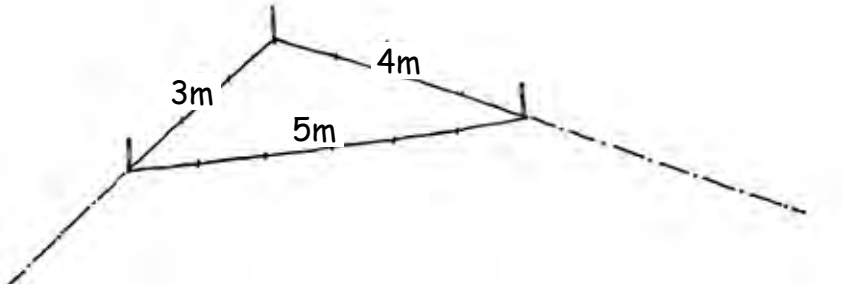
Site preparation

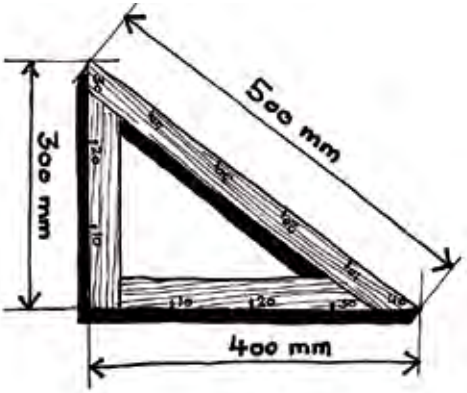
Remove the topsoil and the excavated material, and place it in 2 (or more) different heaps, away from the excavated area.

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

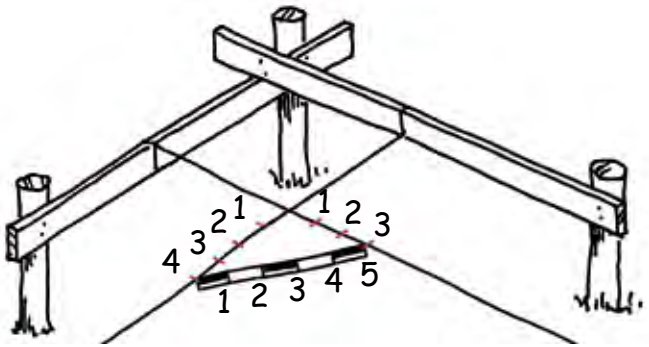


Tracing a right angle (3 : 4 : 5)

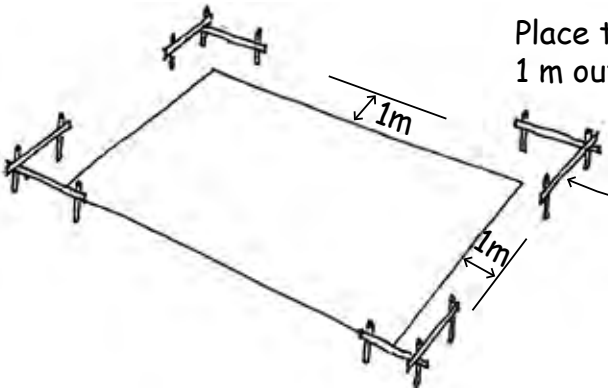




3	4	5
30 cm	40 cm	50 cm
60 cm	80 cm	100 cm
90 cm	120 cm	150 cm
1,5 m	2 m	2,5 m
2,1 m	2,8 m	3,5 m
3 m	4 m	5 m
3 ft	4 ft	5 ft
6 ft	8 ft	10 ft
9 ft	12 ft	15 ft



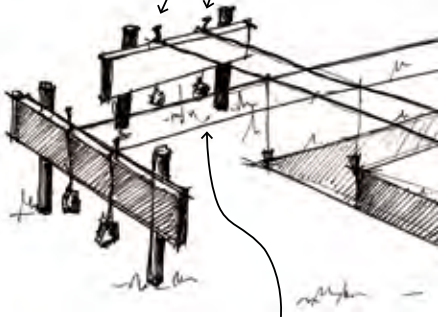
Layout



Place the batter boards
1 m outside the trenches.

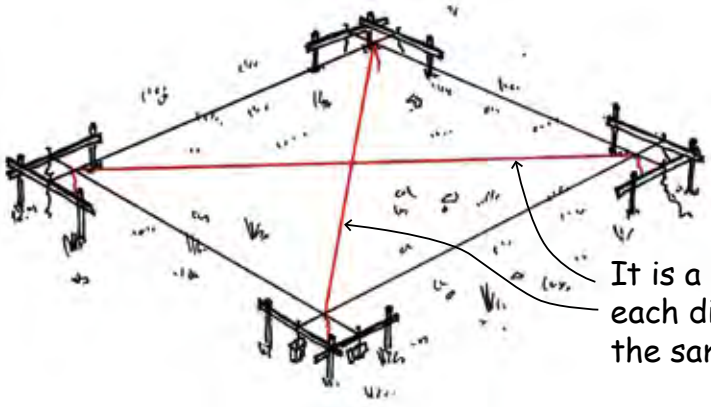
batter board

nail



Drive in nails in order
to pull strings.

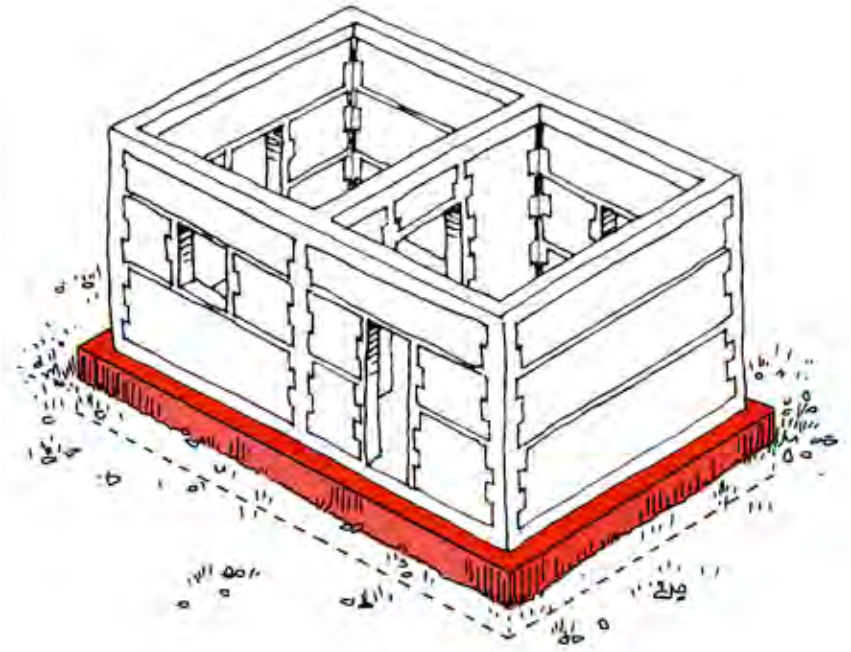
Marking strings



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

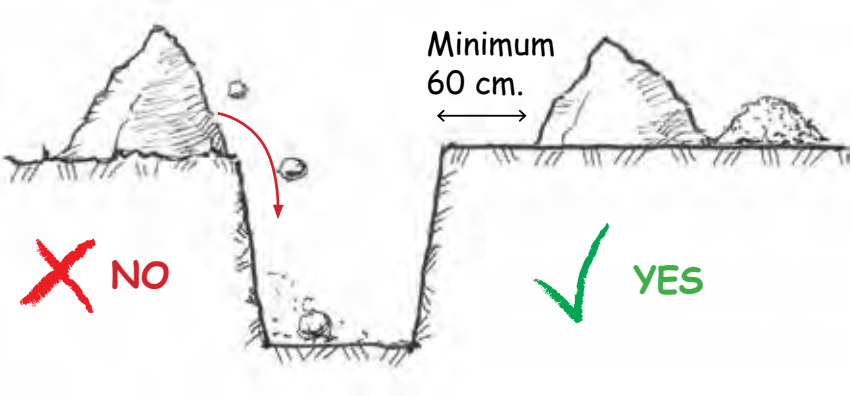
STONE FOUNDATION

5

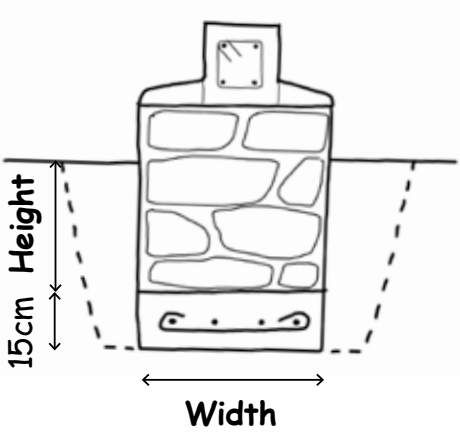


Excavation

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 !!!



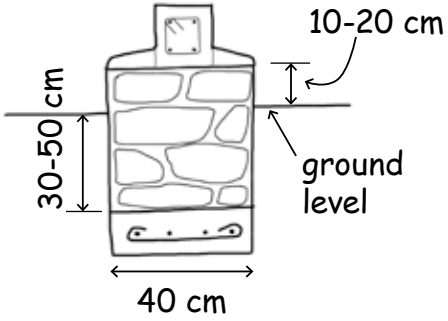
Foundation height :

hard soil :	min 30 cm
rammed soil :	min 50 cm
soft soil :	min 80 cm

Foundation width :

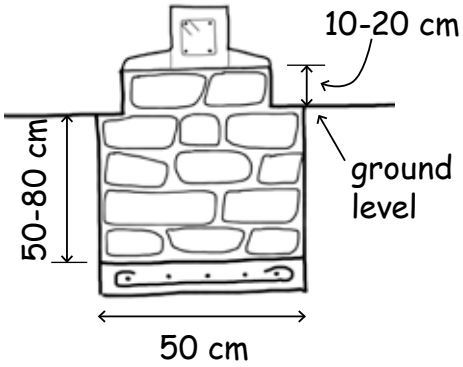
hard soil :	40 cm
rammed soil :	60 cm
soft soil :	70 cm

Foundation dimensions



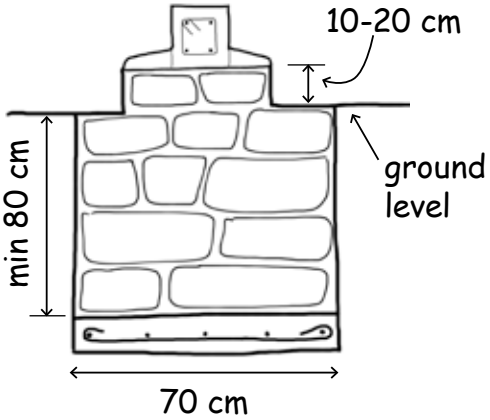
Hard soil

height :	30-50 cm
width :	40 cm
strip footing :	40 cm



Rammed soil

height :	50-80 cm
width :	50 cm
strip footing :	50 cm



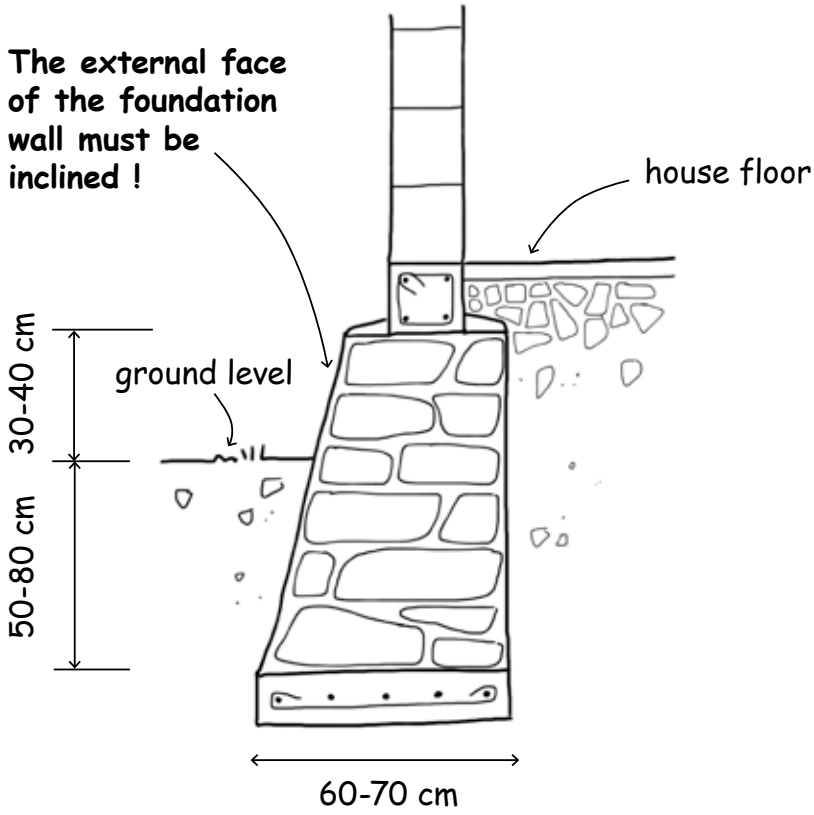
Soft soil

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 !



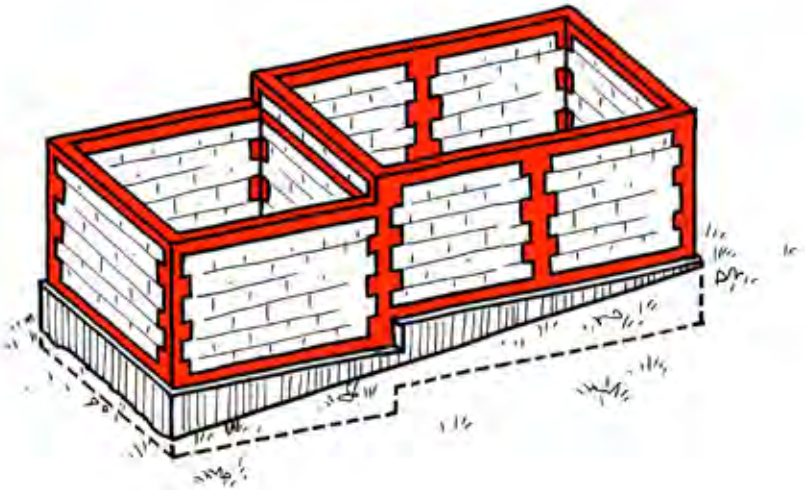
Foundation height :
rammed soil : min 50 cm
soft soil : min 80 cm

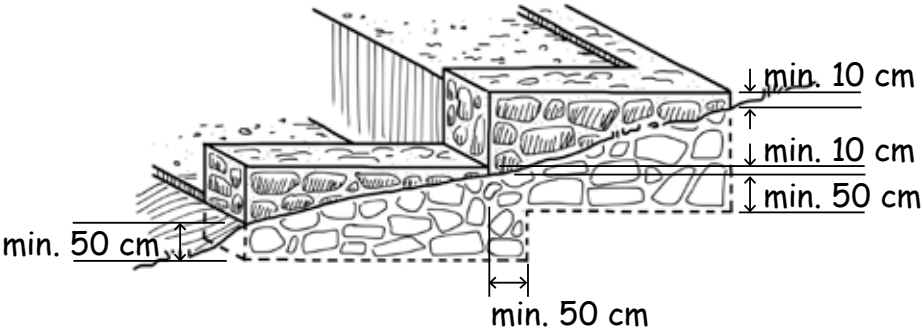
Foundation width :
rammed soil : min 60 cm
soft soil : min 70 cm

Avoid building in a flood-prone area !

Stepped foundations

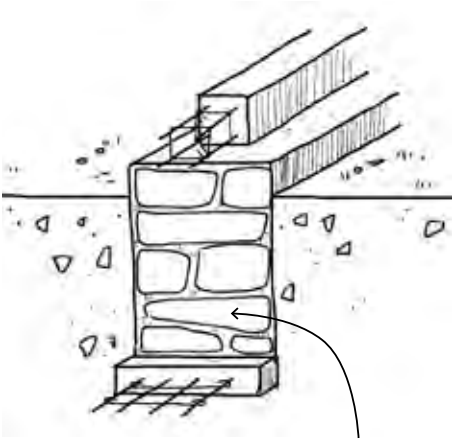
If you build on a slope, the foundation must be stepped,
keeping the bottom of the trench always horizontal !



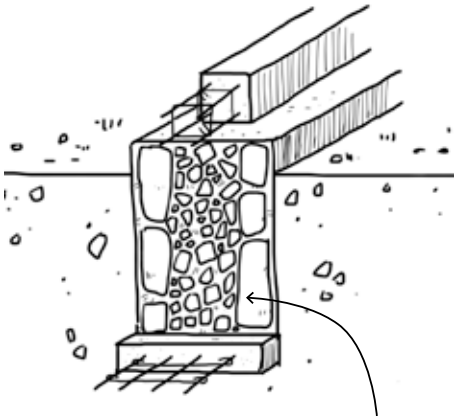


Avoid building parallel to the slope !

Stone masonry construction



Place all the stones in a horizontal position !



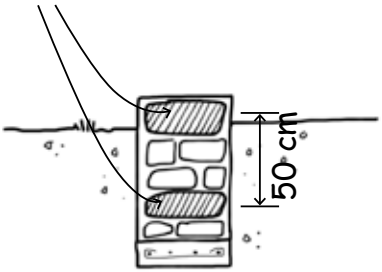
Do not place the stones in a vertical position !

YES

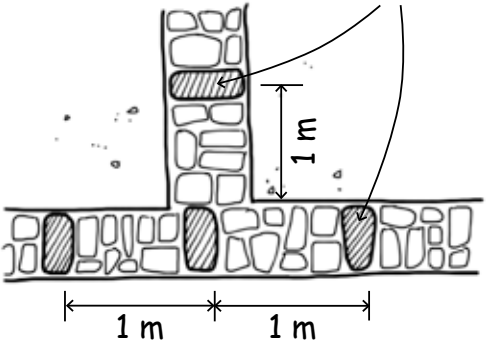
NO

Place through-stones :
Horizontally : at least every **1 m**
Vertically : at least every **50 cm**

Place through-stones **in section :**

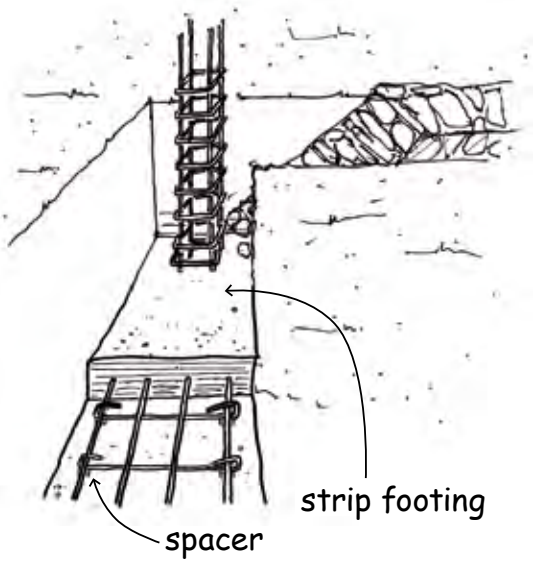


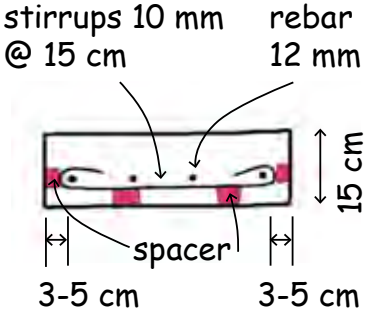
Place through-stones **in plan :**



Reinforced concrete strip footing

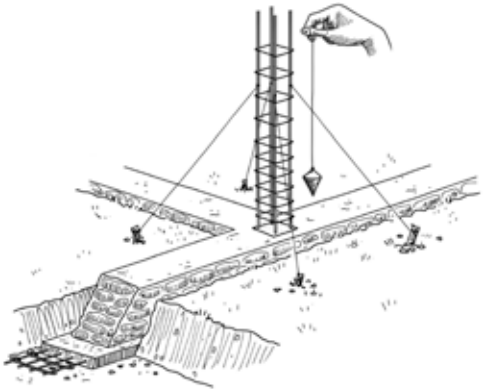
A strip footing is a must for soft soil conditions !
It is also recommended for other soil conditions.



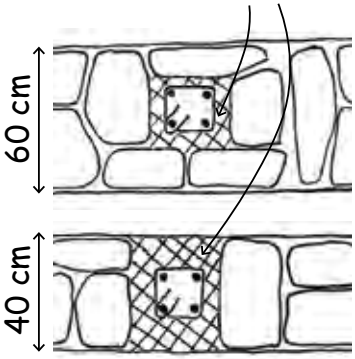


Strip footing :
Width 40 cm = 4 rebars
Width 50 cm = 4 rebars
Width 70 cm = 5 rebars

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



Leave a space around the reinforcement for the concrete.

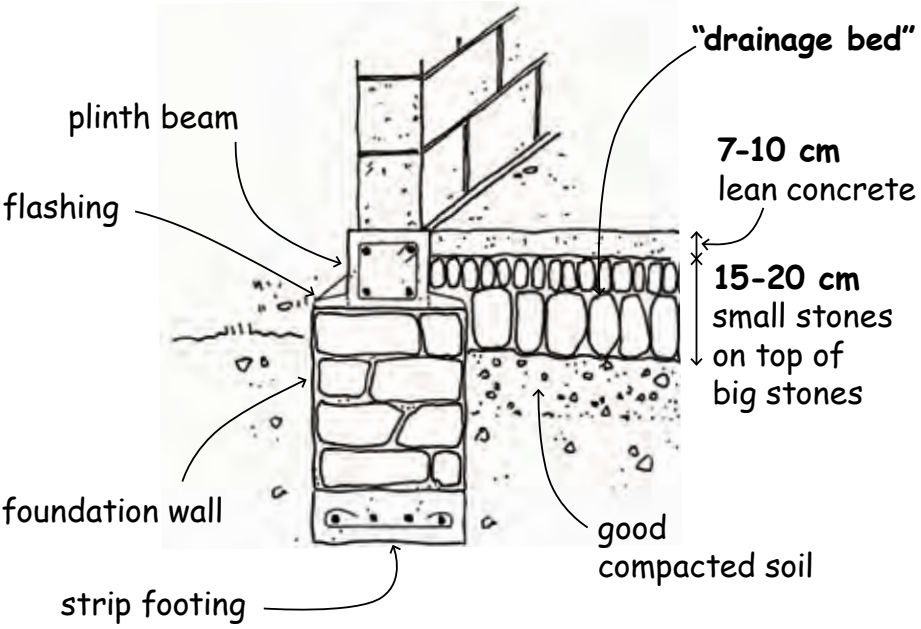


Curing and ground floor

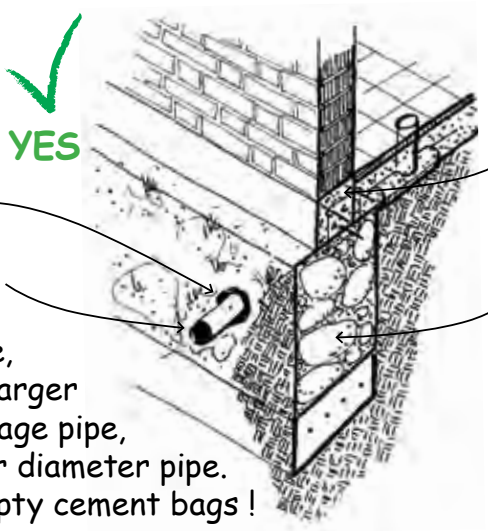
Cure the foundation walls !
Wet every day,
for the three first days !

Always interrupt
foundation work
on a sloped line.

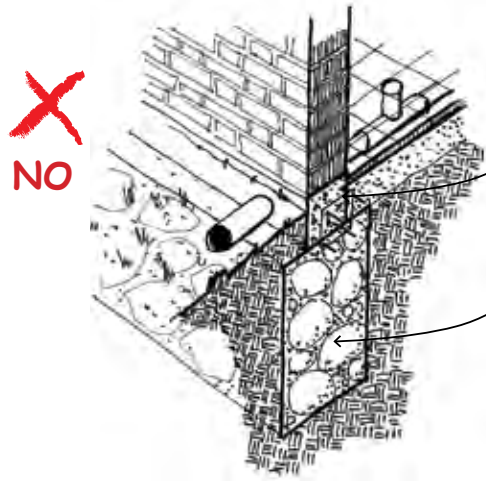
Build a "drainage bed" to avoid moisture coming in !



Placing sewage pipes

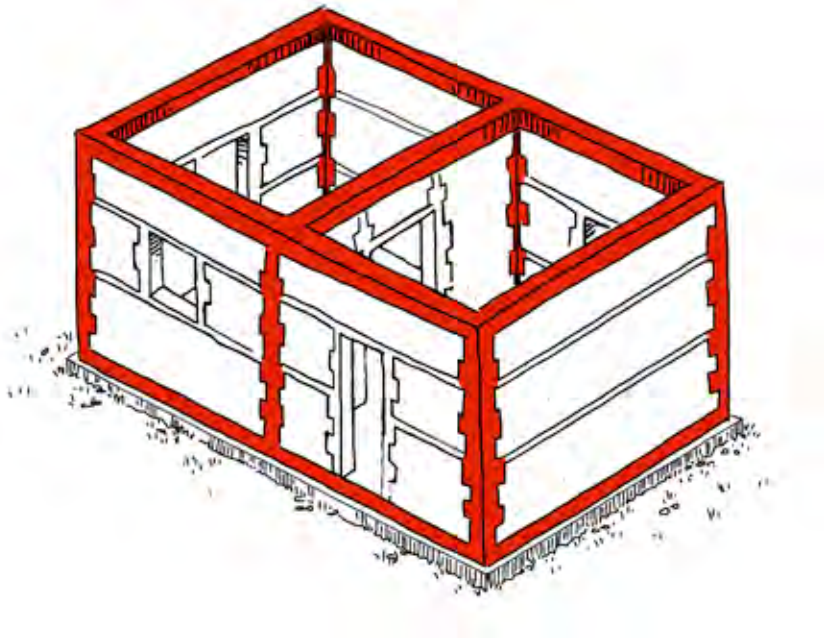


The pipe must go through the foundation, under the plinth beam !



Do not go through the plinth beam !

Reinforced Concrete Ties

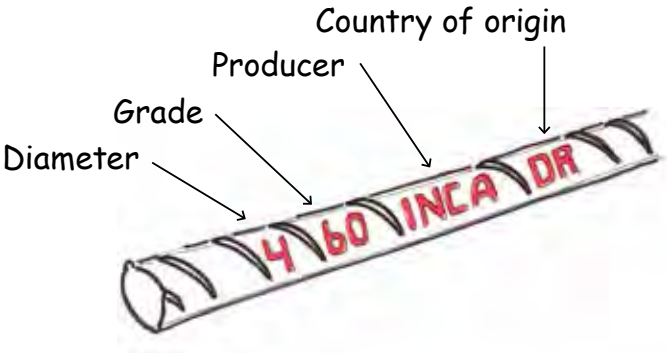


Types of steel rebars

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) !

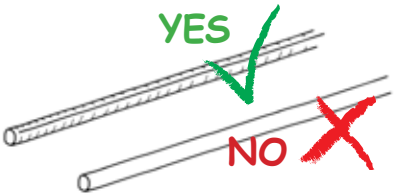
Strength indication are written on the rebar :



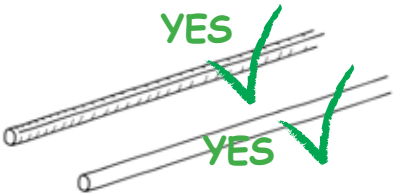
Do not use second hand rebars !

Steel bar diameters

For rebars :



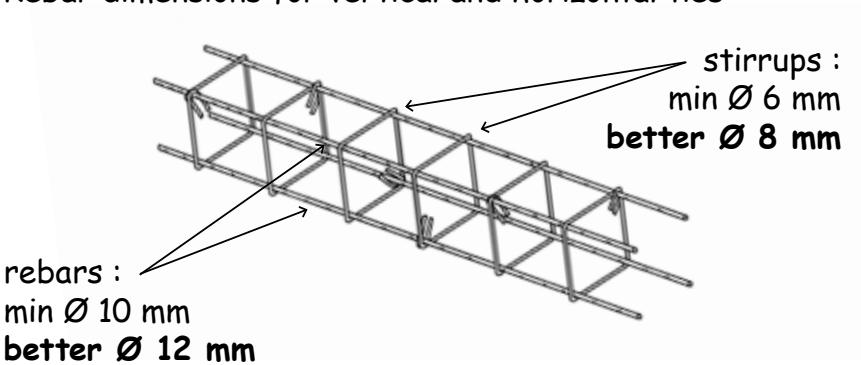
For stirrups:



Rebars diameters (imperial and metric) :

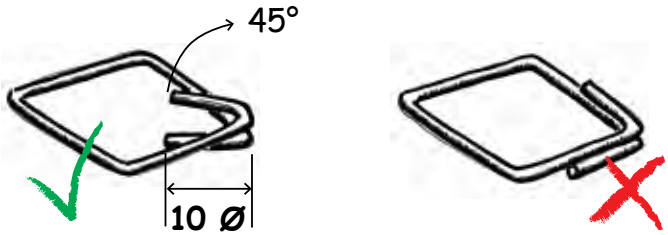
imperial	inch	metric	rebars	stirrups
#6	3/4 in.	19 mm	✗	✗
#5	5/8 in.	16 mm	✗	✗
#4	1/2 in.	12 mm	✓	✗
#3	3/8 in.	10 mm	✓	✗
-	1/3 in.	8 mm	✗	✓
#2	1/4 in.	6 mm	✗	✓

Rebar dimensions for vertical and horizontal ties :



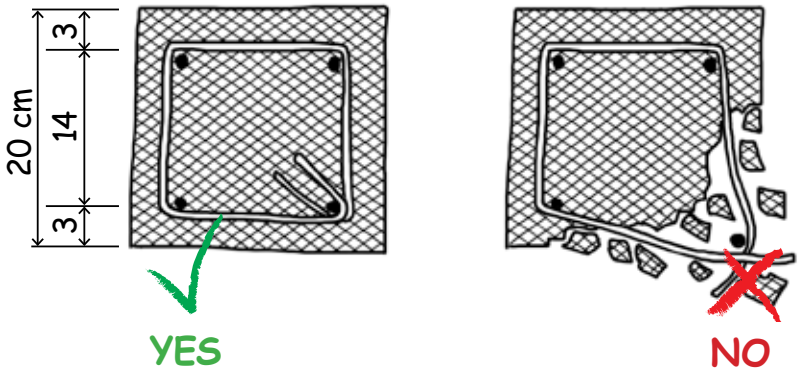
Stirrups

Bend stirrup ends at 45° !

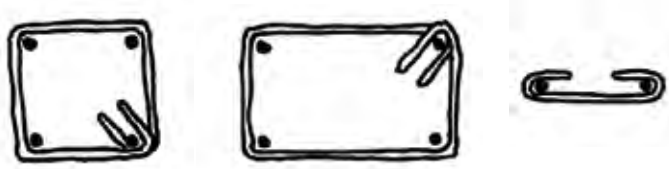


6 cm (rebar 6 mm)
8 cm (rebar 10 mm)

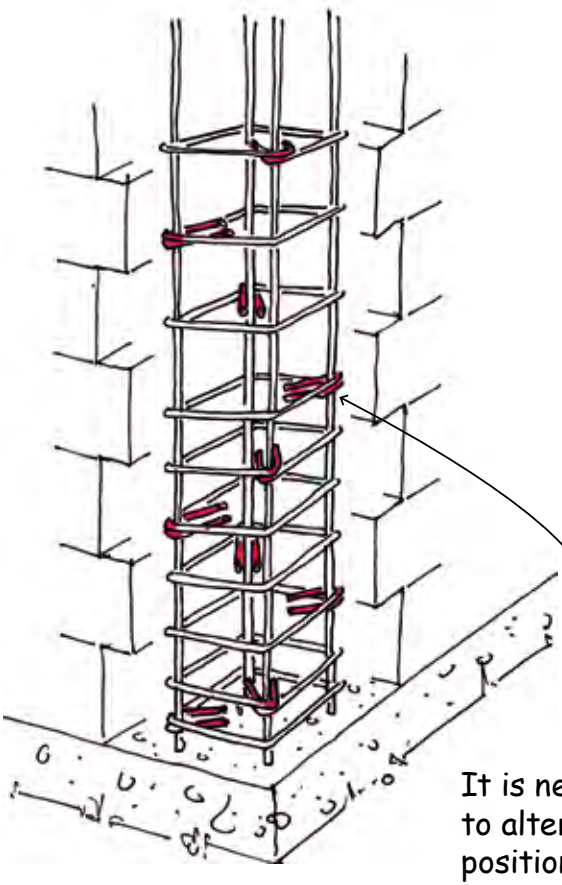
If stirrups are not bent at 45°,
they will open during an earthquake !



Possible stirrup types :



Alternate stirrup positions



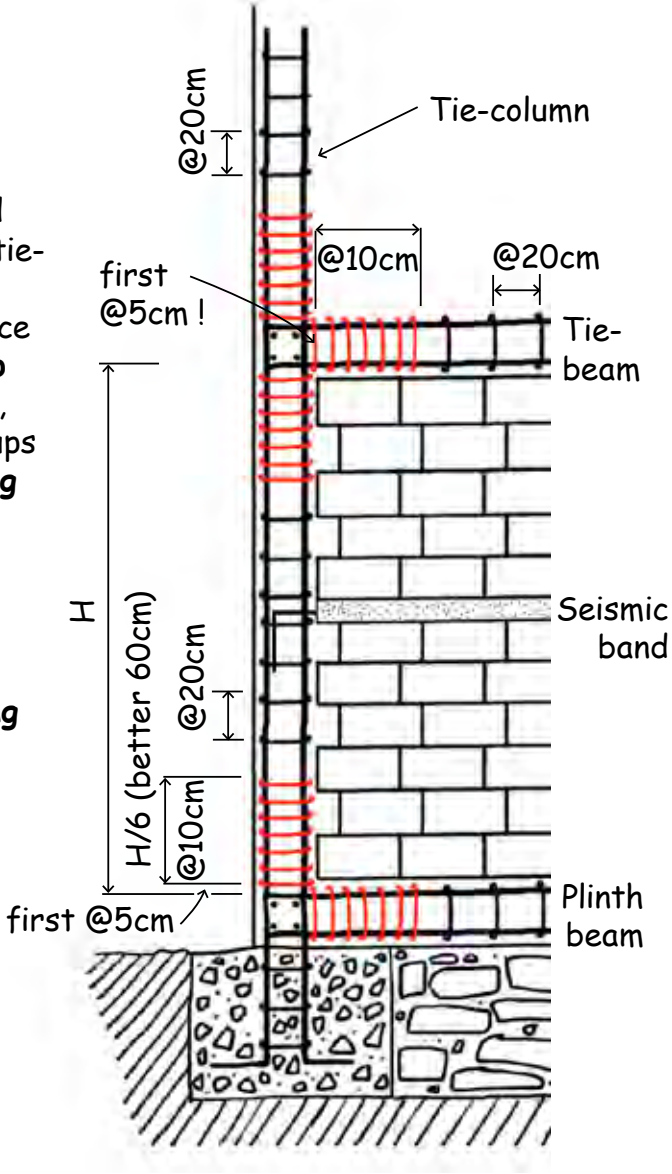
It is necessary to alternate position of stirrup hooks !!

Stirrup spacing

Rules for stirrup spacing:

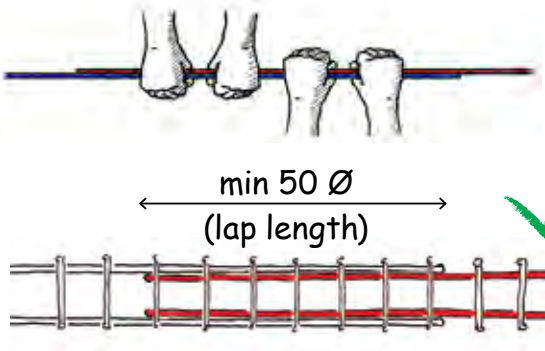
1. At the top and bottom of each tie-column and ends of tie-beams place the **first stirrup at 5 cm spacing**, then place stirrups **at 10 cm spacing** over a **length of H/6** (better 60cm).

2. Place stirrups **at 20 cm spacing** elsewhere.

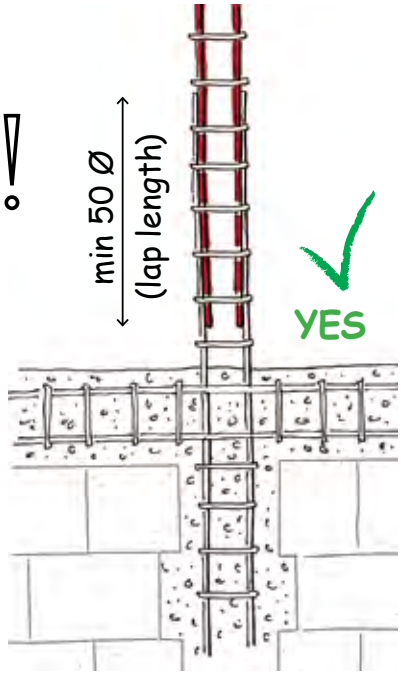


Lap length

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



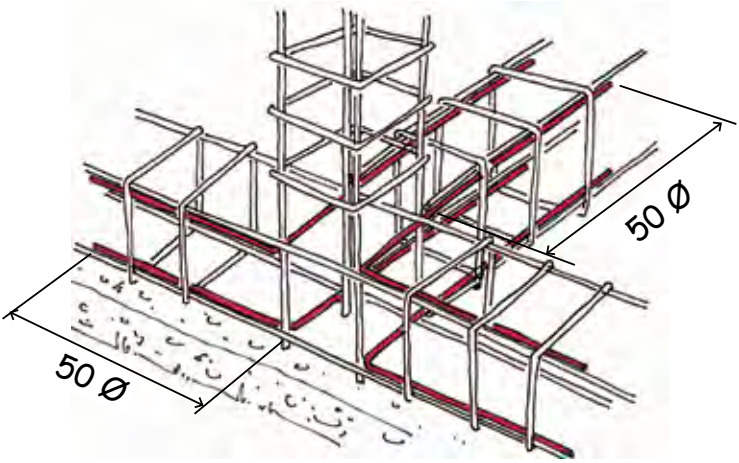
Tie wires only hold the rebars in place. They don't add strength to the connections !



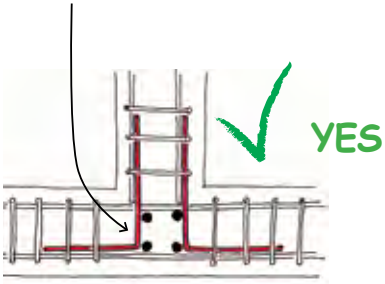
Lap length :
(overlapping)
50 x Ø
(50 times the diameter)

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

Tie-beam : T-connection



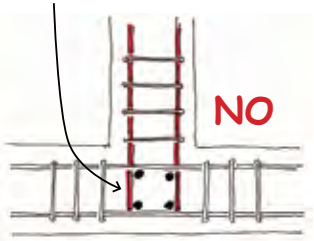
Always :
extend hooked bars from the inside to the outside !



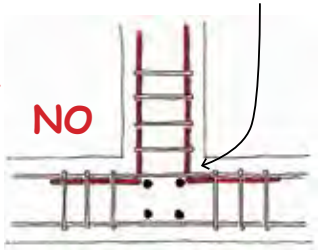
Lap length :
(overlapping)
50 x Ø
(50 times the diameter)

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

Connection with straight bars.

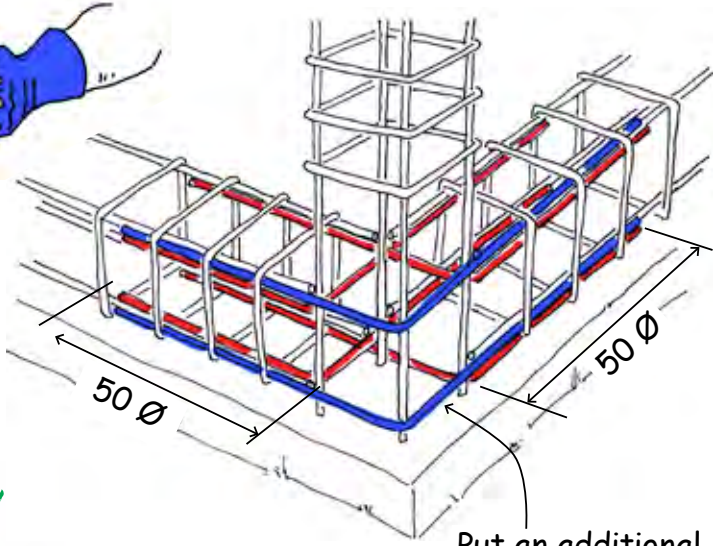


Connection around the inner corner.

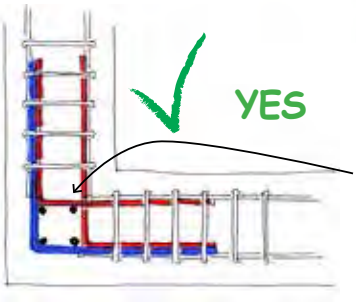


Tie-beam : L-connection

Rebars must cross like the fingers of a hand !

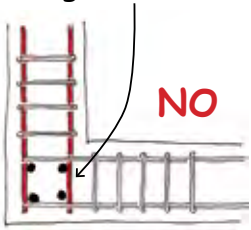


Put an additional rebar around the outer corner.

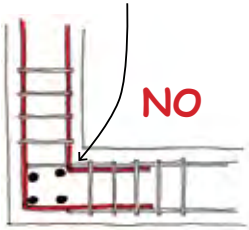


Extend hooked bars from the inside to the outside !

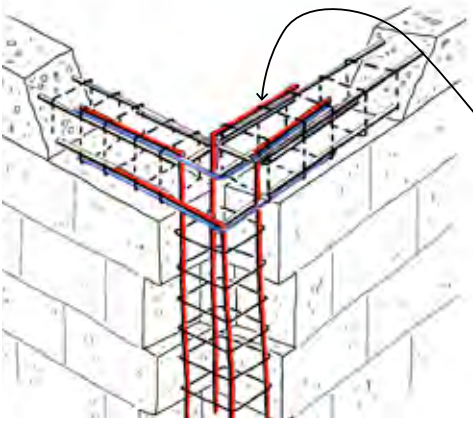
Connection with straight bars.



Hooked bars from inside to inside.



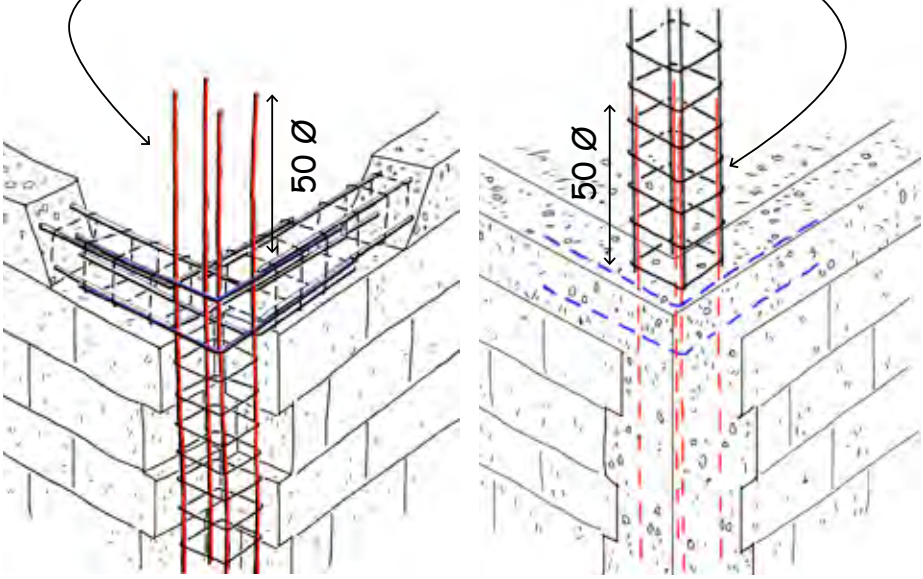
Tie-beam to Tie-column connection



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

One-storey building

If the wall continues, add vertical rebars with an 50 Ø overlapp.

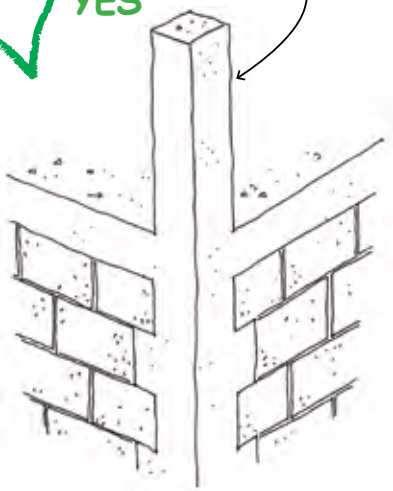


Two-storey building

Protection of rebar ends

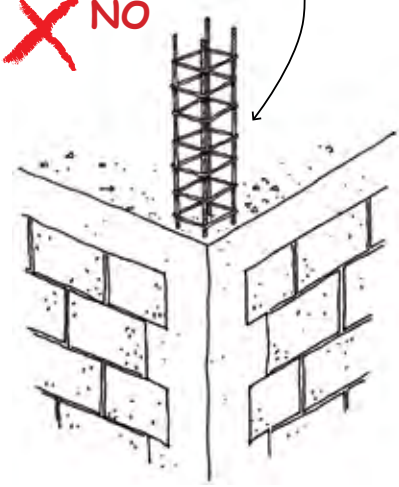
Protect rebar ends with lean concrete.

YES



Exposed rebar ends will rust and cannot be reused.

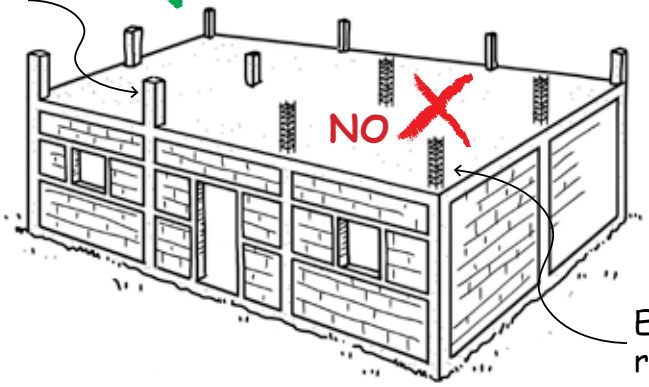
NO



YES

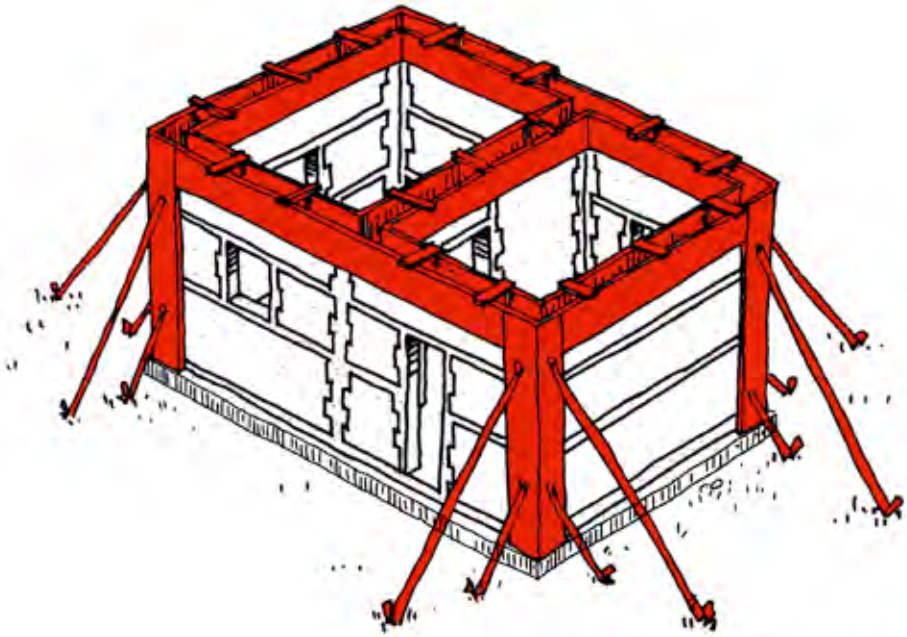
Protected rebar ends.

NO



Exposed rebar ends.

FORMWORK

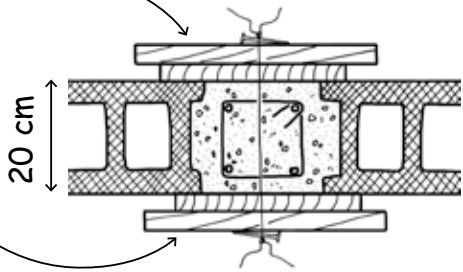


Formwork for Ties

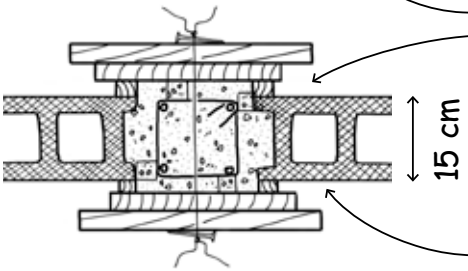
Block walls :

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

Tie = 20x20cm



Tie = 20x20cm

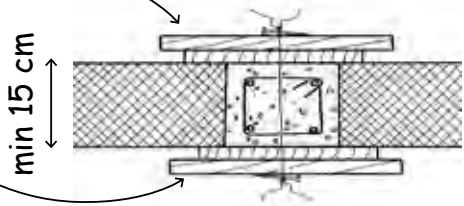


15cm wall thickness: Place a 1 inch board under the formwork board.

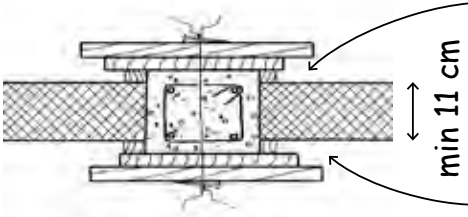
Brick walls :

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

Tie = 20x20cm
min 15x20cm



Tie = 15x20cm

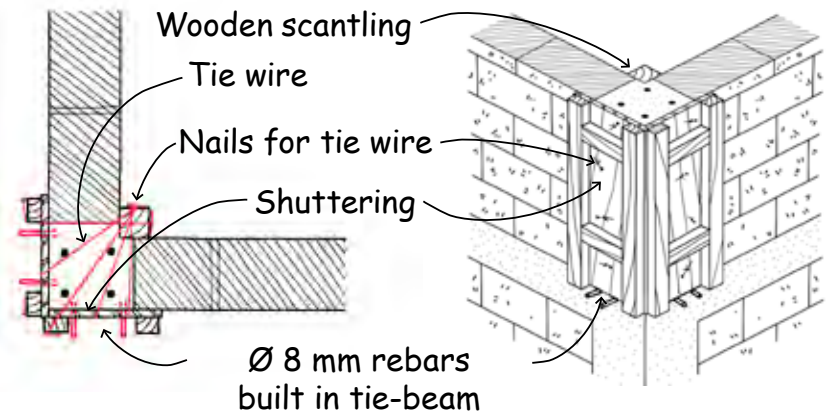


15cm wall thickness: Place a 1 inch board under the formwork board.

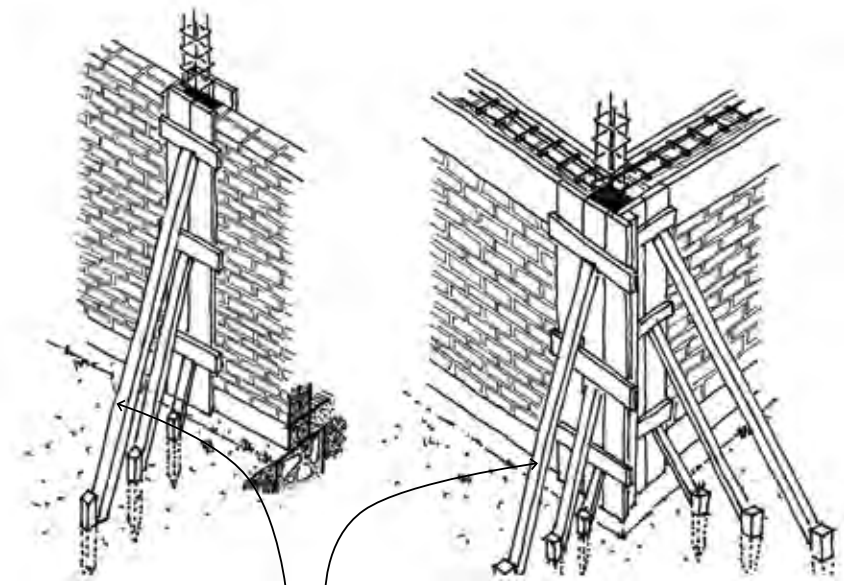
Sizes of tie-columns and tie-beams :
20 x 20 cm recommended / 15 x 20 cm minimum !

Vertical formwork

Vertical formwork at upper floor level :



Vertical formwork at ground floor level :



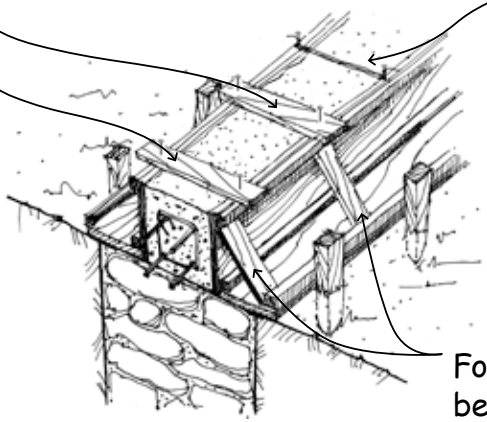
Horizontal formwork

YES

NO

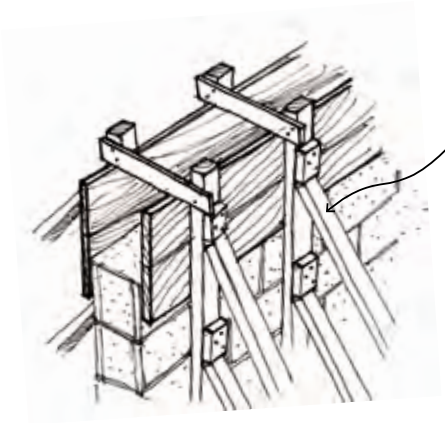
Use wood planks to connect formwork.

Don't use tie wire.



Formwork must be well fastened !

To be able to reuse the formwork, use small nailed planks. Do not use tie wire. !

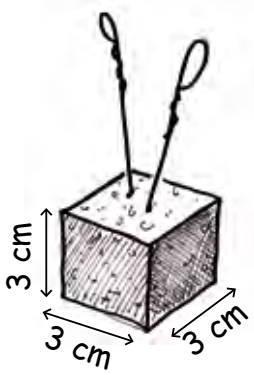


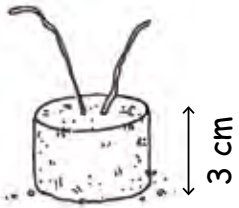
Formwork must be well braced !

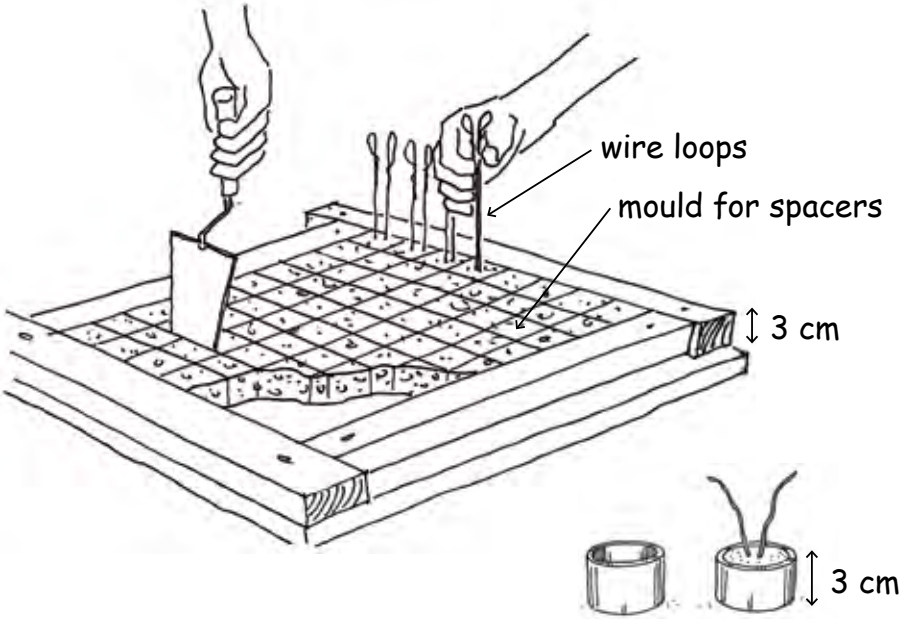
Spacers - 1

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 !

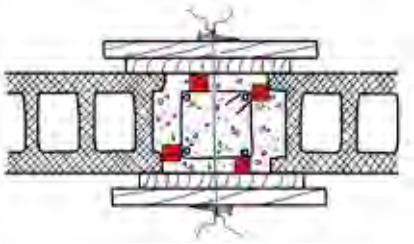






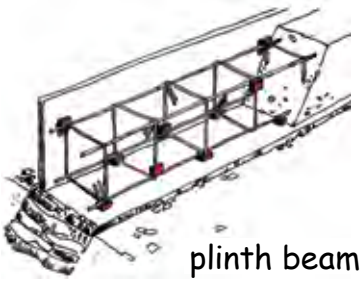
Spacers - 2

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

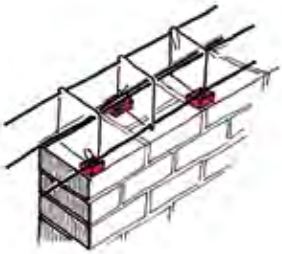


tie-column

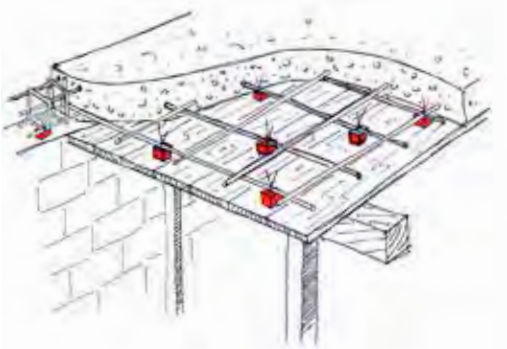
Alternate the position of the spacers around the stirrups !



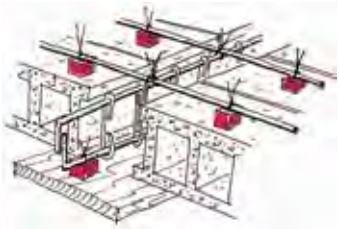
plinth beam



tie-beam

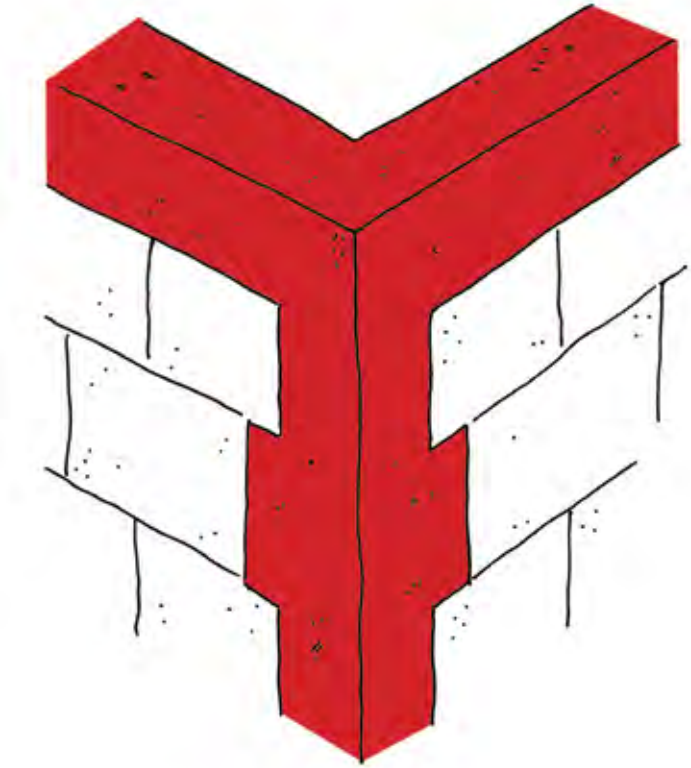


reinforced concrete slab



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) :

	Cement	Sand	Gravel	Strength	
minimum →	1	2	4	200 kg/m3	
preferred →	1	2	3	250 kg/m3	✓
	1.5	2	3	350 kg/m3	

Peferred 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 conrete 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 !**

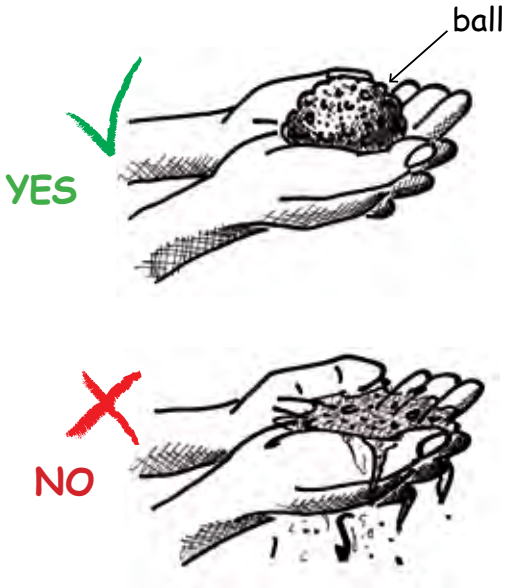
Mixing with a concrete mixer :

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

Always use the concrete within 90 min after mixing !!!

Concrete test

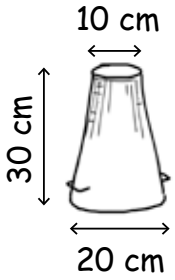
QUICK TEST :
Take a handful of concrete.
If the concrete leaks through your fingers, it is too wet !



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 !

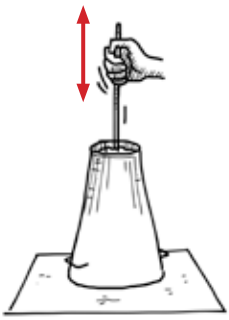
Slump test

Use a standard steel cone :



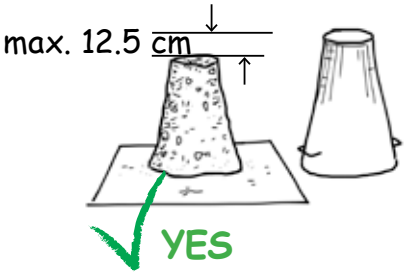
SLUMP TEST PROCEDURE :

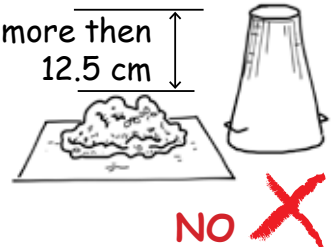
1. Fill cone in 3 equal layers.



2. Tamp down each layer 25 times with a rod (rebar).

3. Lift the cone vertically and place next to the slump.

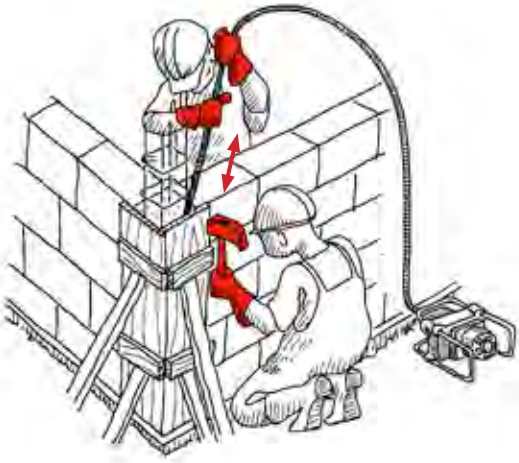




Result : the difference between slump and cone should be **less then 12.5cm !**

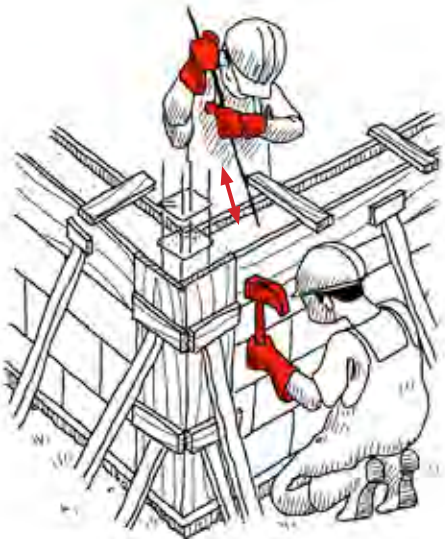
Pouring concrete : Tie-Columns

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

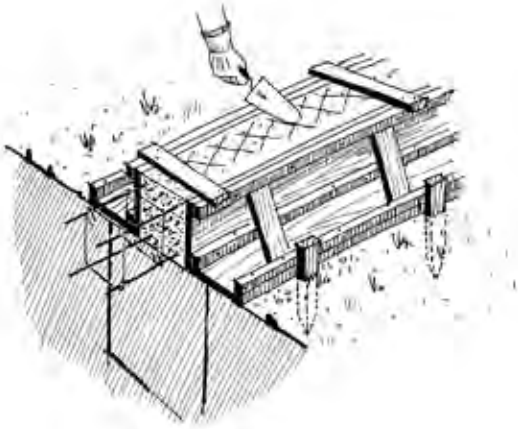


Use a stick (or rebar) and a hammer to help the concrete
flow down, to compact it and avoid air pockets.
Use a mechanical vibrator if one is available !

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

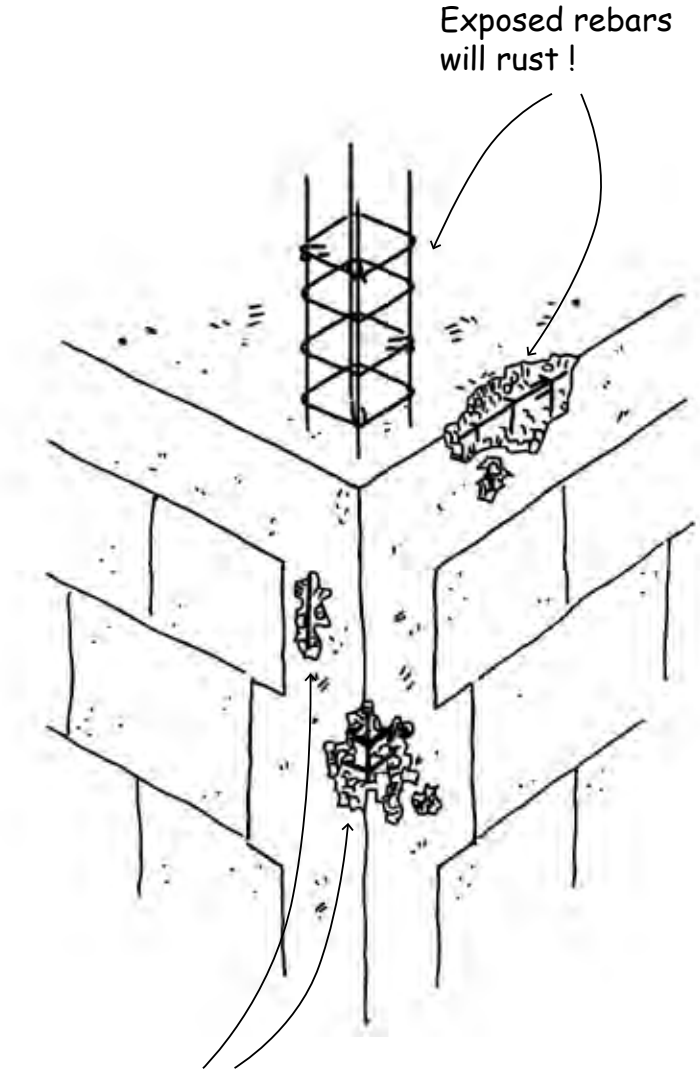
Curing the concrete elements

Concrete needs water to harden !

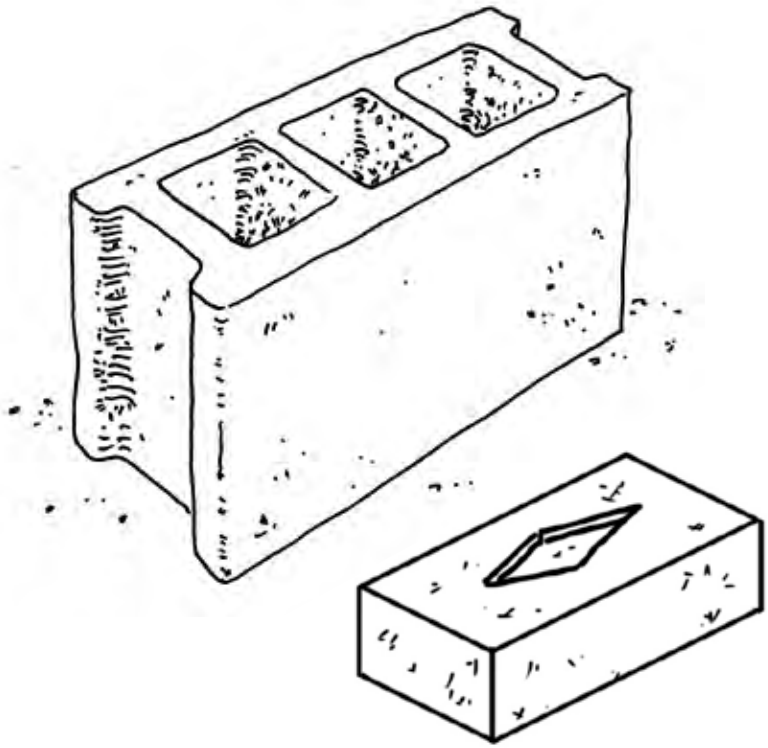
After placing concrete, cure the concrete by wetting the formwork 3 times a day for 3 days. Remove formwork only after three days !

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

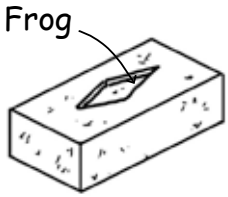
Ensure good quality concrete



BRICKS & BLOCKS

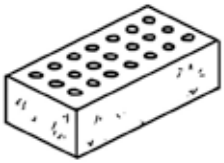


Which clay bricks to use



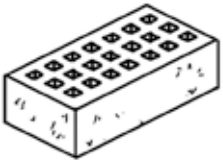
YES

Best brick :
solid burnt clay brick
with frogs.



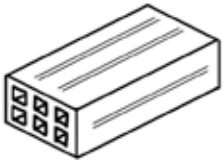
YES

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



NO

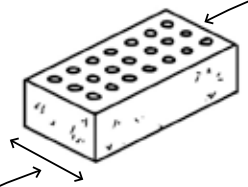
Bad brick :
vertical holes more then
50% of surface area.



NO

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

Solid bricks are better then multiperforated ones !



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

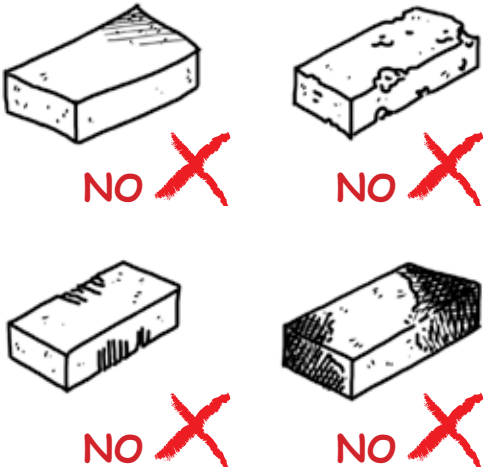
min 11 cm
(recommended 12.5-15cm)

Note : we recommend to use 10MPa bricks.

Brick test

Visual test :

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



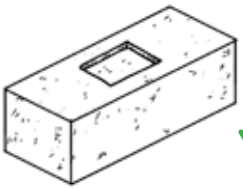
Physical test :

1. Bricks cannot be easily scratched by a knife.

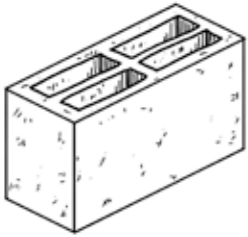
2. Resists the **"3 point test"** : Person standing on a brick spanning between two other bricks.

3. Bricks must give a ringing sound when struck against each other.

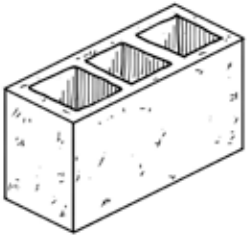
Which concrete blocks to use



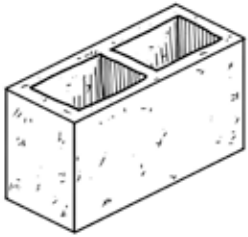
Best block :
15-20 cm thick,
solid block.



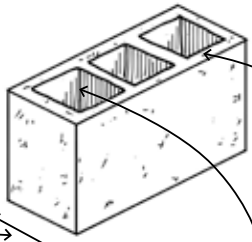
Best block :
15-20 cm thick,
with 4 holes.



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



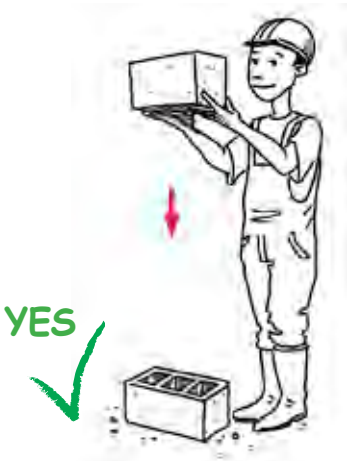
Only if excellent quality !
20 cm thick,
with 2 holes.



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)

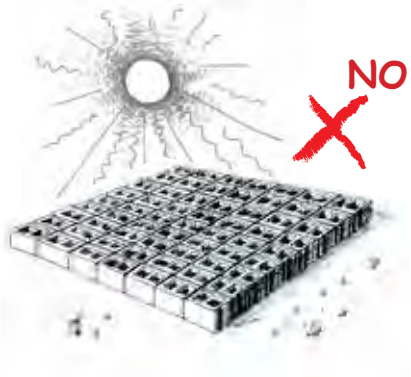
Acceptable quality :
(less than 1 broken)

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

Check if blocks were cured in the shade !

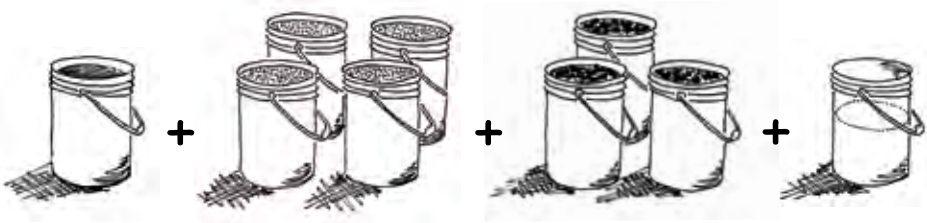
Stored in the shade : good.

Stored under plastic sheets : good !



Blocks that dry in the sun : very bad !

Concrete mix for blocks (1 : 4 : 3)



1 part cement | 4 parts clean sand | 3 parts gravel (8-10mm) | 3/4 part clean water

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

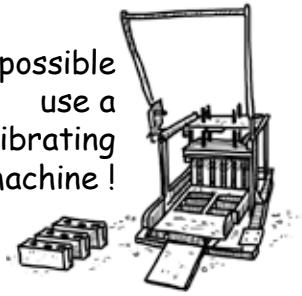
Add water only at the end !

Making the blocks

Wait 8 days before using the blocks !

Fill the molds with the mixture.

If possible use a vibrating machine !



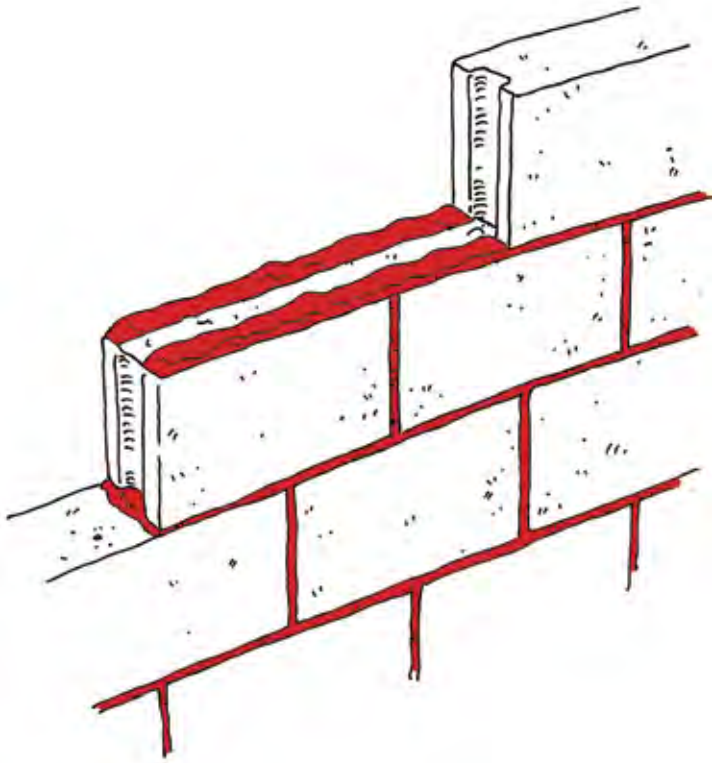
To compact the concrete, hit the mold with a shovel and a hammer.

Cover the blocks with plastic sheets immediately!

Cure the blocks 3 times a day for **minimum 7 days** and cover with plastic sheets.

Store the blocks in the shade.

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

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.

Add the water only at the end !

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 :

	Cement	Lime	Sand	
	x	y	z	
preferred →	1	0.5	4.5	✓
	1	1	6	
minimum →	1	2	9	

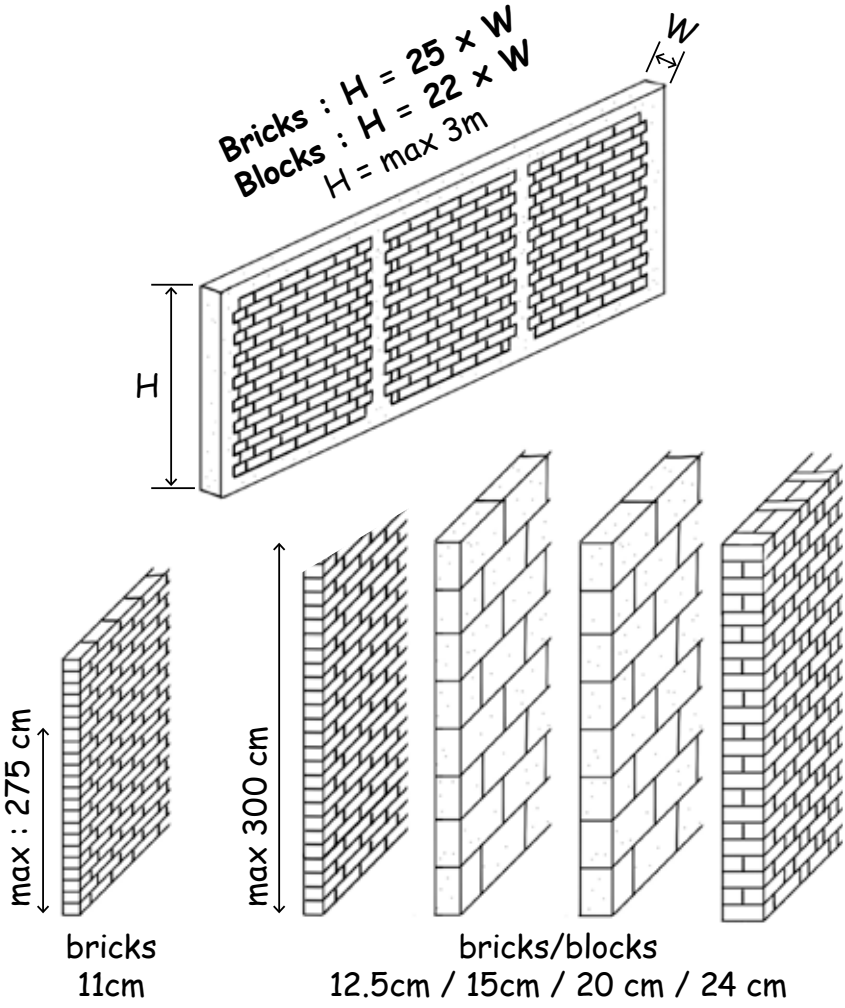
Mix the mortar:

X parts cement | Y parts lime | Z parts clean sand | 3/4 part clean water

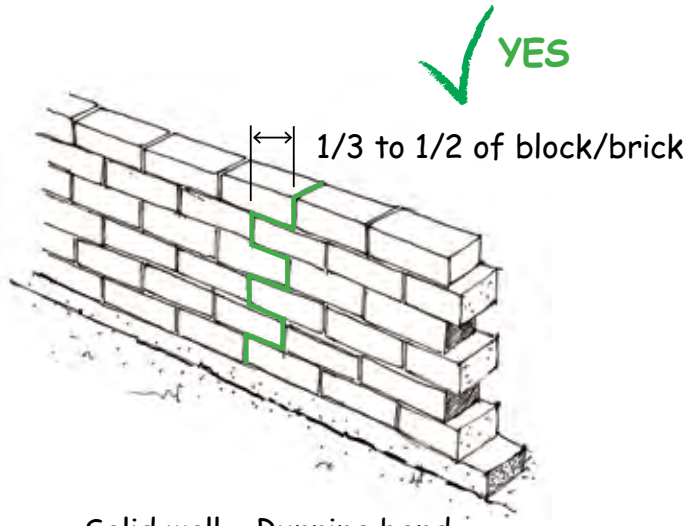
Masonry walls height

The Width of masonry unit defines the wall height.

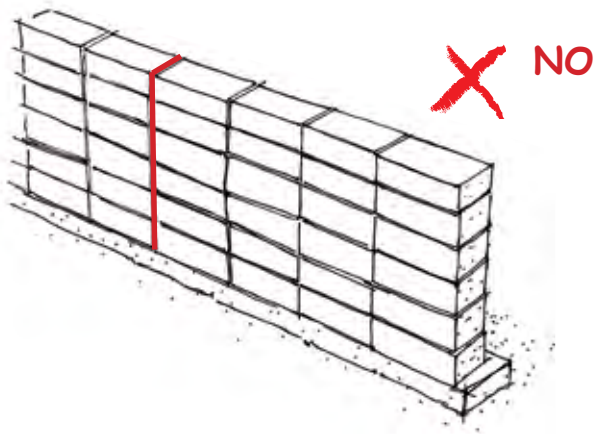
For bricks: Height smaller then 25 x wall Width
For blocks : Height max 22 x wall Width
Height = maximum 3m !



Masonry bonds



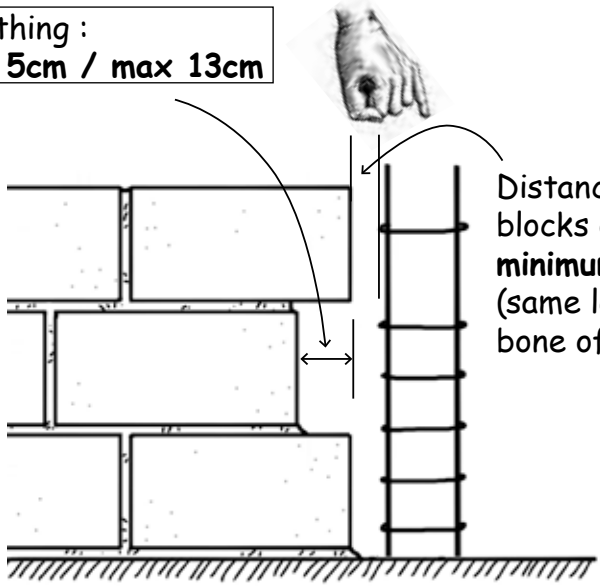
Solid wall = Running bond
vertical joints are not continous.



Weak wall = Stack bond
vertical joints are continuous.

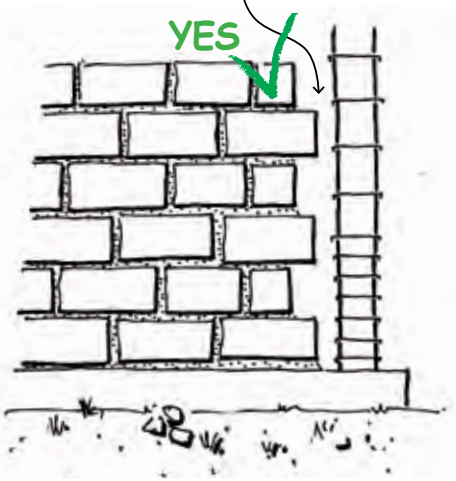
Toothing

Toothing :
min 5cm / max 13cm

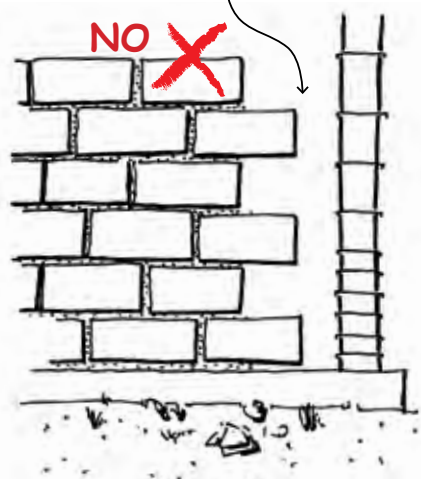


Distance from blocks or bricks : **minimum 3 cm !** (same length as last bone of thumb).

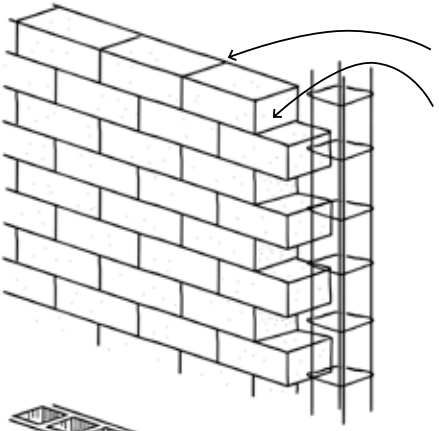
Toothing 1/3-1/4 of a block :
(max 1/2 of brick length)
GOOD !



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



Toothing options

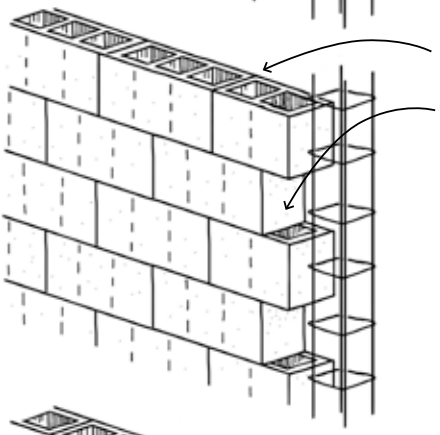


50% running bond

toothing

Clay bricks (23-24 cm):

50% running bond
(half of a brick)
Toothing = max 12 cm

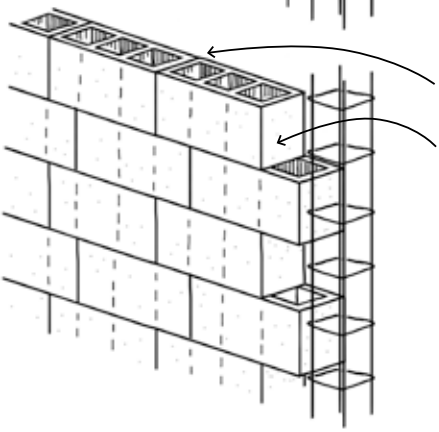


50% running bond

toothing

Concrete blocks (40 cm):

50% running bond
(half of a block)
Break 1/3 of last block!
Toothing = min 5 cm



33% running bond

toothing

Concrete blocks (40 cm):

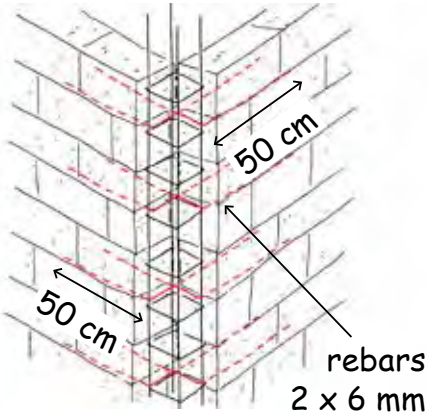
33% running bond
(1/3 - 2/3 of a block)
Toothing = max 13 cm

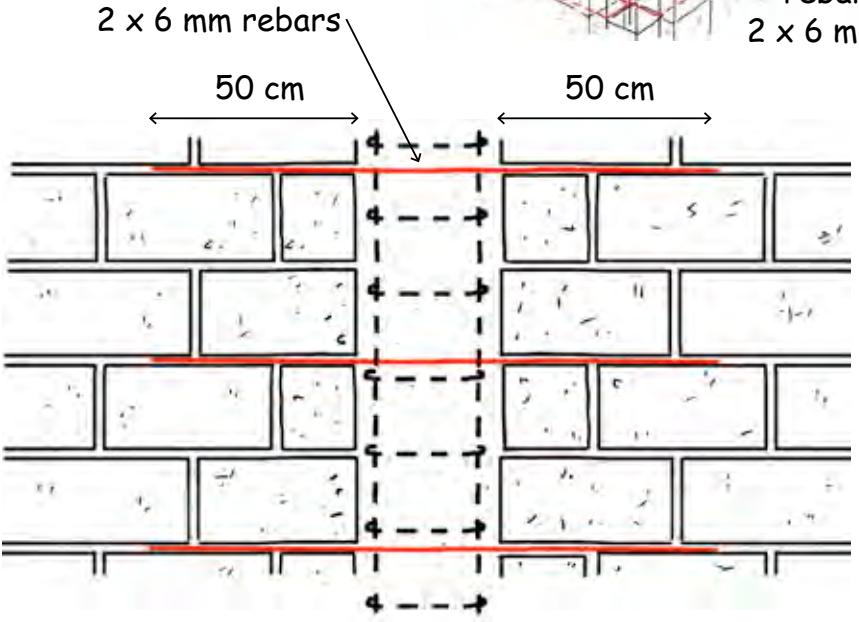
Dowels

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



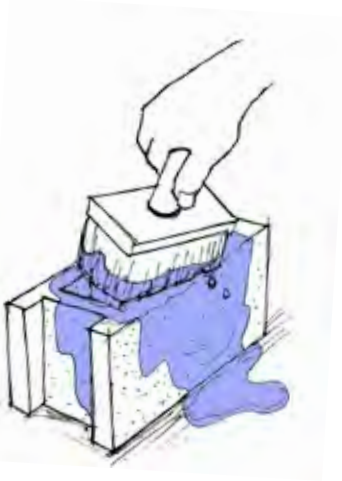


Note :
Dowels should be covered with enough mortar to protect them properly. **Test if dowels can be placed properly !**

Preparing the masonry units

Soak the blocks in water for a while...

... or ...

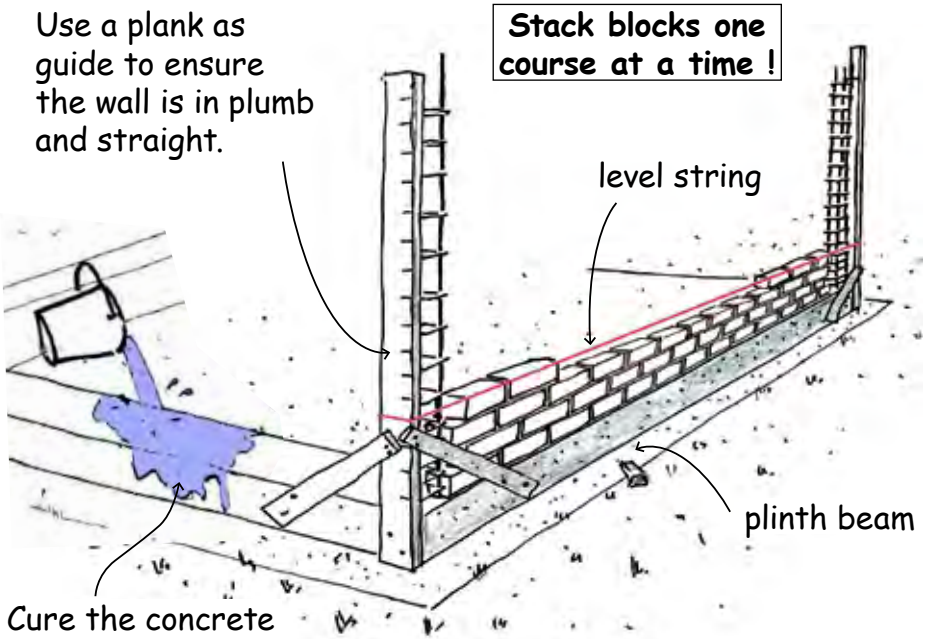


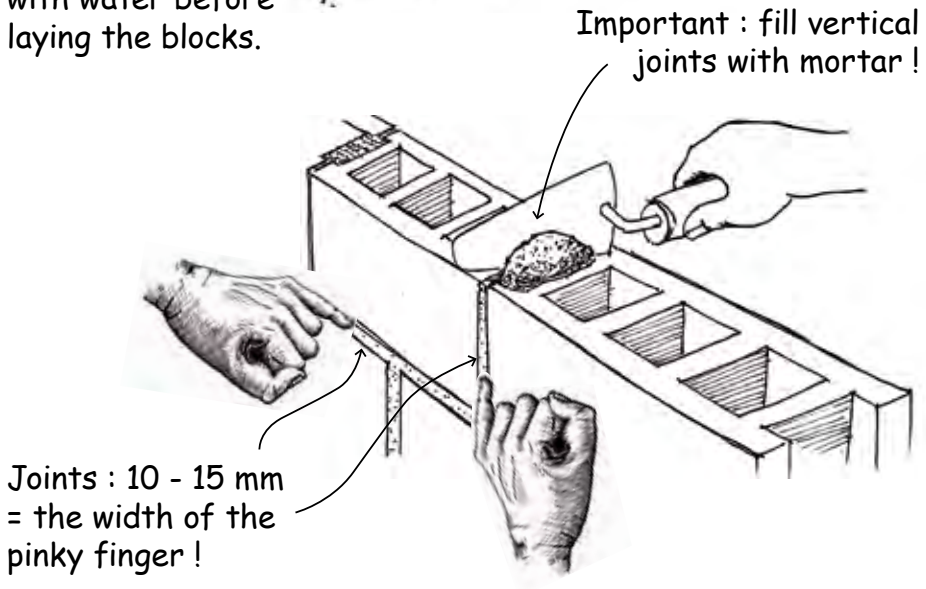
... water them with a brush before use.

... or ...

... water all blocks together.

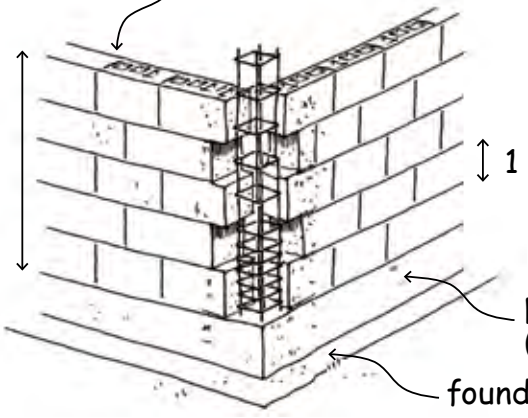
Good masonry practice - 1



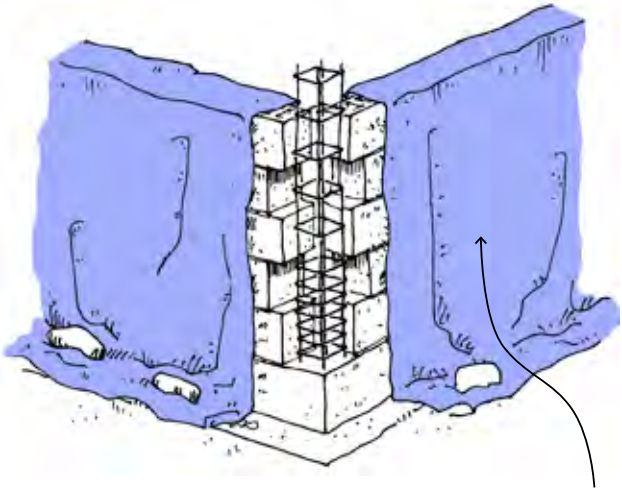


Good masonry practice - 2

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

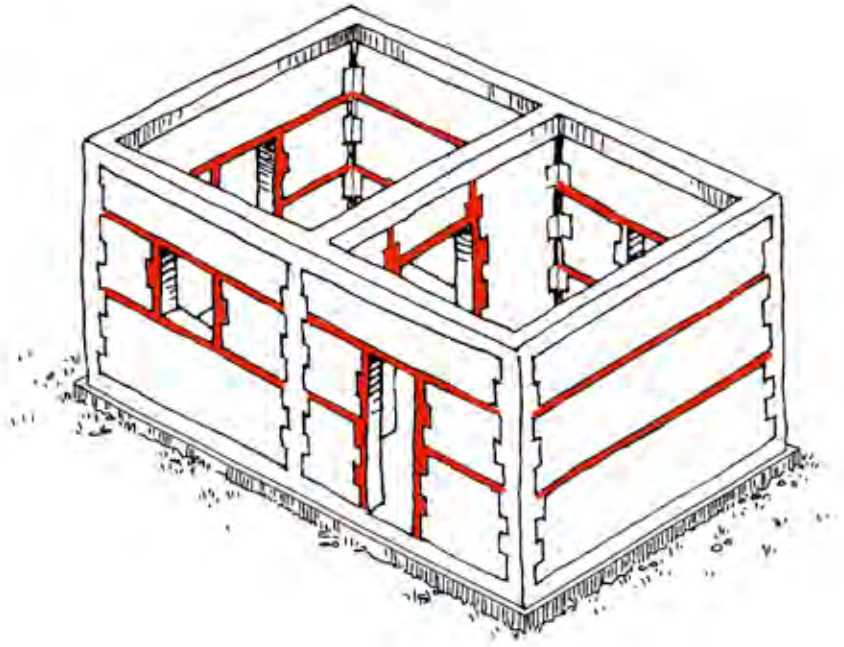


Protect the wall in warm weather:
mortar must not dry out in the sun!



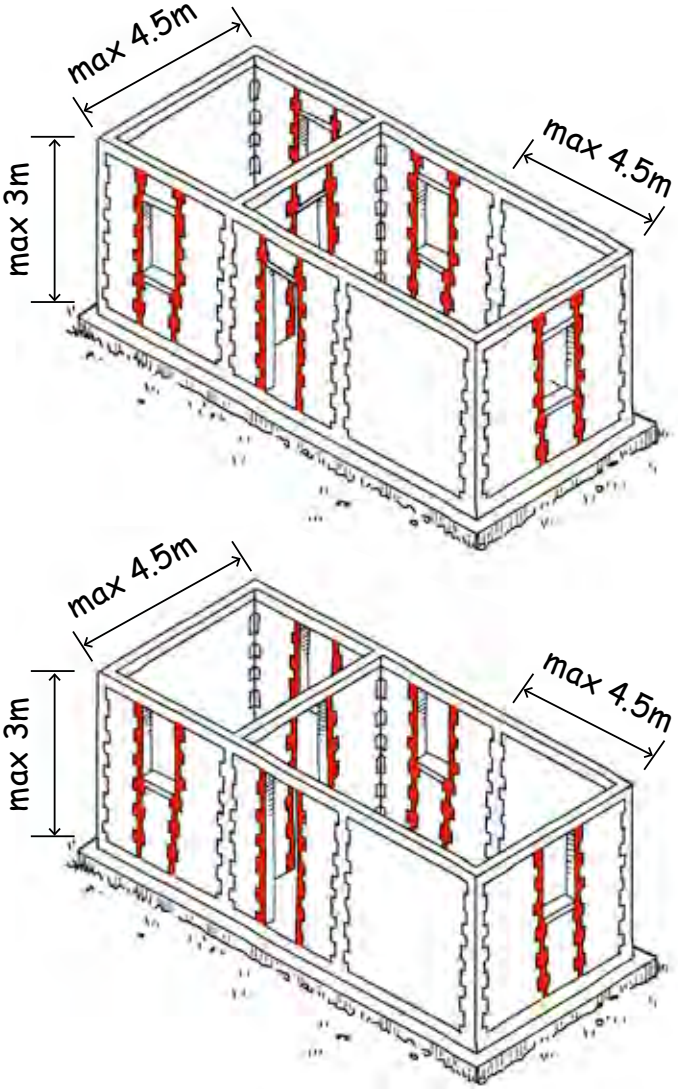
Keep wall moist by pouring water on them 3 times a day for 7 days and/or by covering them with a plastic sheet for 7 days.

SEISMIC REINFORCEMENT



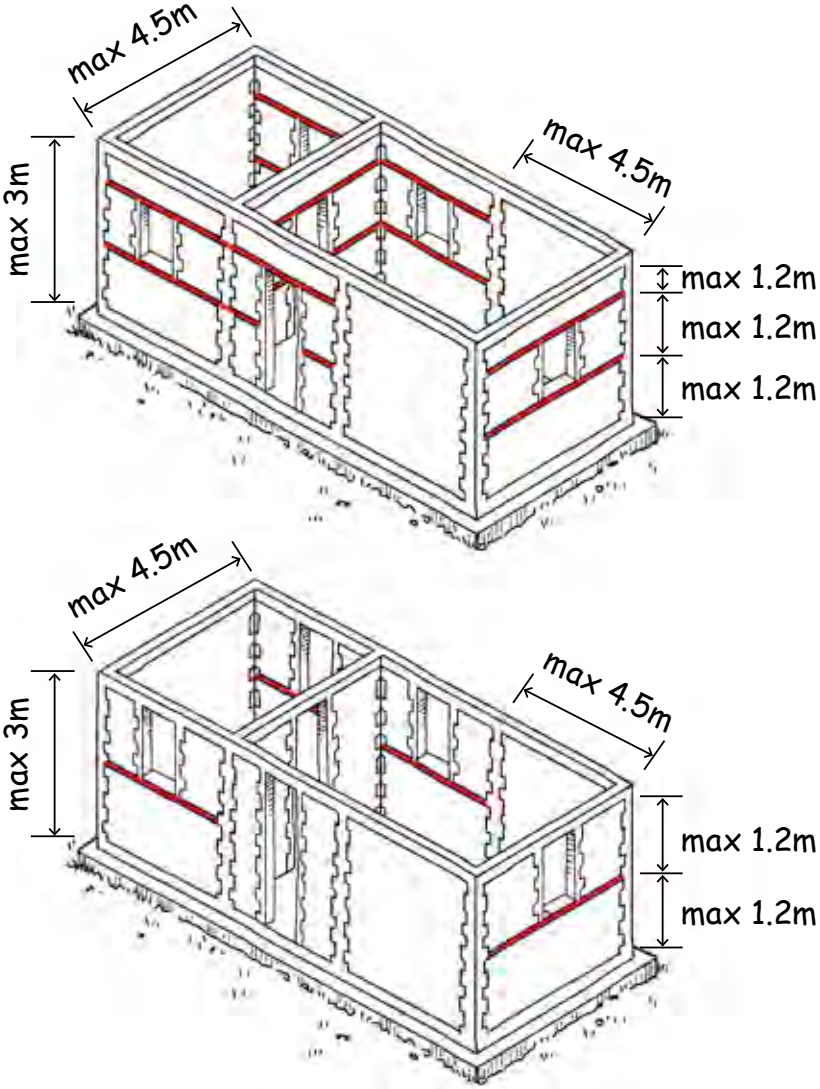
Vertical reinforcement (V)

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



Horizontal reinforcement (H)

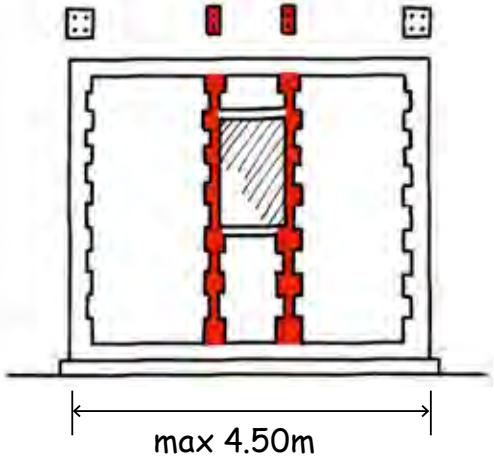
Place a seismic band below and above every opening !
Don't go higher than 6 courses of blocks, don't exceed 1.20m !



Adding vertical bands

Place vertical reinforcement on each side of every opening.

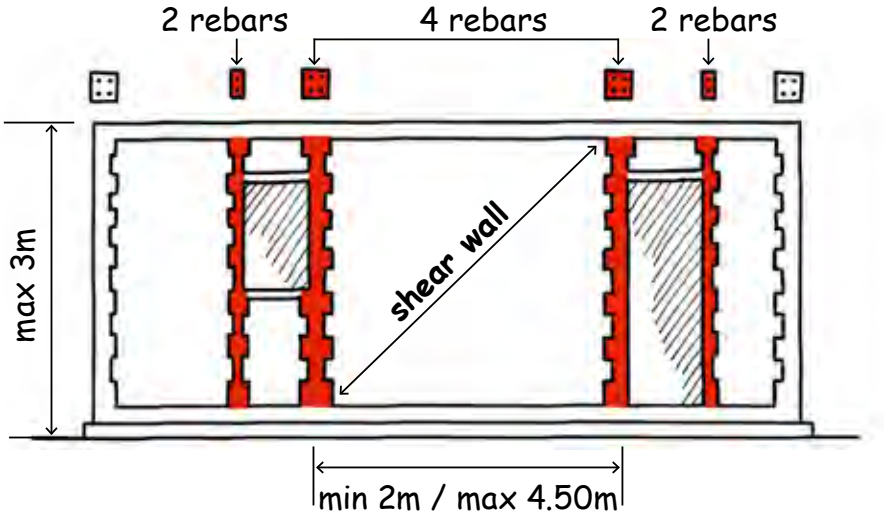
Vertical bands are "half tie-columns" : **add two rebars.**



Vertical bands :
(for openings)

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

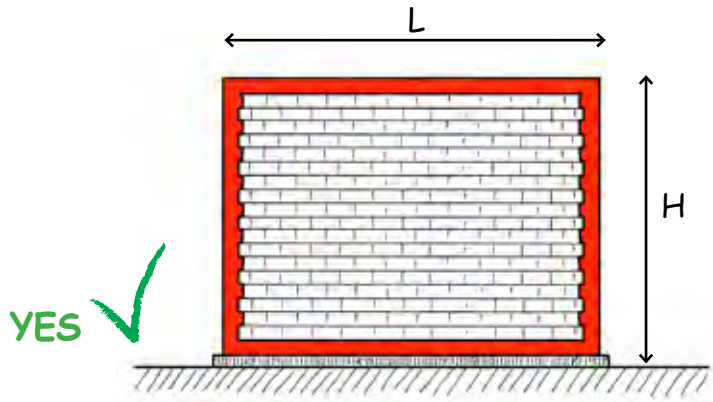
If a wall between openings functions as shear wall, the vertical reinforcement is identical to a tie-column : **add four rebars** !



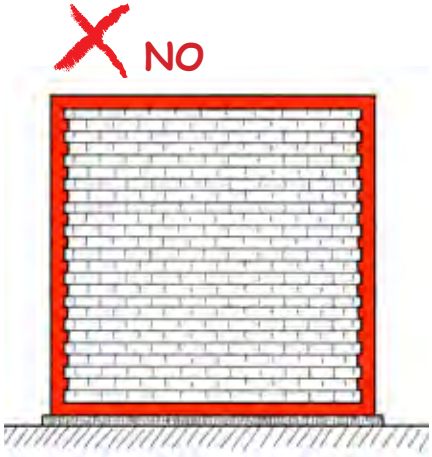
Adding horizontal bands

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

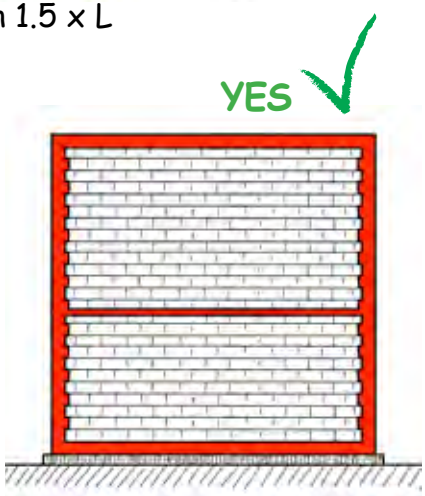
Rule :
H < 1.5 x L



H smaller than 1.5 x L

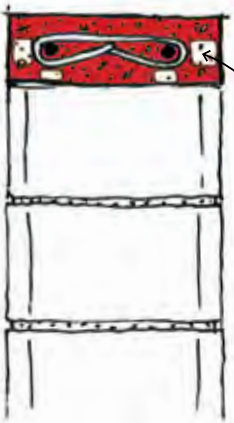


H = bigger than 1.5 x L
No seismic band



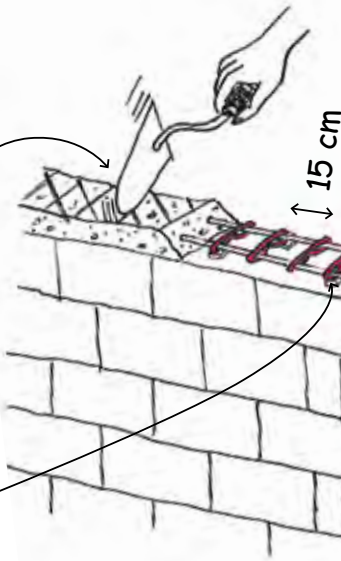
H = smaller than 1.5 x L
With seismic band

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

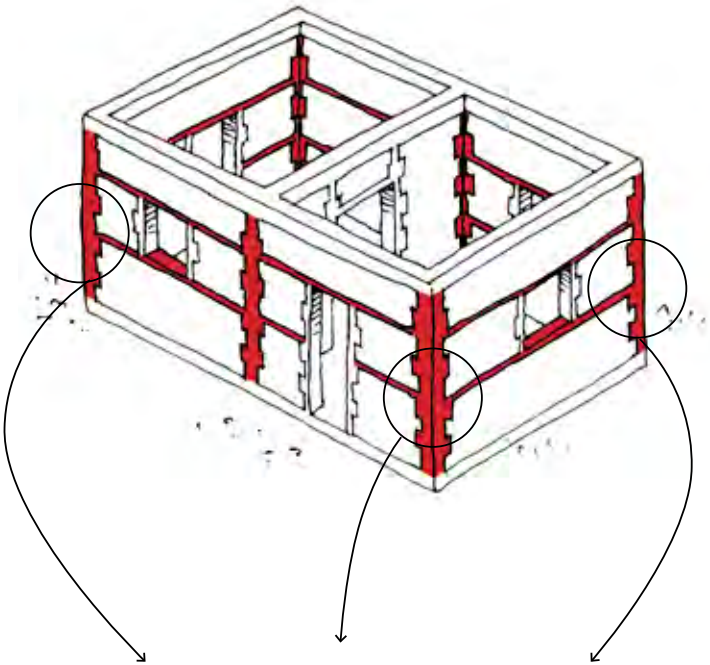


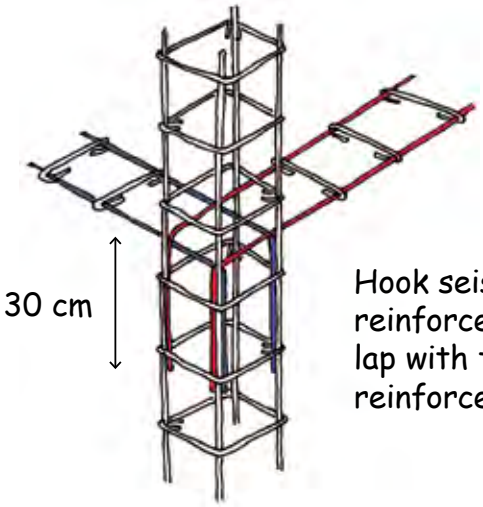
Place a stirrup every 15 cm !

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

spacer

Connect seismic band to tie-column



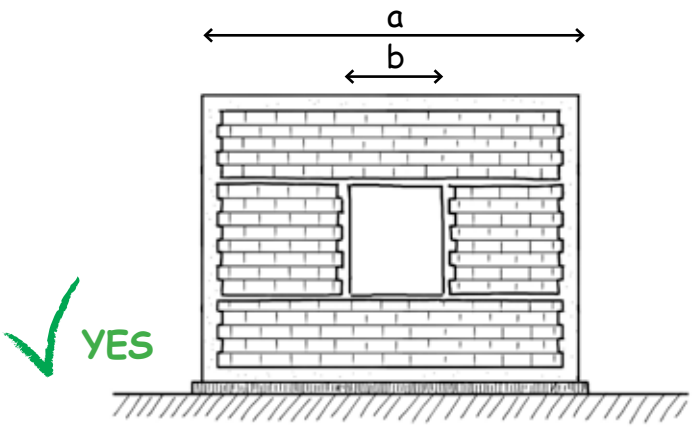


Hook seismic bands reinforcement and lap with tie-column reinforcement.

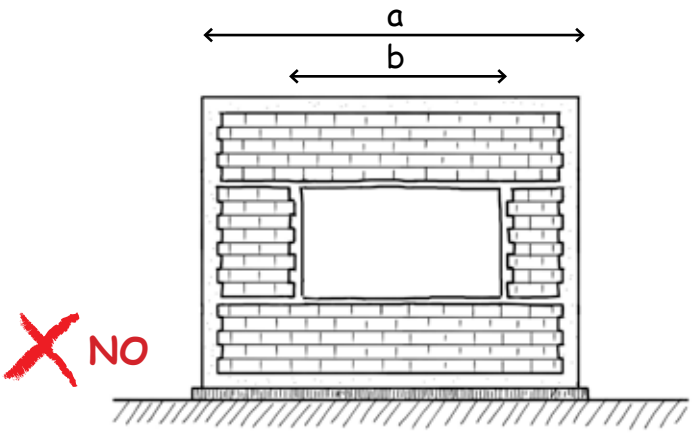
Size of openings

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

Rule :
b smaller than a/2



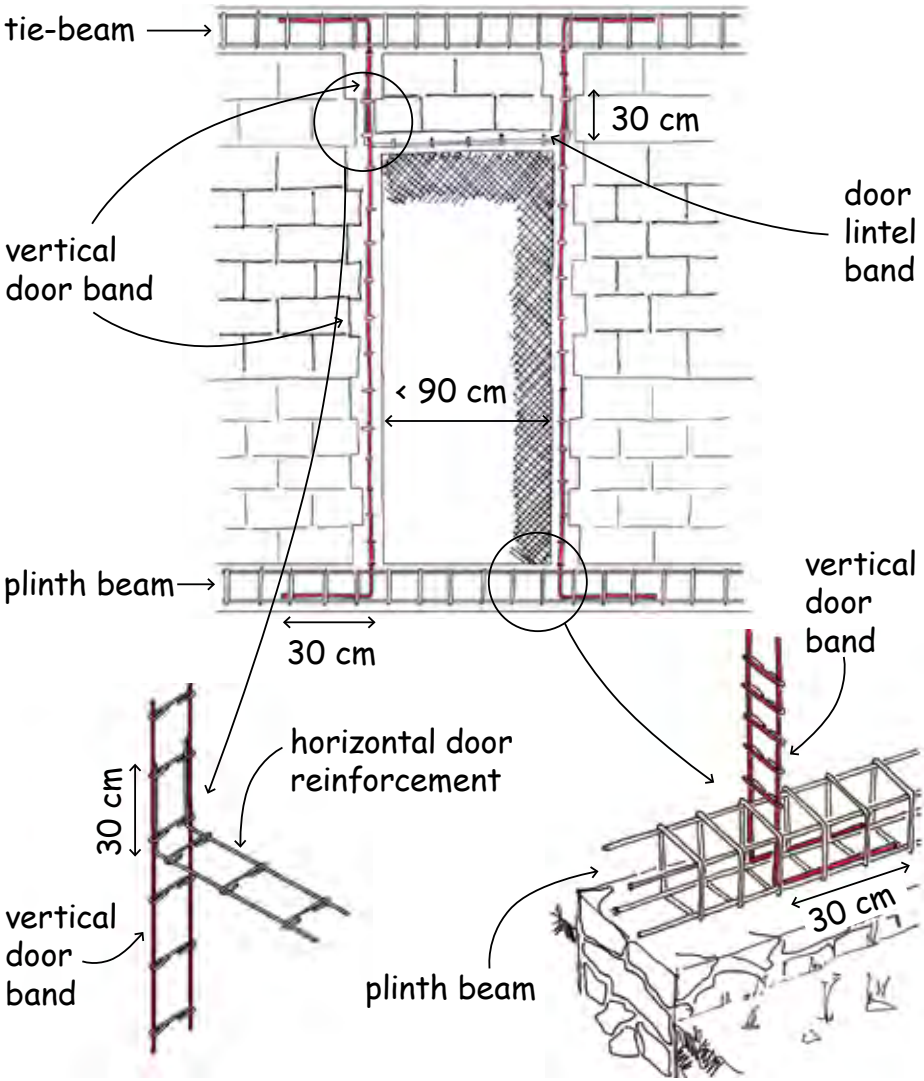
Correct: b smaller than a/2



Incorrect : b bigger than a/2

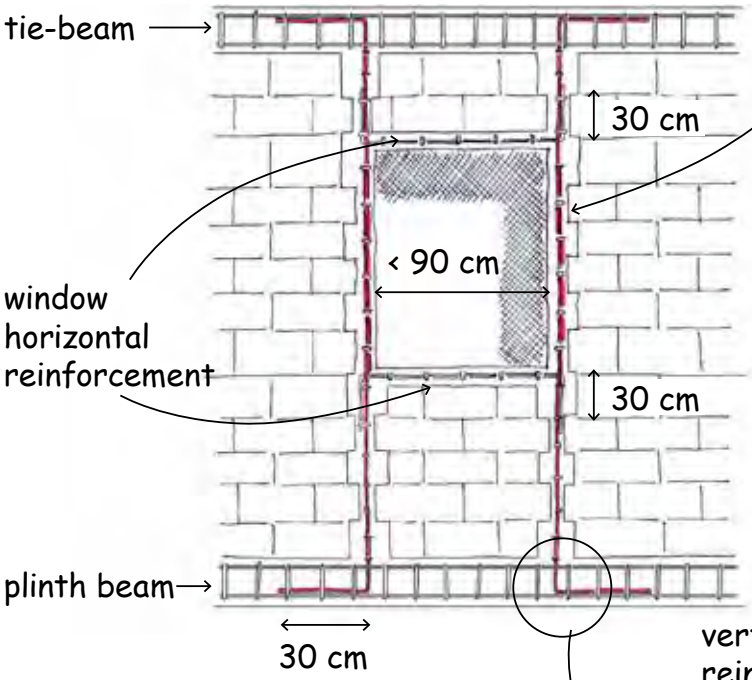
Door reinforcement (V)

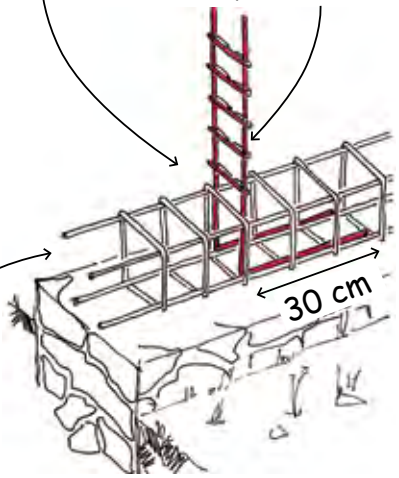
Hook the door vertical reinforcement rebars and lap 30cm with the tie-beam rebars, under the stirrups. Do the same with lintel band and the vertical bands.



Small window reinforcement (V)

For windows smaller than 90 cm.



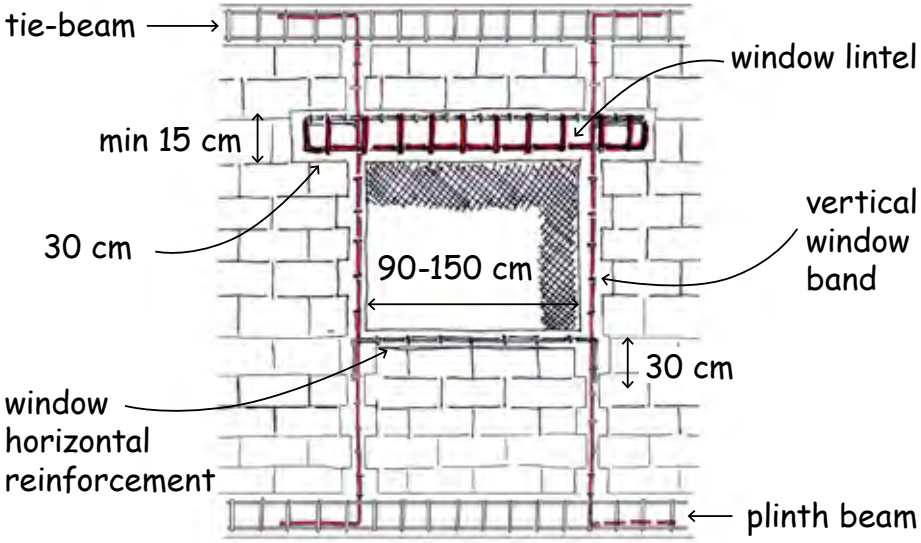


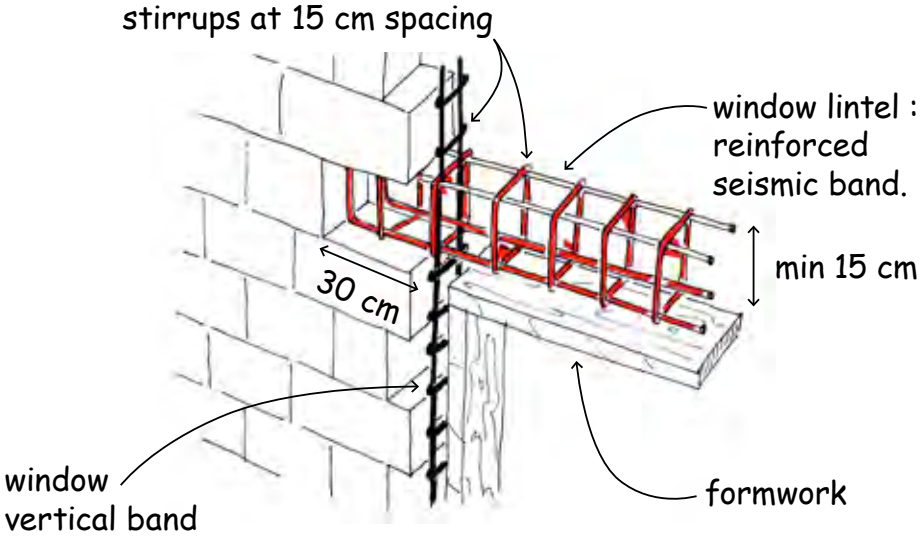
Hook the window vertical reinforcement and lap 30 cm with the tie-beams reinforcement, inside the stirrups.

Do the same with the horizontal reinforcement and the vertical bands.

Large window reinforcement (V)

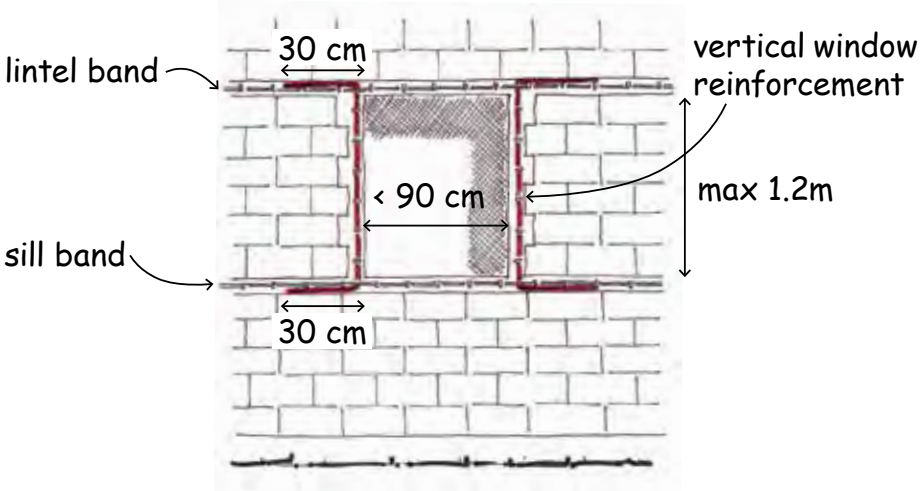
For windows larger than 90 cm.



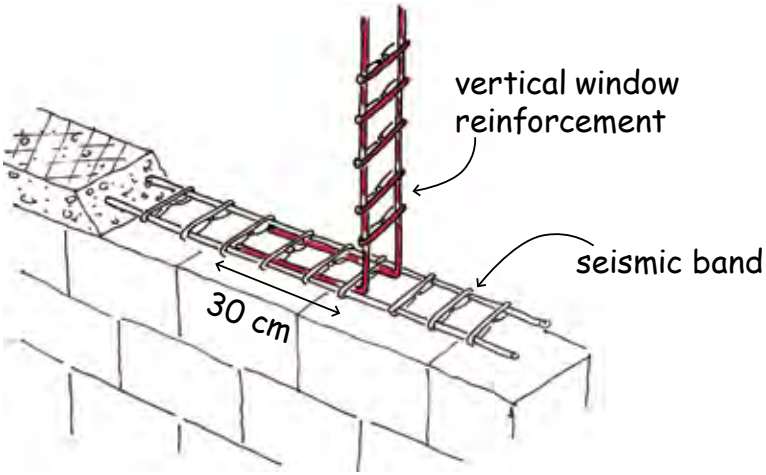


Small window reinforcement (H)

For windows smaller than 90 cm.

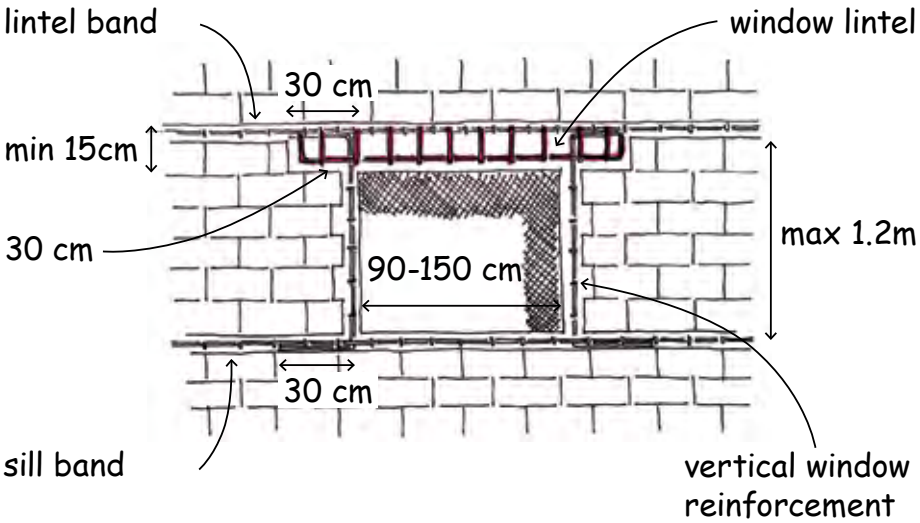


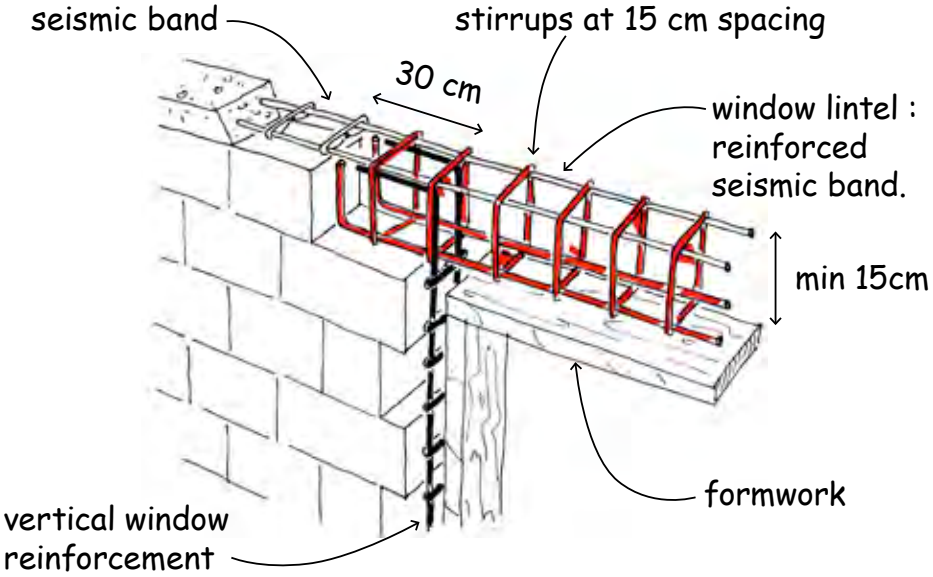
Hook the window reinforcement and lap 30 cm with the seismic band reinforcement, inside the stirrups.



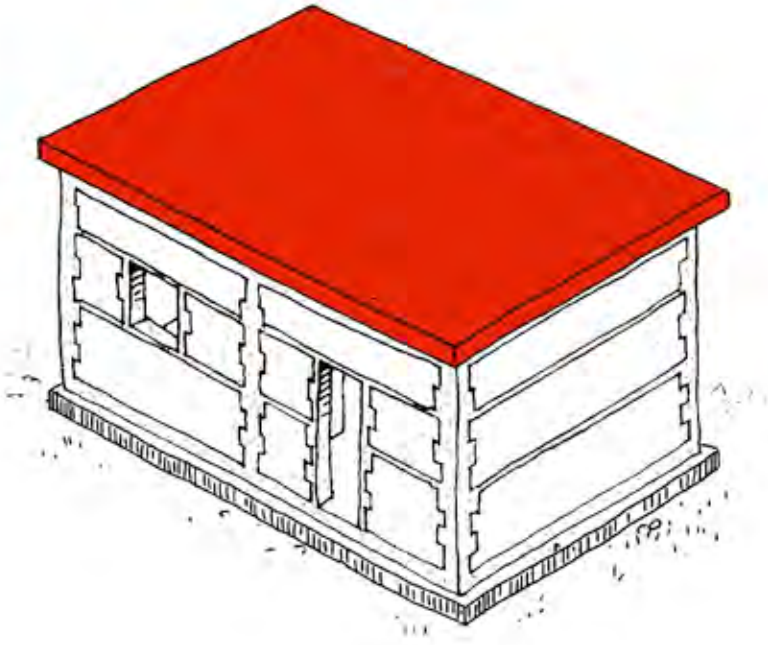
Large window reinforcement (H)

For windows larger than 90 cm.





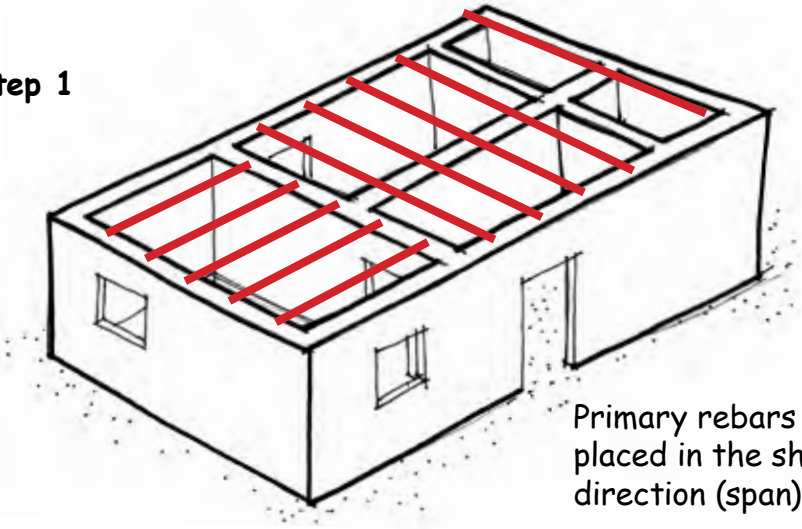
SLAB



Placing of slab reinforcement

Placement of primary rebars.

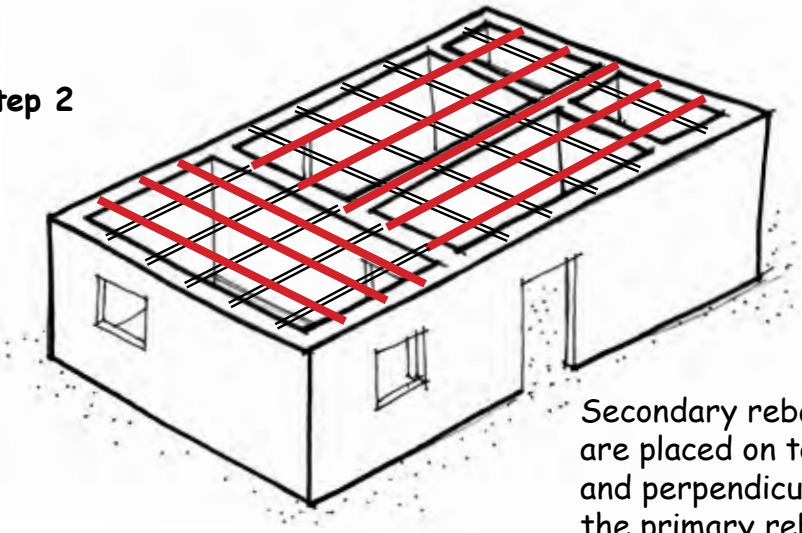
Step 1



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

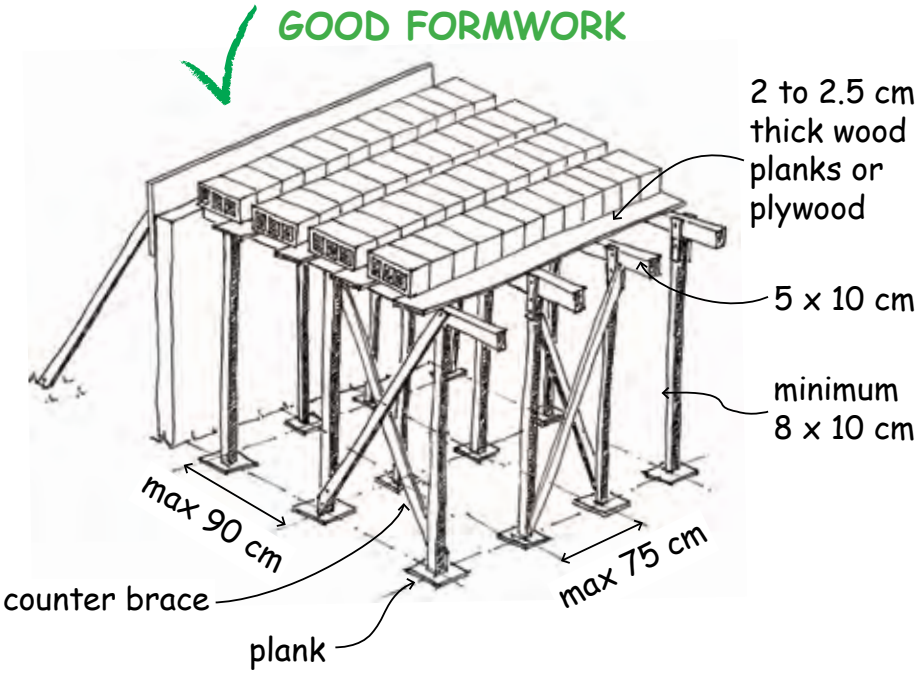
Placement of secondary rebars.

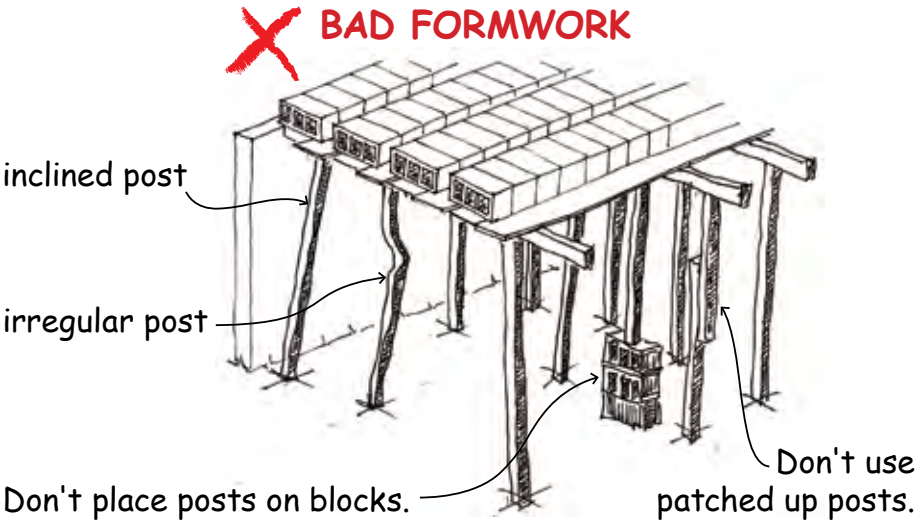
Step 2



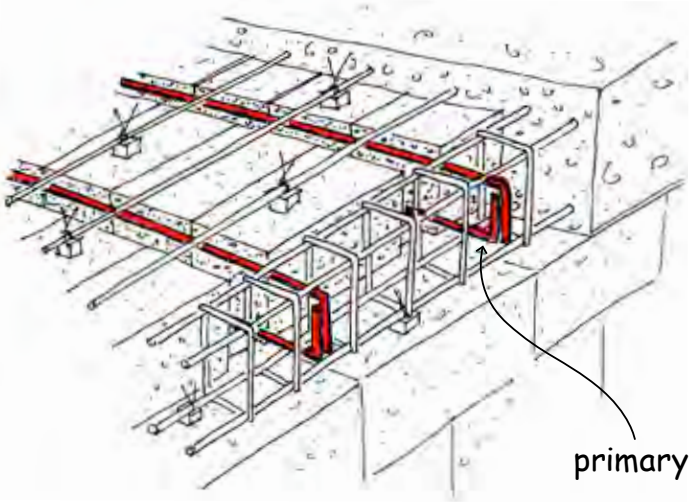
Secondary rebars are placed on top of and perpendicular to the primary rebars

Hollow block slab: formwork

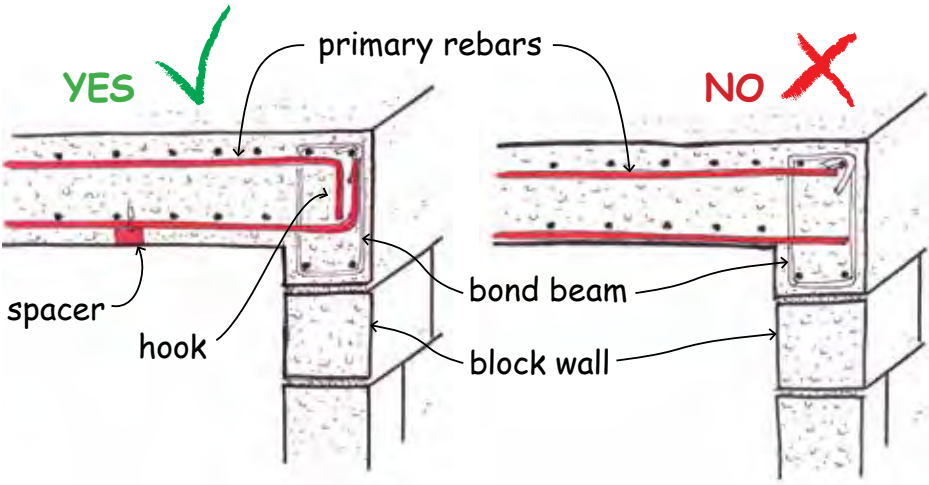




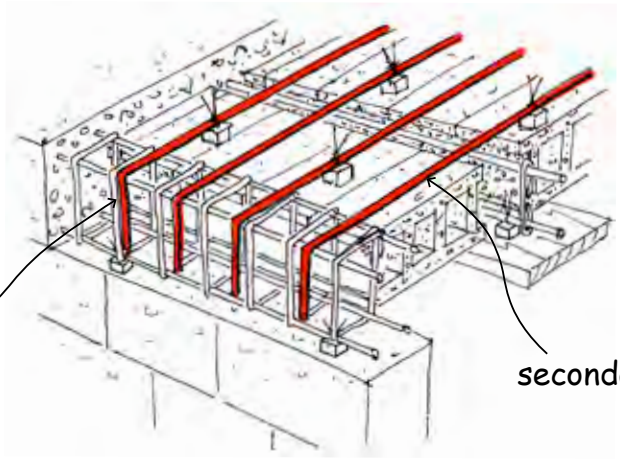
Hollow block slab: main reinforcement

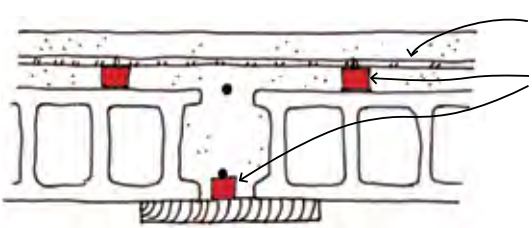


To ensure a good connection, it is important to insert the hooked slab rebars deep into the bond beam.

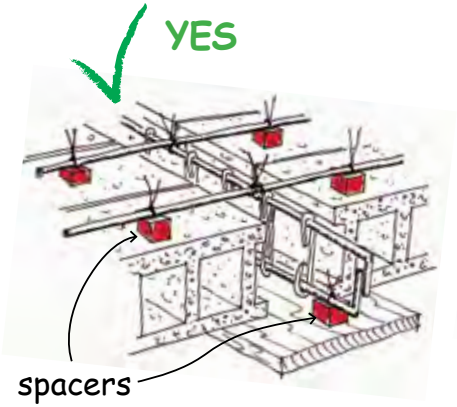


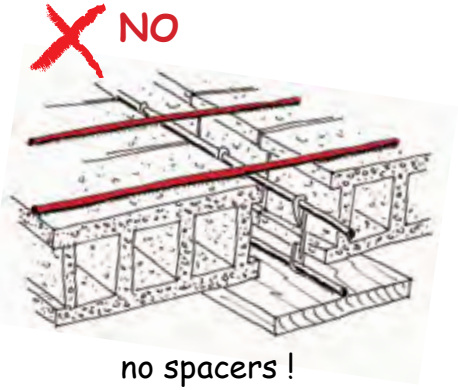
Hollow block slab: secondary rebars



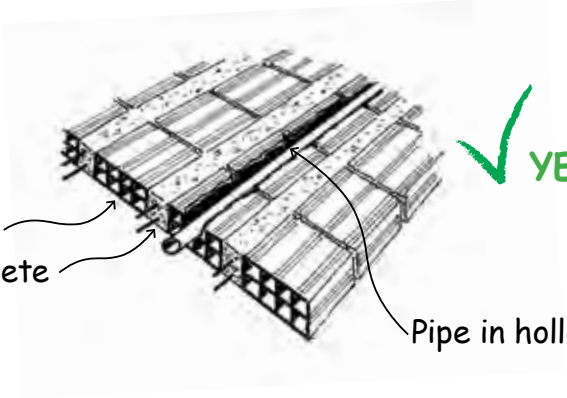


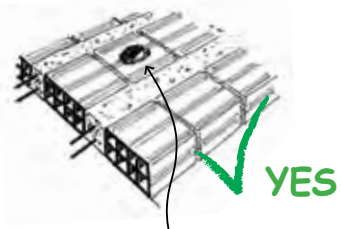
Secondary rebars must be placed in the middle of the concrete covering the hollow blocks with spacers.



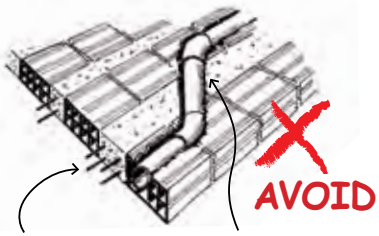


Hollow block slab: positioning pipes 1

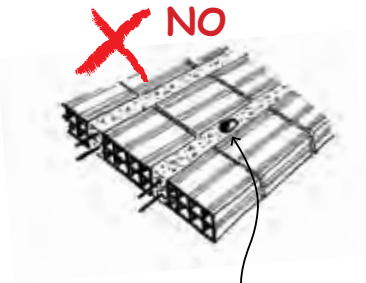




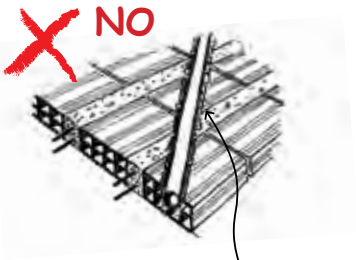
Drill through hollow blocks !



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



Don't drill through concrete !

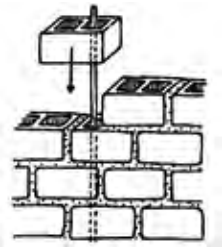


Don't cross concrete all the way !

Hollow block slab: positioning pipes 2

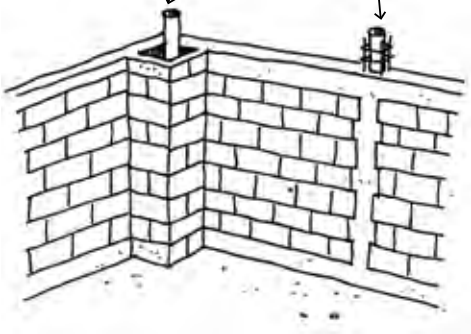
YES

Place pipes in block holes.



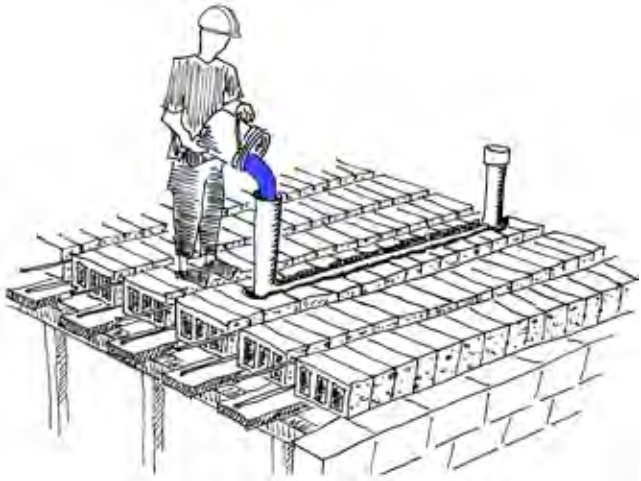
YES

Place pipes in service duct.



NO

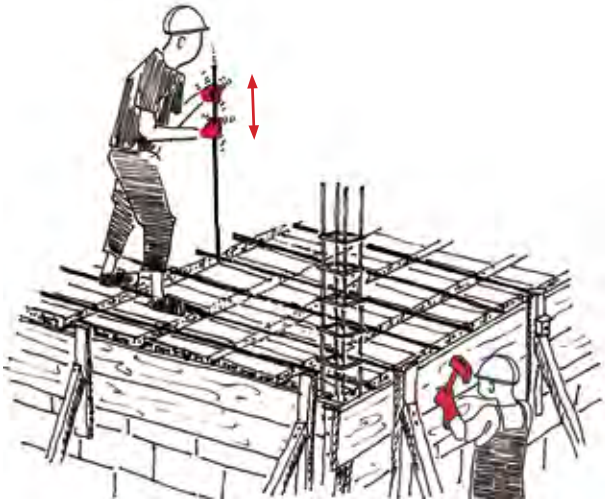
Don't place pipes in walls or in ties !



Test watertightness of the pipes before pouring concrete by filling them with water.

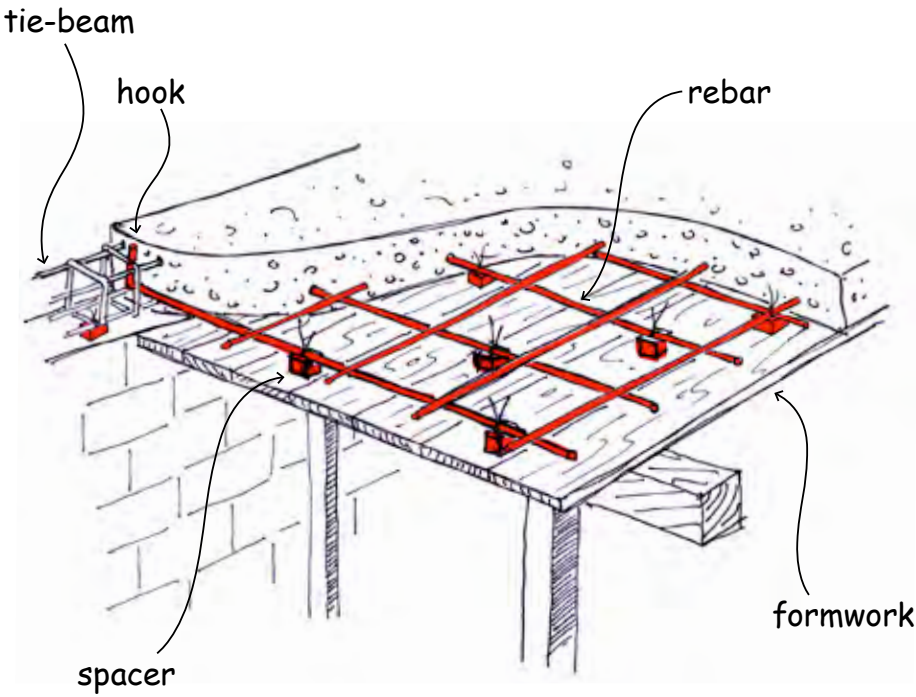
Hollow block slab: pouring concrete

Water the formwork before pouring concrete.



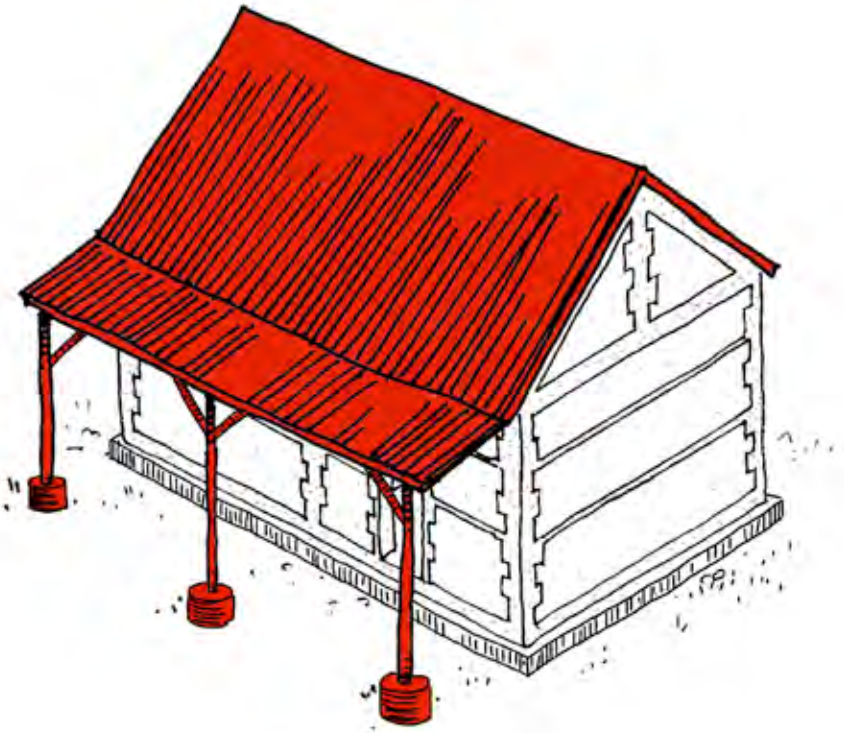
Use a stick (or rebar) and a hammer to compact the concrete and avoid air pockets.

Full concrete slab



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

LIGHT ROOF

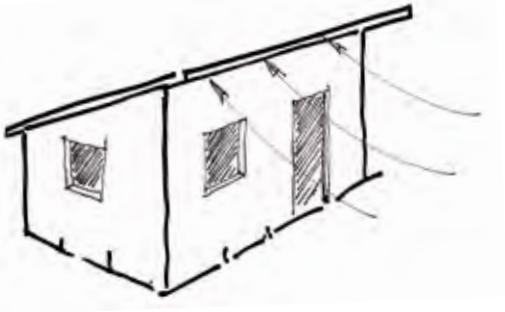


Roof shape

Good
YES

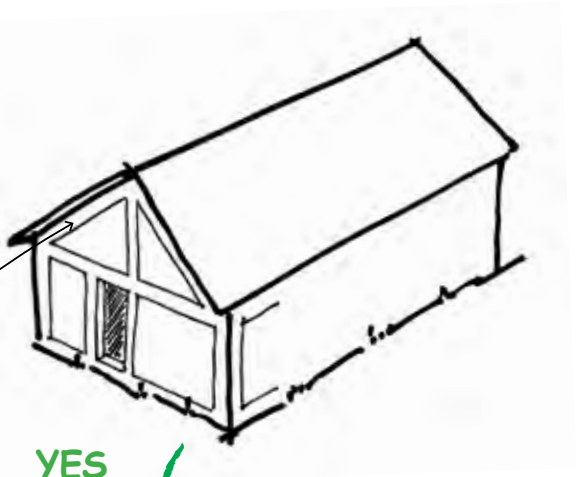
Better
YES

Better
YES



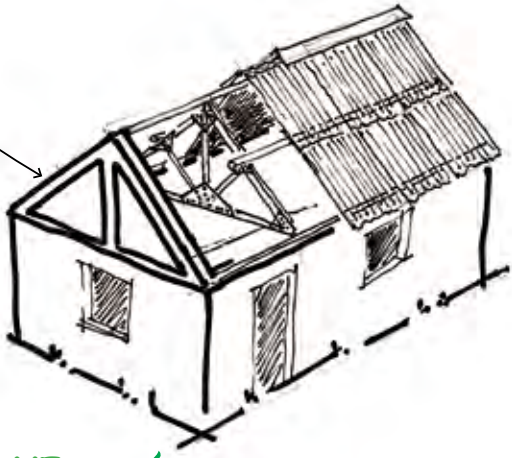
Not so good
AVOID

Gable wall



YES

Concrete tie on top of the gable wall.



YES

Roof structure - Trusses

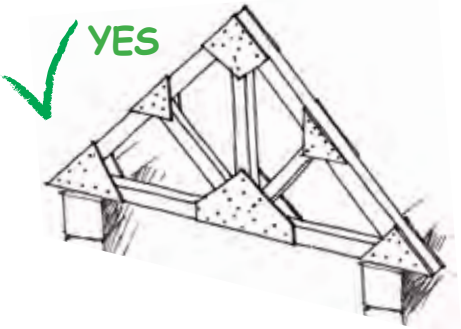
AVOID

Building with planks :
AVOID
(not enough room for nails)

YES

Building with solid timber :
GOOD

YES

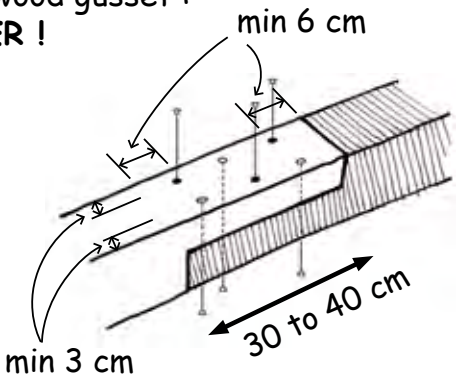


Building with plywood gusset :
BETTER !

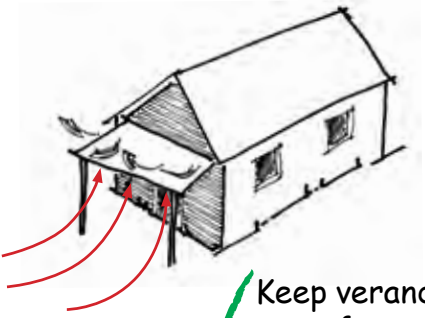
Timber connections :

Put at least
3 nails in each direction !

Nails length should be **twice the thickness** of the timber !

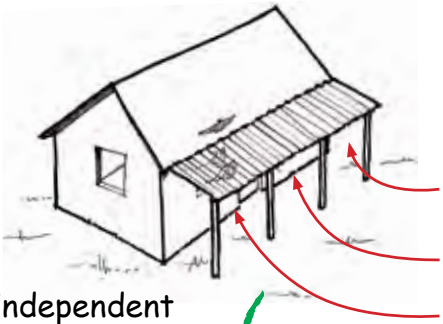


Cyclones



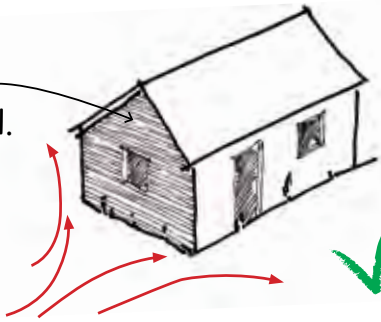
YES

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



YES

Closed gable wall.



YES

NO

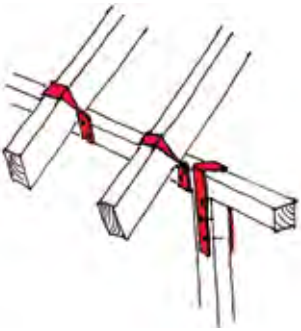
Opened gable wall.

NO

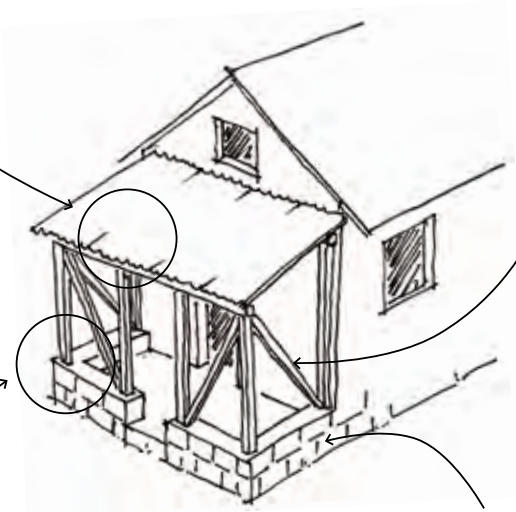
Main roof becoming veranda.

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

Fastening of the veranda framing



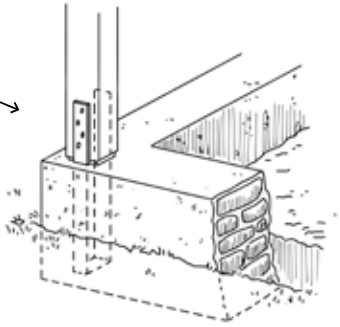
straps



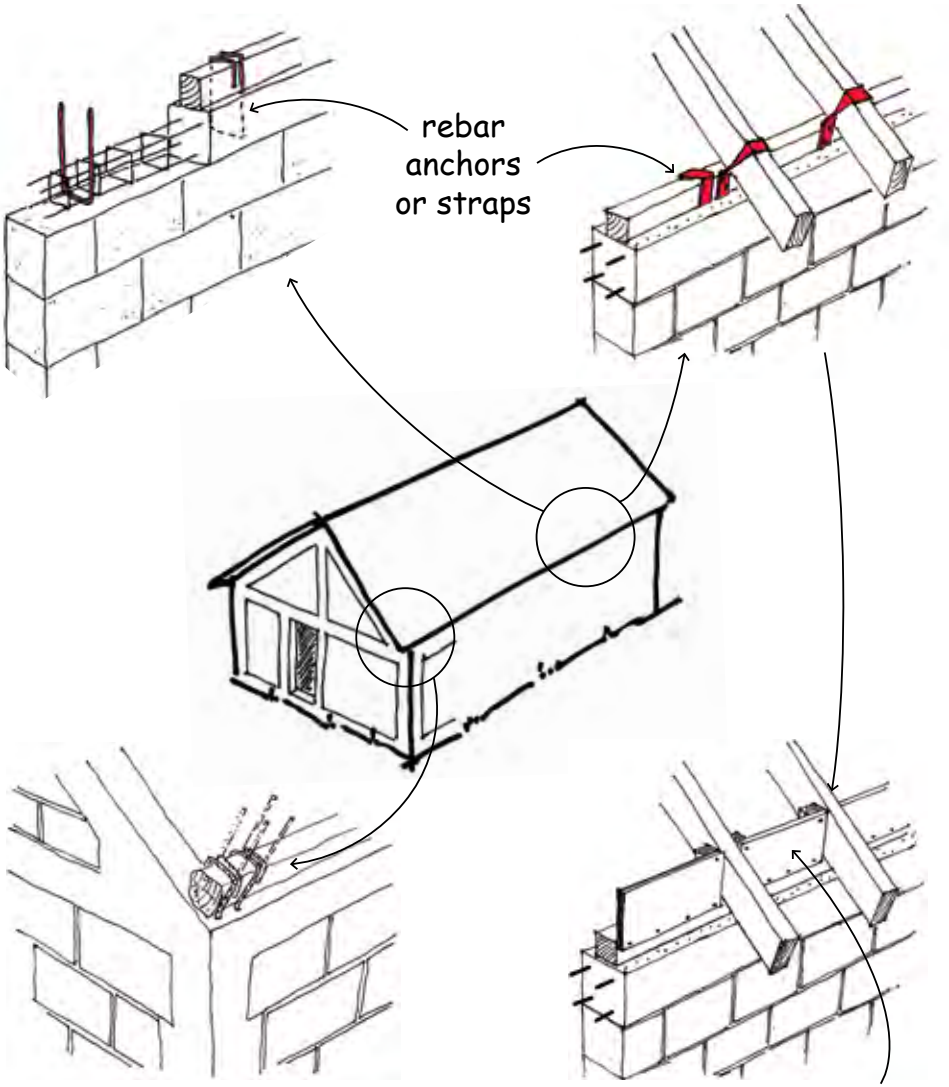
bracing

plinth < 40 cm

solid fastening



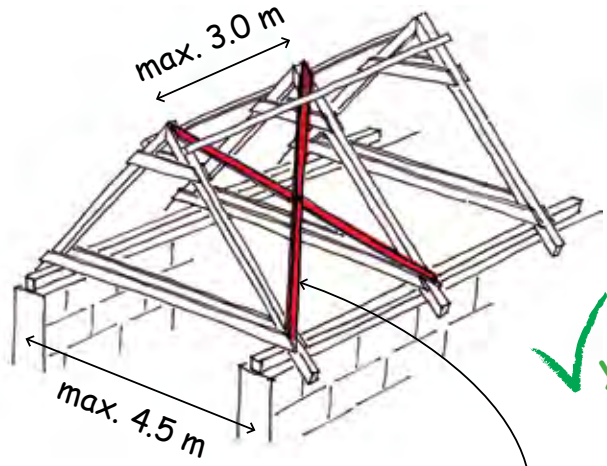
Fastening of the roof structure



Solidly fasten the anchors or straps to the wood framing.

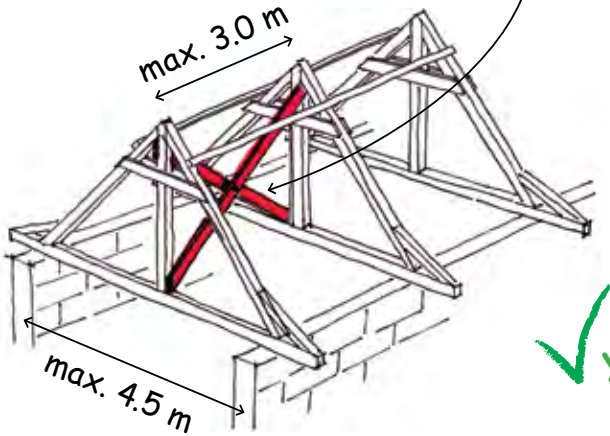
Close the spaces between trusses with a plank or a screen to avoid insects.

Bracing



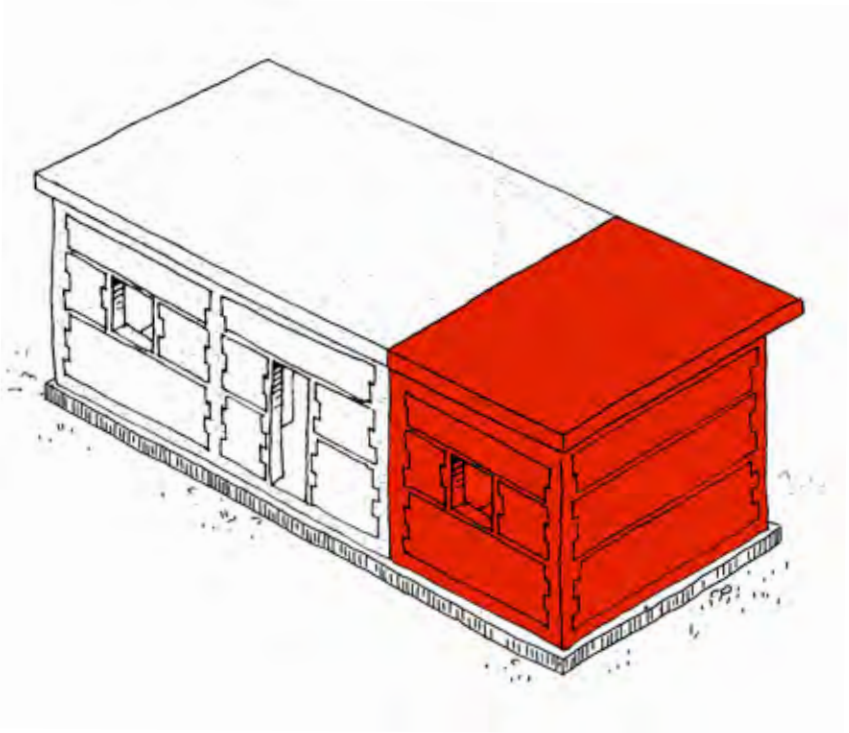
YES

Bracing :
wood planks nailed
to the trusses.



YES

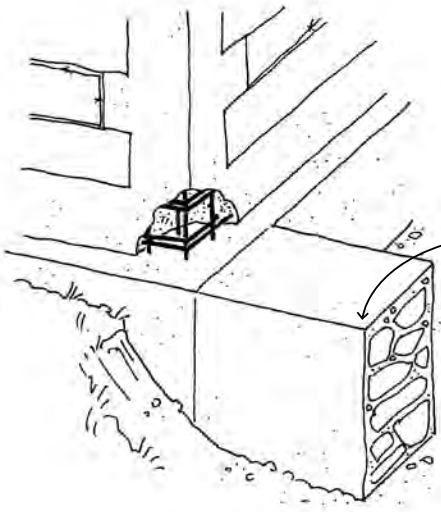
FUTURE EXTENSIONS



14

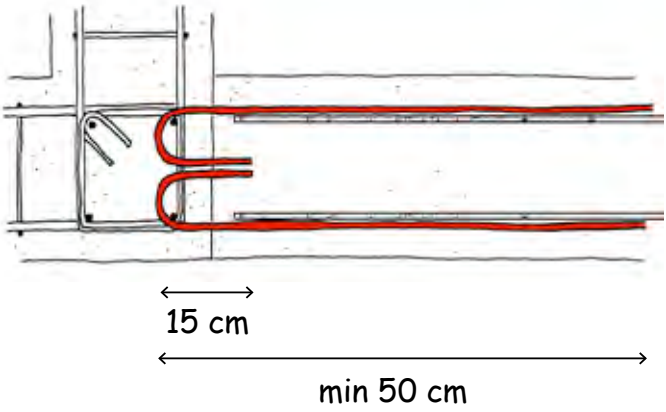
Preparation

Open all corners, all rebar connections.

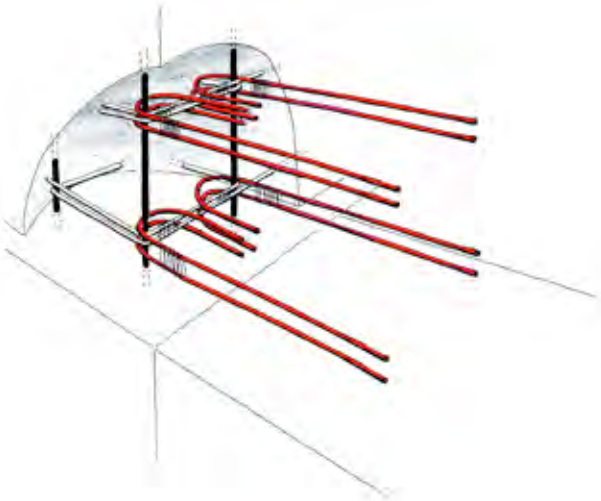


Build a new solid foundation for the new room.

Add anchor bars

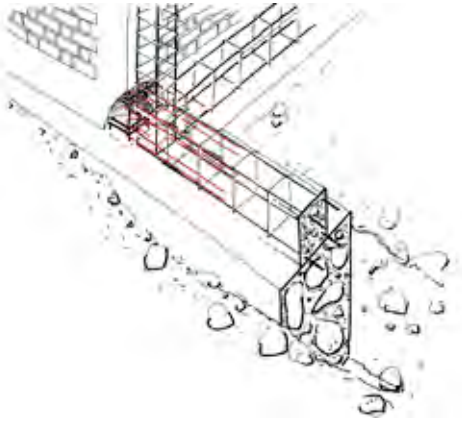


Add hooks : 10 mm rebars.



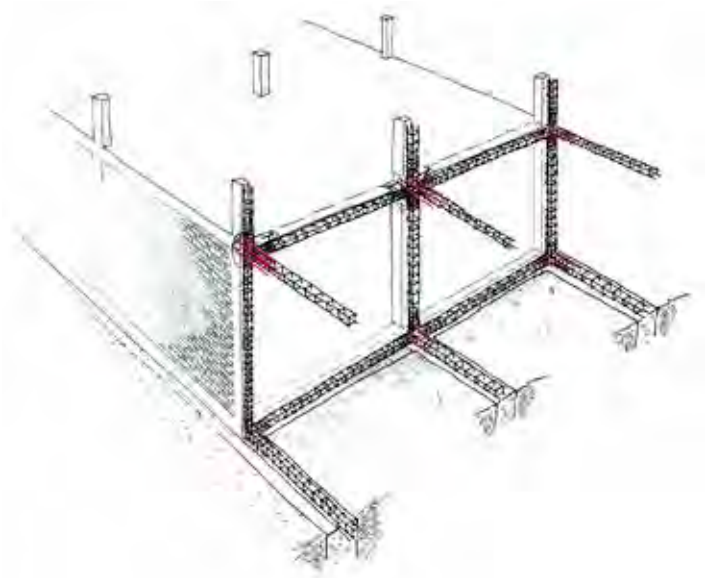
Place the hooks around the vertical rebars :
one on top and one under each stirrup.

Place reinforcement



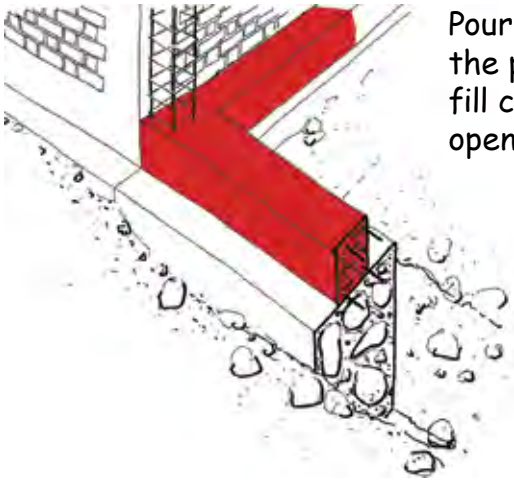
Connect the new plinth beam to the existing one with the hooks.

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



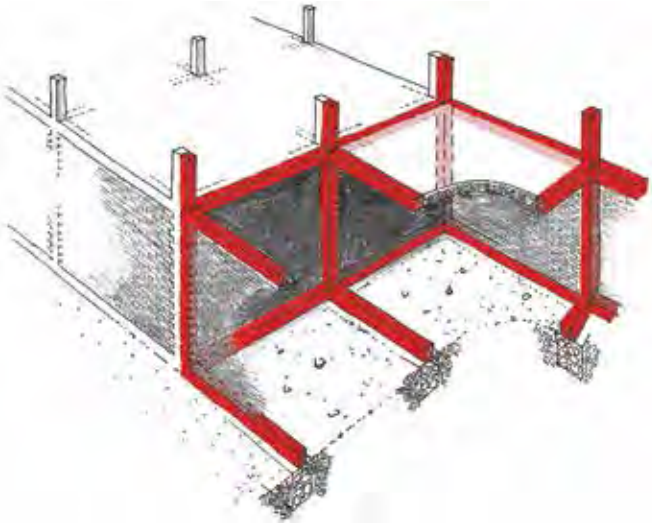
Connect each corner the same way !

Extension of the structure



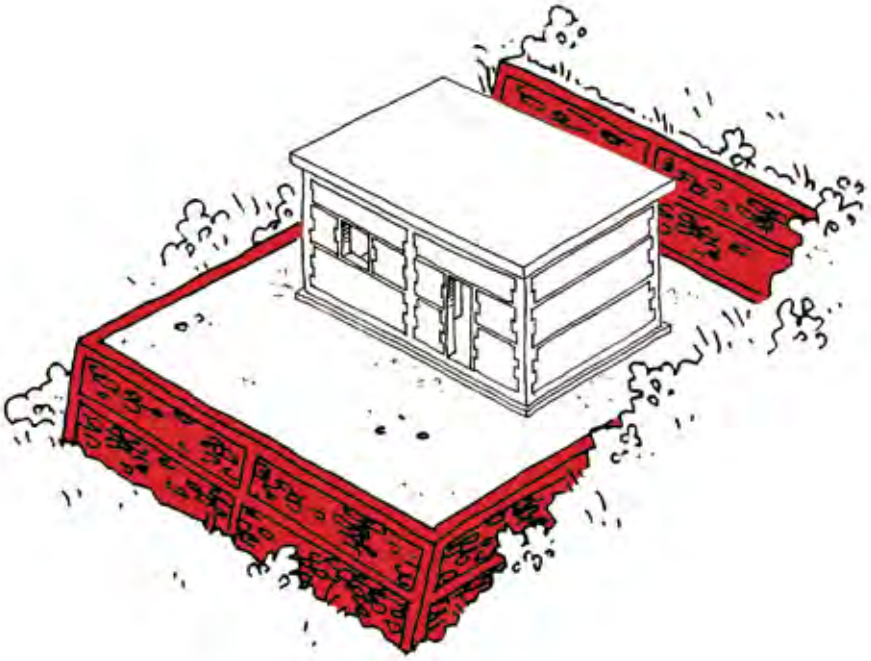
Pour concrete for the plinth beam and fill completely the opened corners.

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



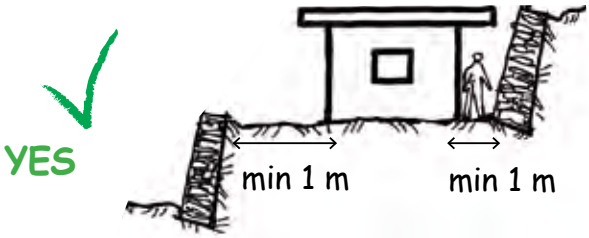
The walls and tie-elements for future extensions should align with the existing structure (existing tie-elements).

RETAINING WALLS



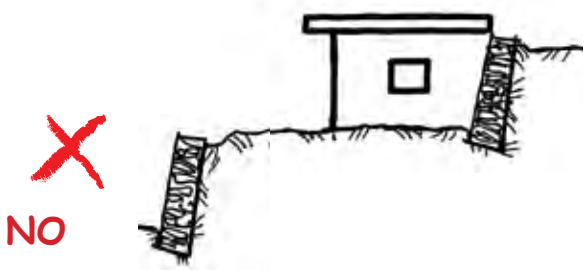
Where to build with retaining walls

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



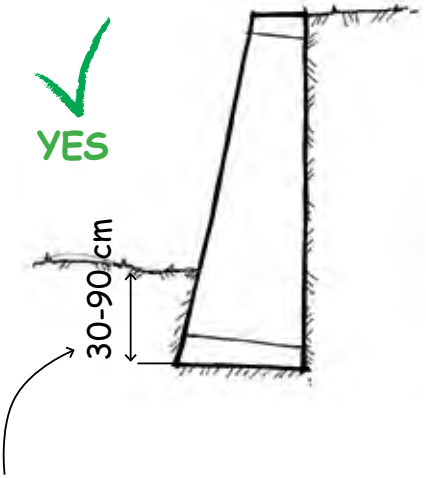
Don't built your house too close to a retaining wall.

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

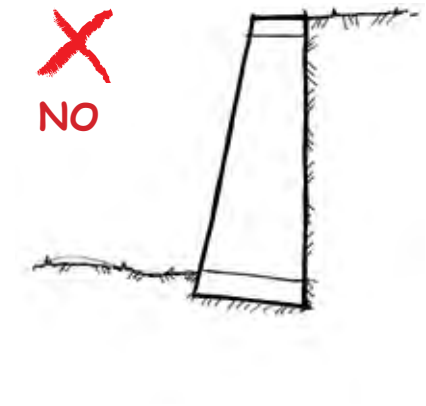


Don't build your house against a retaining wall.

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



Rule 2 - Slope of the wall (5 : 1)

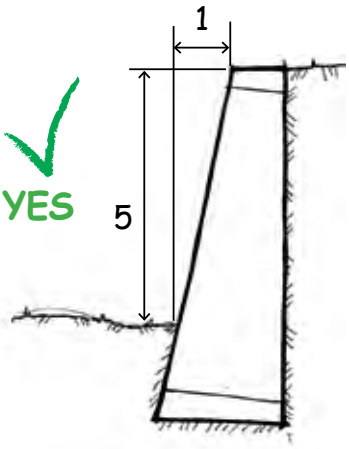
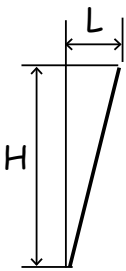
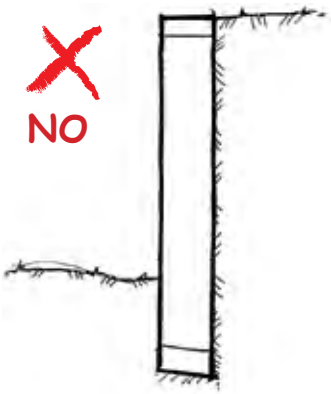


Chart
H : L = 5 : 1

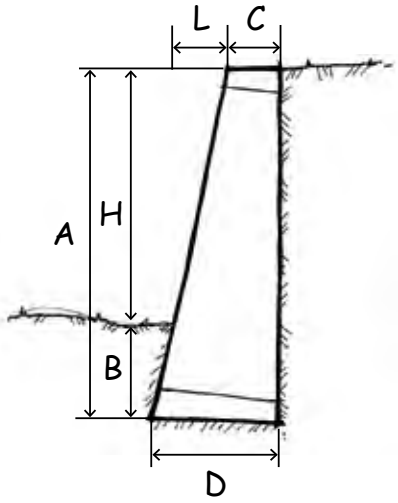


H	L
100	20
125	25
150	30
175	35
200	40
250	50

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 !



Rule 3 - Dimensions of the wall



Height above ground (H) :
H max = 2.50 m !

Top (C) : min 50cm !
50 cm : H ≤ 150 cm
55 cm : H > 150 < 250 cm
60 cm : H ≥ 250 cm

Total height (A) :
A = H + B
(-> B = 30-80 cm)

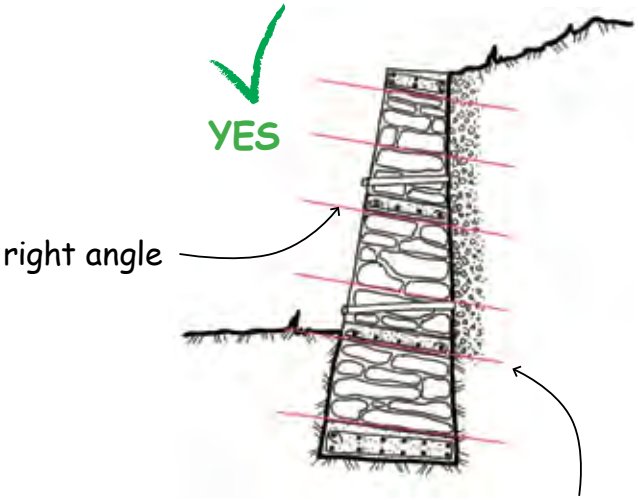
Wall base width (D) calculation :
The base of the wall (D) equals the total height (A) divided by 5, plus the top's width (C) :

$$D = A/5 + C$$

Table

H	C	B	A	D
100	50	30-80	130-180	75-85
125	50	30-80	155-205	80-90
150	50	30-80	180-230	85-95
175	55	30-80	205-255	95-100
200	55	30-80	230-280	100-110
250	60	30-80	280-330	115-125

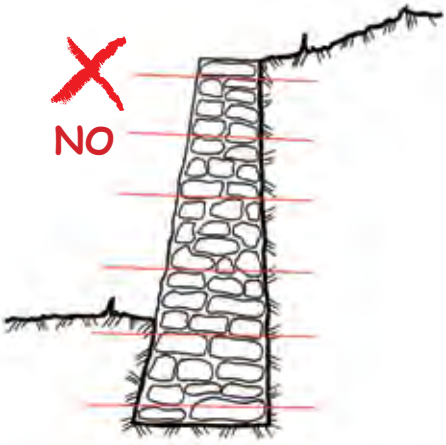
Rule 4 - Placing the stones



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

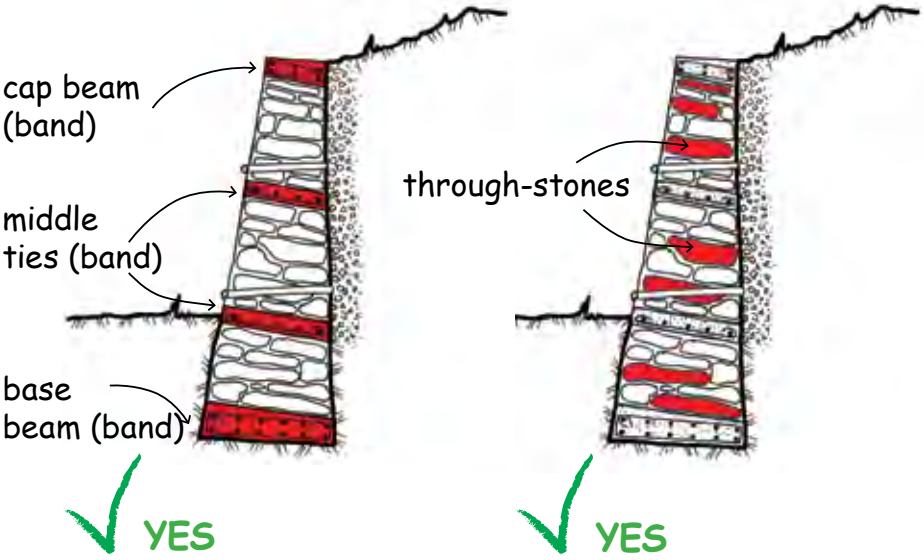
Place the stones at right angles to the wall's external face.

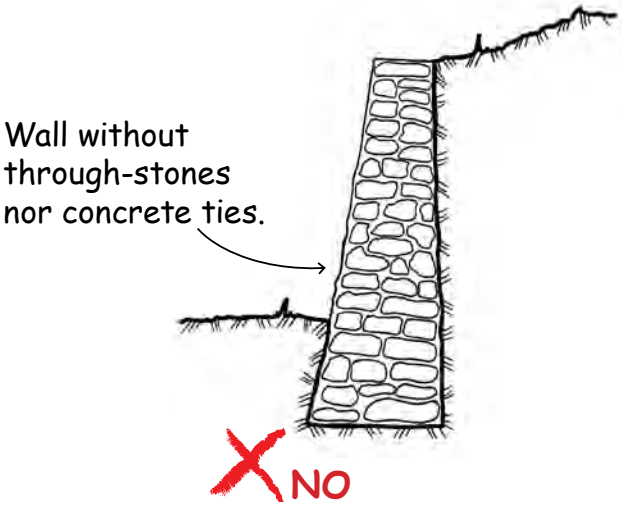
Don't place the stones
in vertical position !



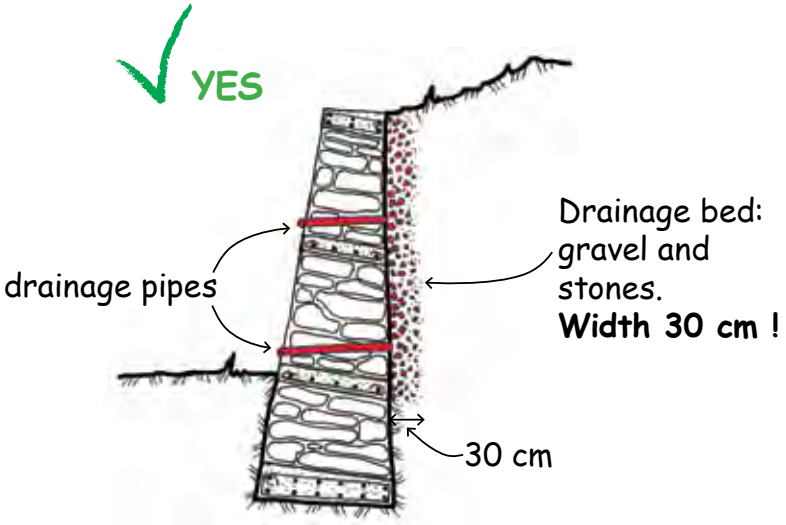
Don't place the stones
at grade !

Rule 5 - Through-stones (or bands)

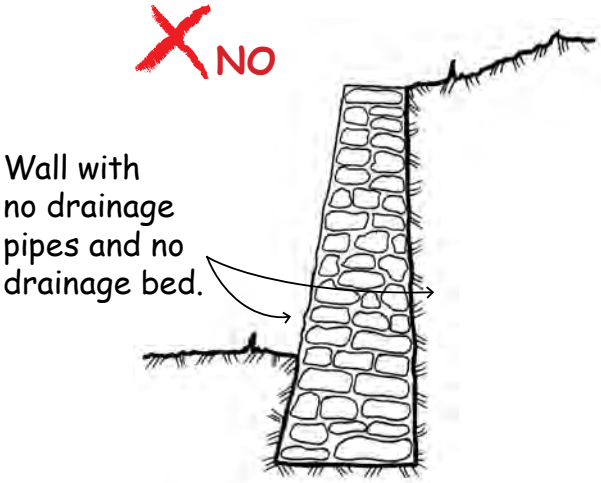




Rule 6 - Drainage

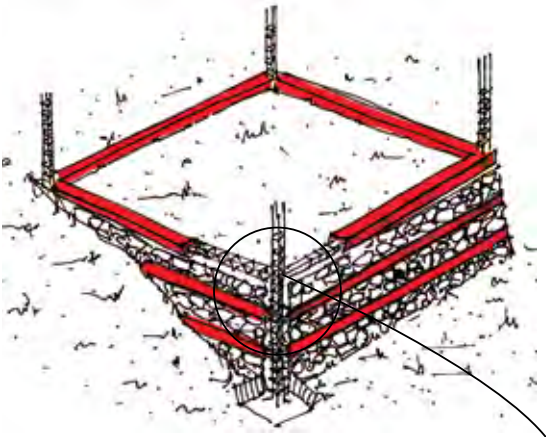


Place a drainage pipe every 1.50 m !
(vertically and horizontally)



Retaining wall - Confining elements

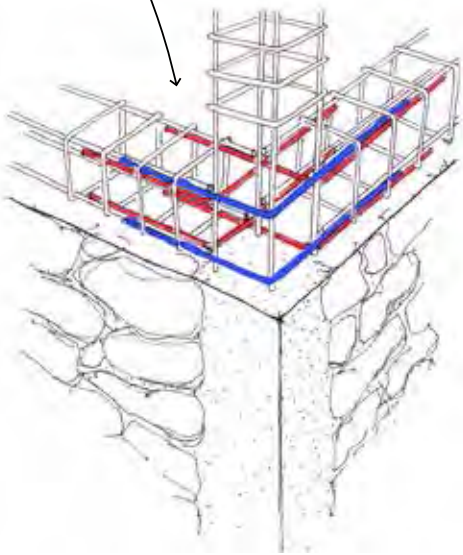
These recommendations are for building a house on retaining walls: **only if there is no other solution !**

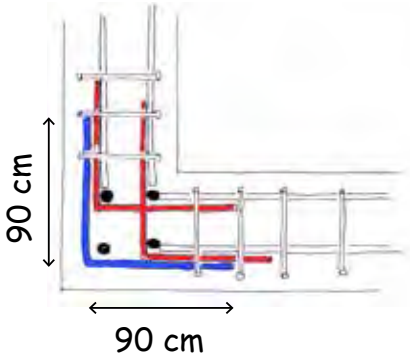


Tie-columns
Every 3 - 4.50 m

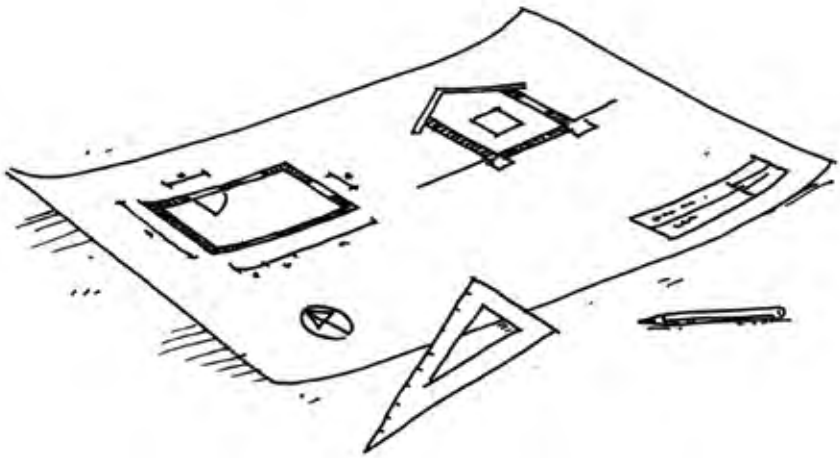
Tie-beams
Must go all around the foundation !
Every 1 m height
Add one at the top !

If possible : avoid building the house on retaining walls !!!

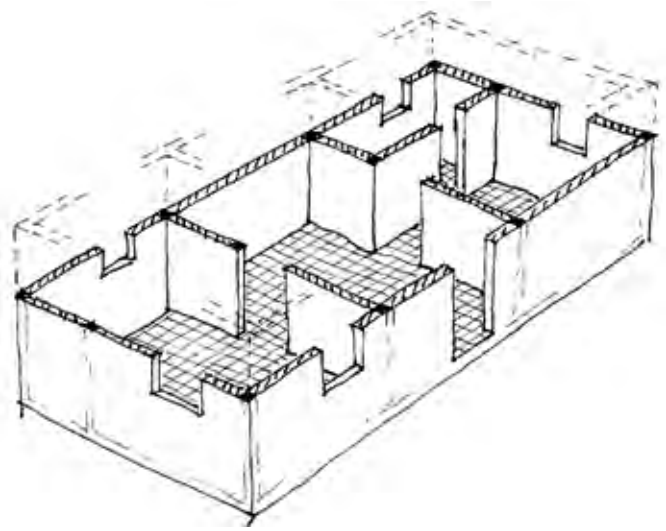




CONSTRUCTION DRAWINGS

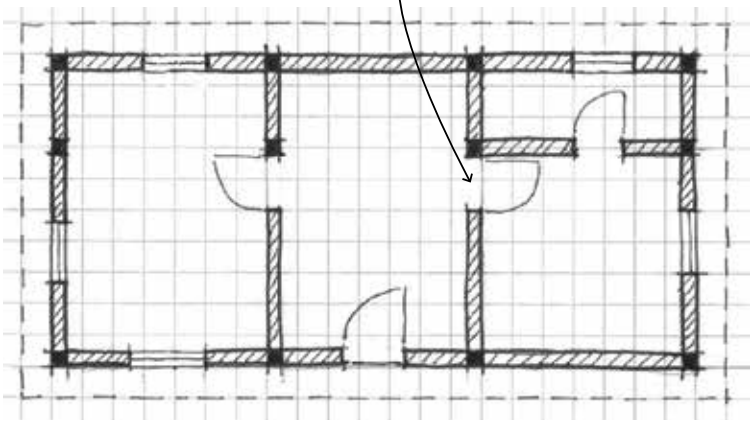


Reading plans



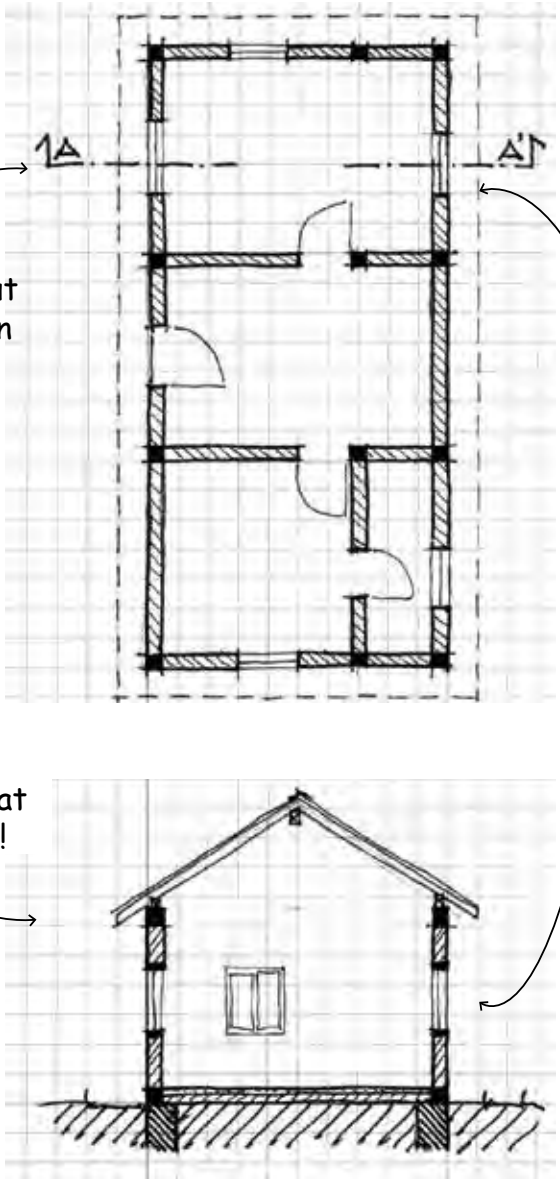
To draw a plan, cut the house at the window height.

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



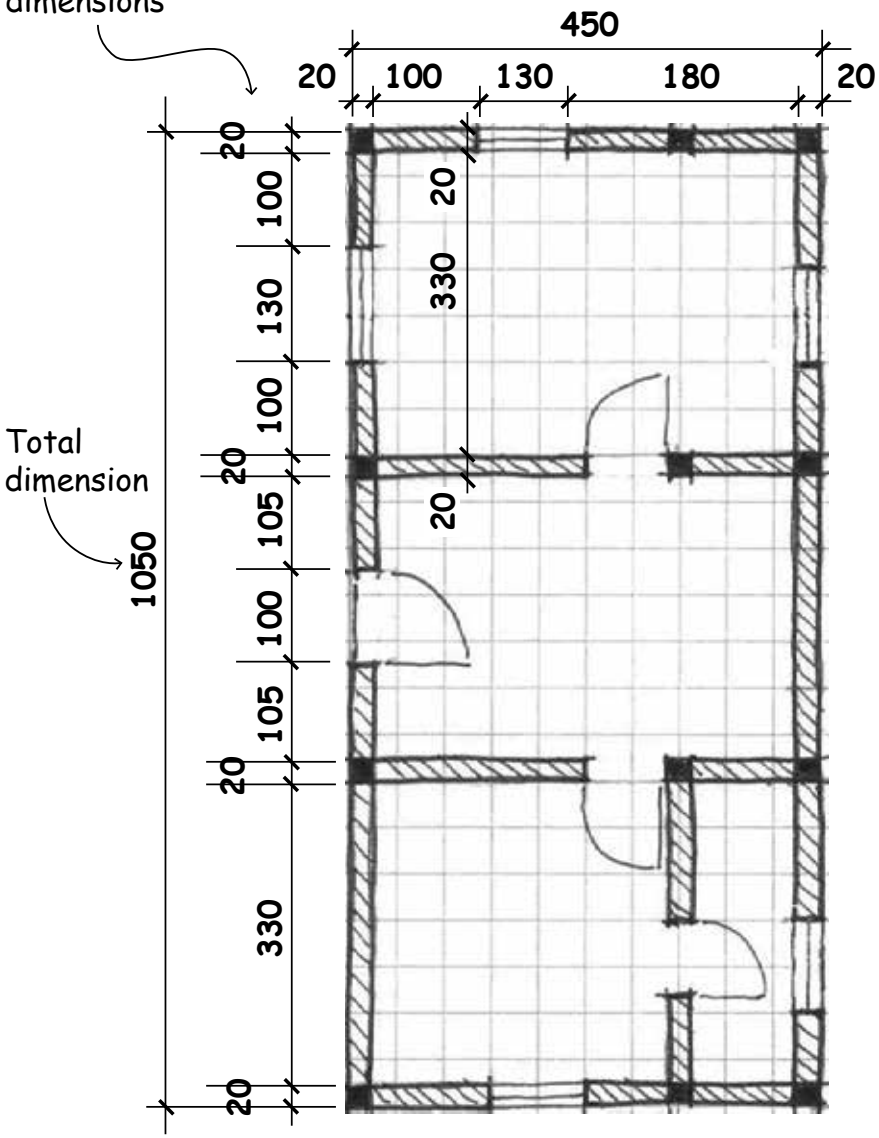
House plan (seen from the top).

Reading sections

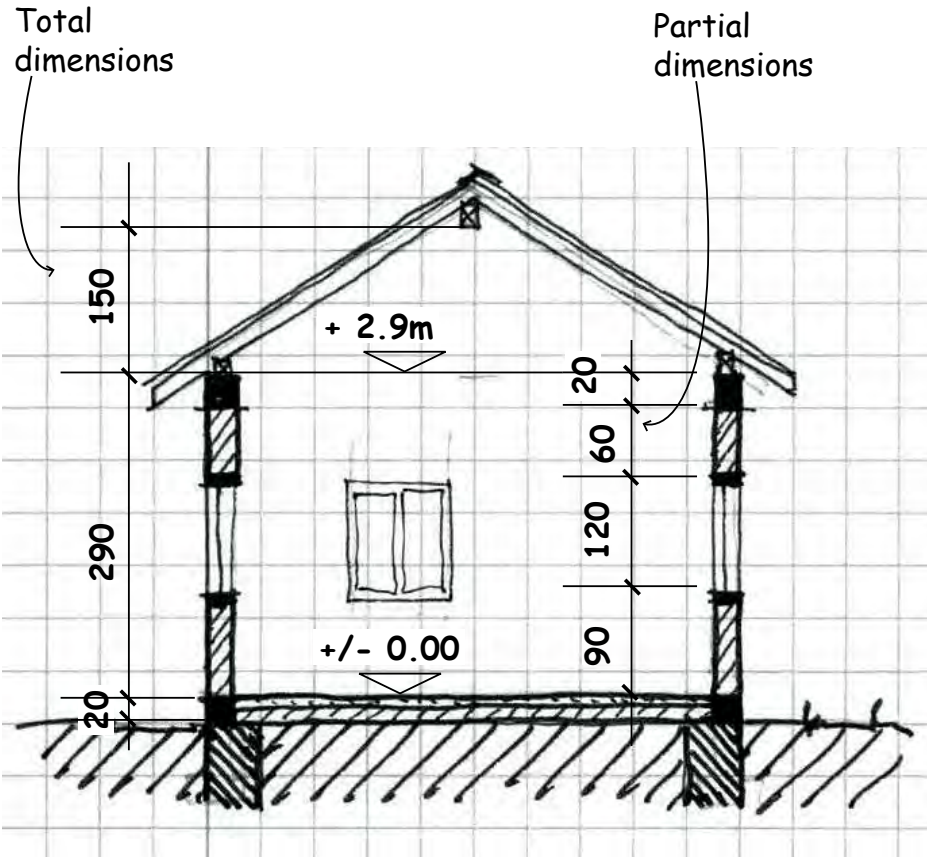


Plan dimensions

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



Section dimensions



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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.

Revised version, August 2015