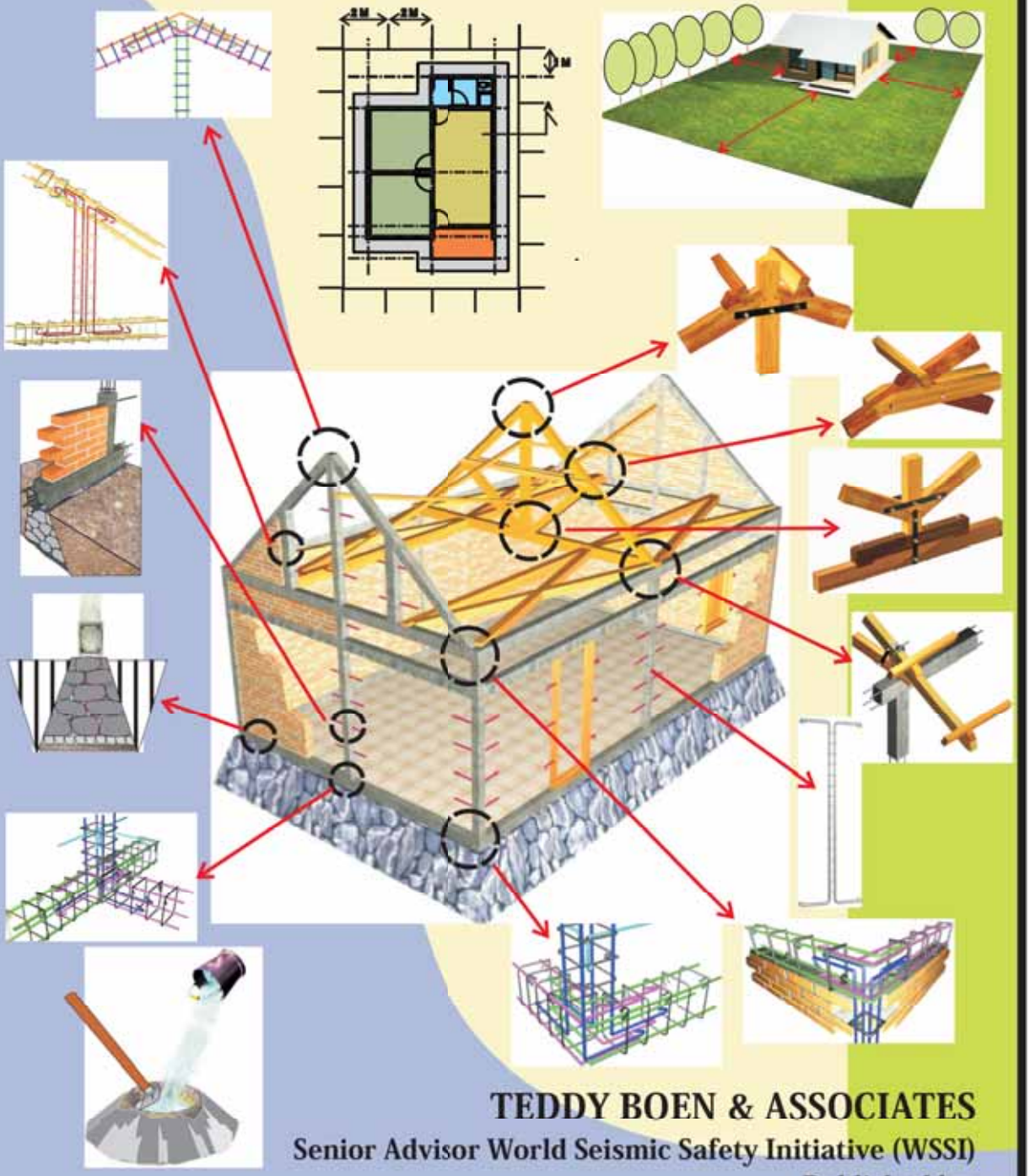
CONSTRUCTING SEISMIC RESISTANT MASONRY HOUSES



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PREFACE

Throughout the centuries, earthquakes have taken a high toll of human lives and caused property losses. Earthquakes do not kill people but the collapse of man made buildings does.

Until today, human beings cannot prevent earthquakes, however, human beings can try to reduce the impact by designing and constructing earthquake resistant buildings. Almost all of Indonesia is earthquake pone.

Currently people all over Indonesia build half brick masonry or concrete block houses. Masonry houses have become a new culture. Many of those masonry houses are built without confinement in the form of reinforced concrete beams and columns and in almost all past earthquakes, masonry houses without confinement generally were heavily damaged or collapsed. Half brick thick masonry wall houses without confinement is not recommended for earthquake prone areas.

Houses recommended to be built are half brick thick masonry wall with confinement in the form of foundation beam, practical columns and ring beam. Past earthquakes showed that such type of houses are earthquake resistant provided that they are built properly.

This guideline tries to explain in a simple way the principles of constructing half brick thick confined masonry houses.

This guideline contains the basic and elementary principles concerning how to lay bricks, how to prepare concrete mix, how to bend reinforcing bars, detailing of joints and other basic things already forgotten by local artisans, construction workers and by most engineers all over Indonesia.

The methods and details recommended in this guideline are basic and are minimum requirements for constructing earthquake resistant masonry houses.

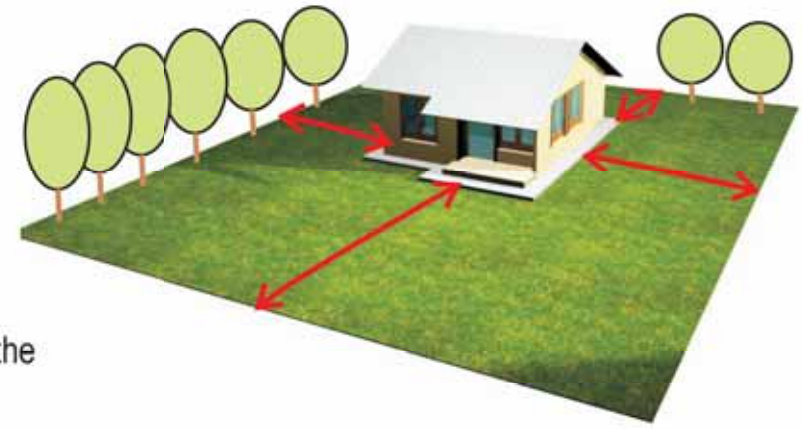
Materials for this guideline are taken from ref 13, 15, 17, 19, 20, 22, 23, 24, 28, 30 and 35.

It is hoped that this guideline is useful for the common people in earthquake prone areas and for stakeholders involved in reducing the impact of future earthquakes.

Jakarta, April 2005

Teddy Boen & Associates

1. GENERAL REQUIREMENTS AND LAYOUT OF HOUSES



Items to be observed:

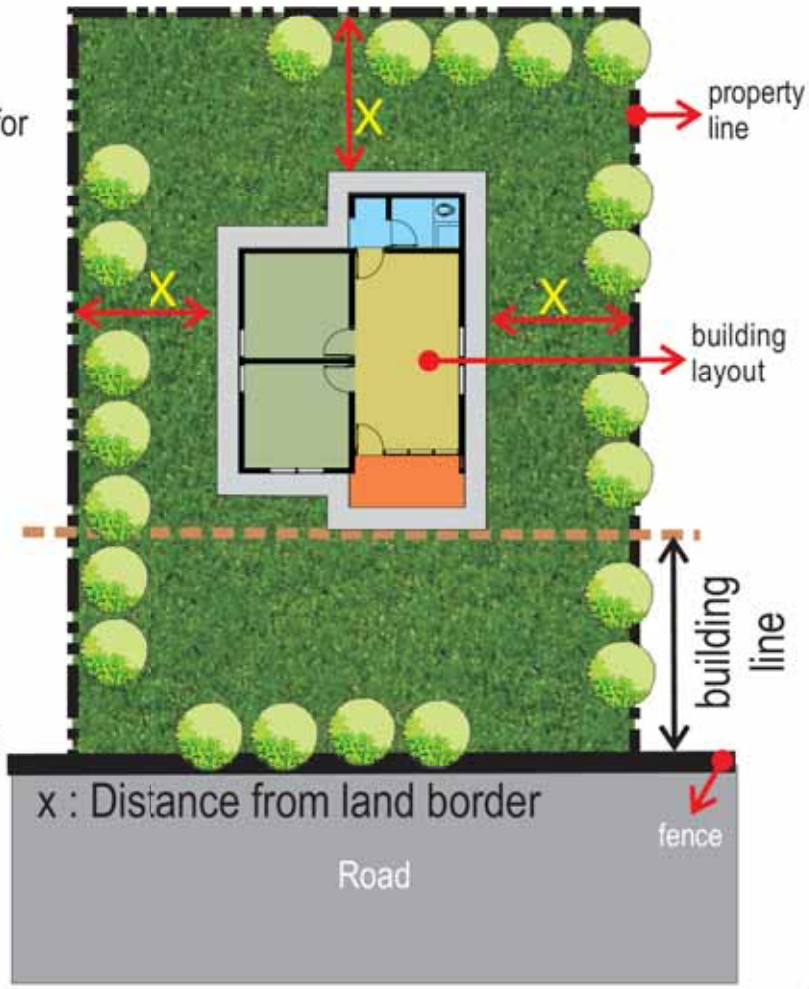
1. Distance of house from the property line

   Ratio of houses / property area

   Height of house shall be proportional

   Form should be suitable for local climate

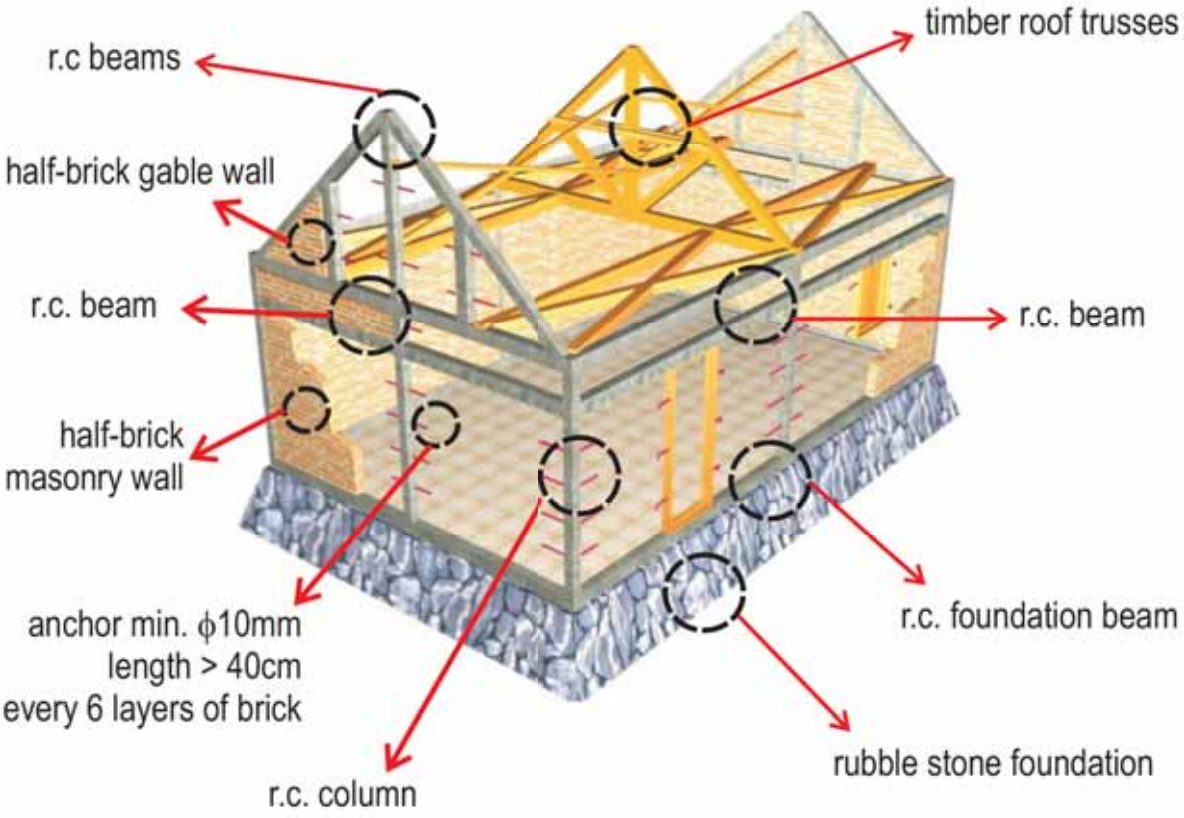
2. Building line
3. Layout:
   - House
   - Septic tank
   - Leaching
   - Drainage
   - Water pipe
   - Well
4. Ground level shall be the 100 year flood level



2. CLEAN WATER AND SEWERAGE

3. PRINCIPLES OF SEISMIC RESISTANT HOUSE CONSTRUCTION

1. Good **quality materials**.
2. Good **workmanship**.
3. All building components (foundation, columns, beams, walls, roof trusses, roofing) **MUST** be **TIED** to each other, so that when **SHAKEN BY EARTHQUAKES**, the building will act as **ONE INTEGRAL UNIT**.



4. BUILDING MATERIALS

SAND:

- from rivers / quarries
- clean from mud
- clean from organic materials

SAND

GRAVEL:

- from rivers / quarries
- clean from mud
- clean from organic materials
- ϕ 1-2cm

GRAVEL

CEMENT:

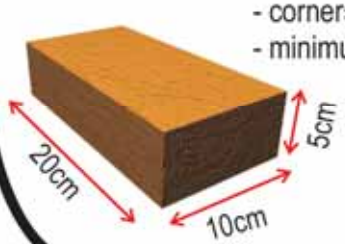
- Portland Cement
- not hardened
- dry
- in 40/50 kg bags
- not mixed with other materials
- uniform color

WATER :

- clean
- clear and does not smell
- no oil, acid, alkali, salt, organic materials that can affect the r.c. bars
- potable

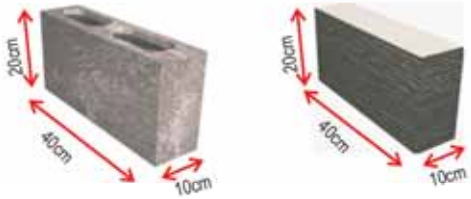
BRICKS:

- completely burnt
- flat, not warping
- does not break easily
- uniform size
- corners not damaged
- minimum size 20x10x5cm



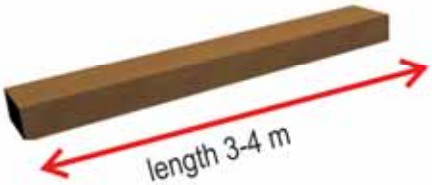
CONCRETE BLOCK:

- best from concrete mix
- corners not damaged
- no cracks



TIMBER:

- dry
- straight
- no cracks
- no notch
- treated against termite



RUBBLE STONE:

- size as uniform as possible
- rough surface, not smooth

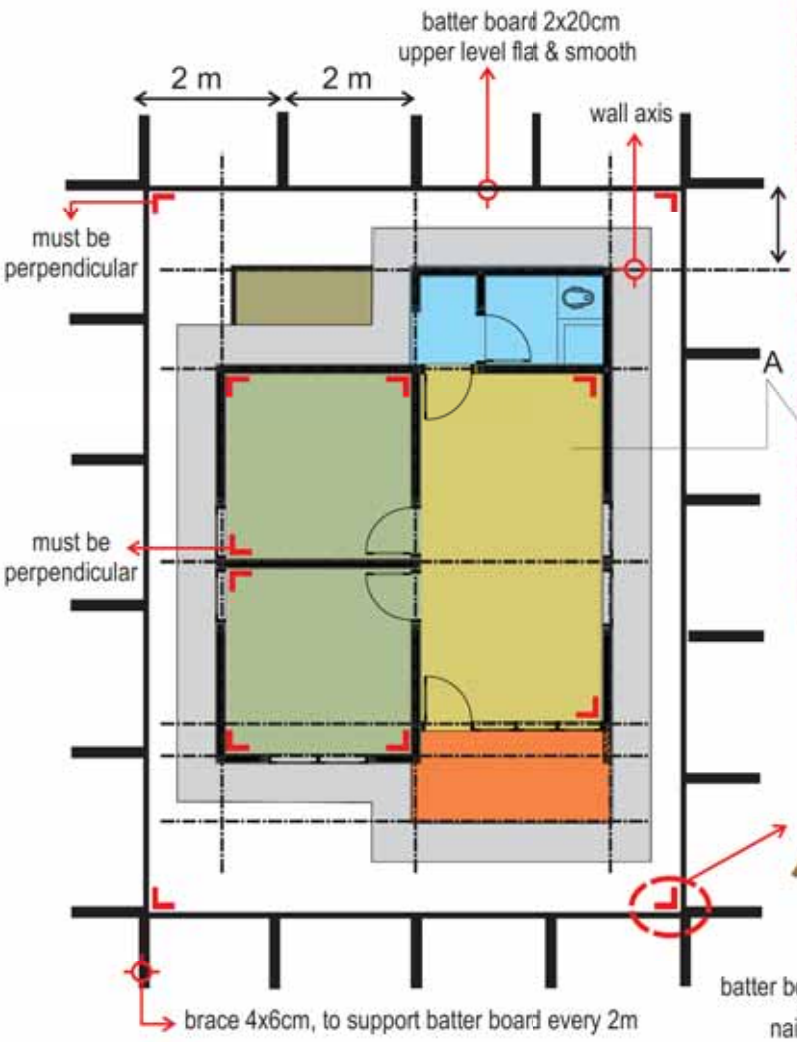
R.C. BARS:

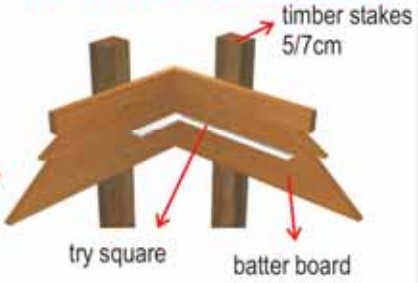
- uniform size
- conform with standard bars
- not rusted
- straight
- diameter in accordance with drawings

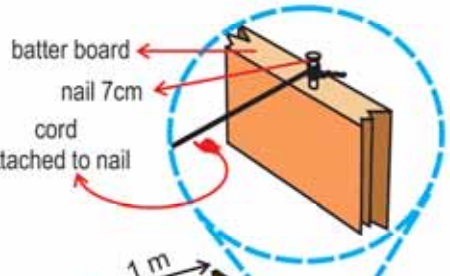
5. ERECTION OF BATTER BOARDS

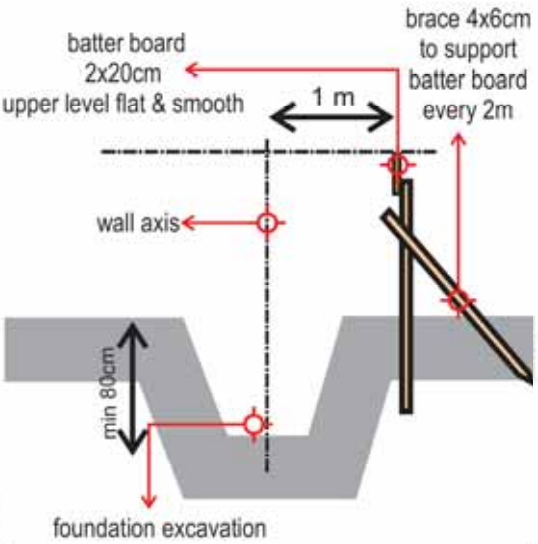
ERECTION OF BATTER BOARD:

1. Batter board is used as benchmark for the levels of the house.
2. Batter boards shall be erected prior to construction.
3. Batter boards 2x20cm are supported by timber stakes 5/7cm and placed 2m apart.
4. Upper part of batter board is flat and smooth.
5. Upper part of batter board must be horizontal and this leveling is done using flexible water tube.
6. Corners must be perpendicular.

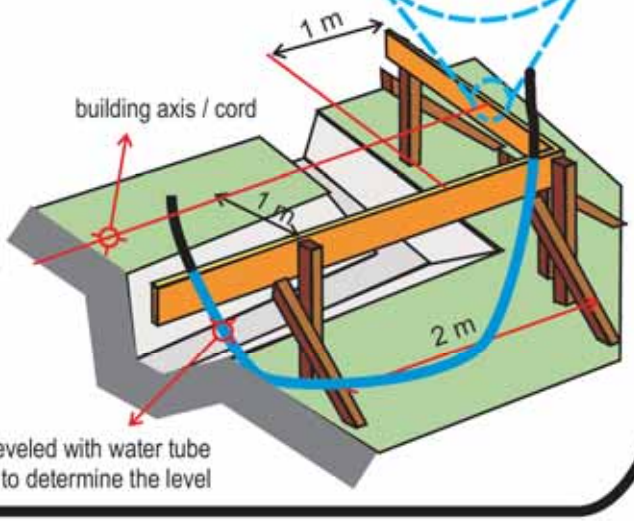




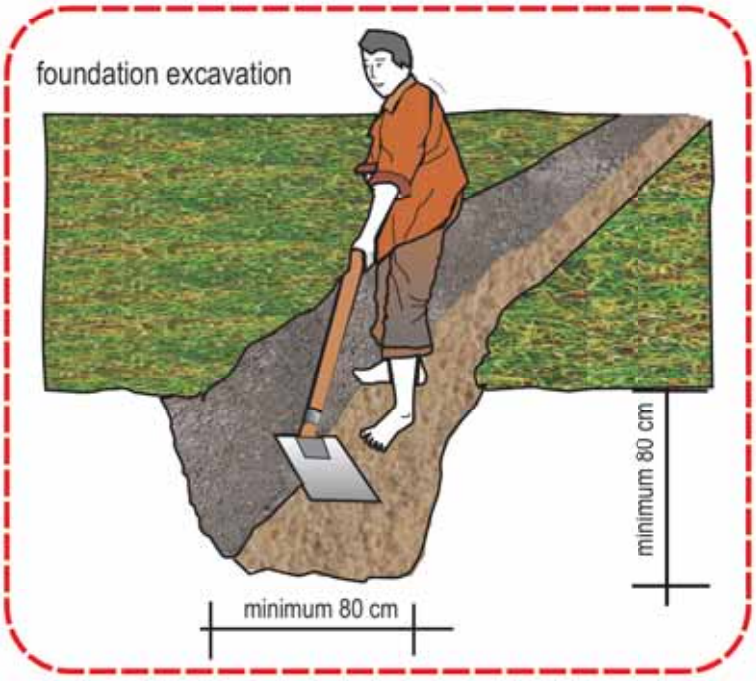


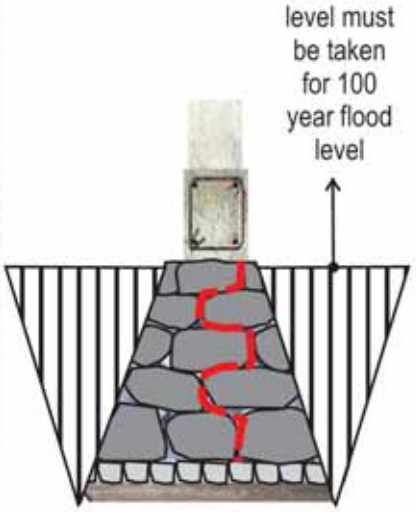


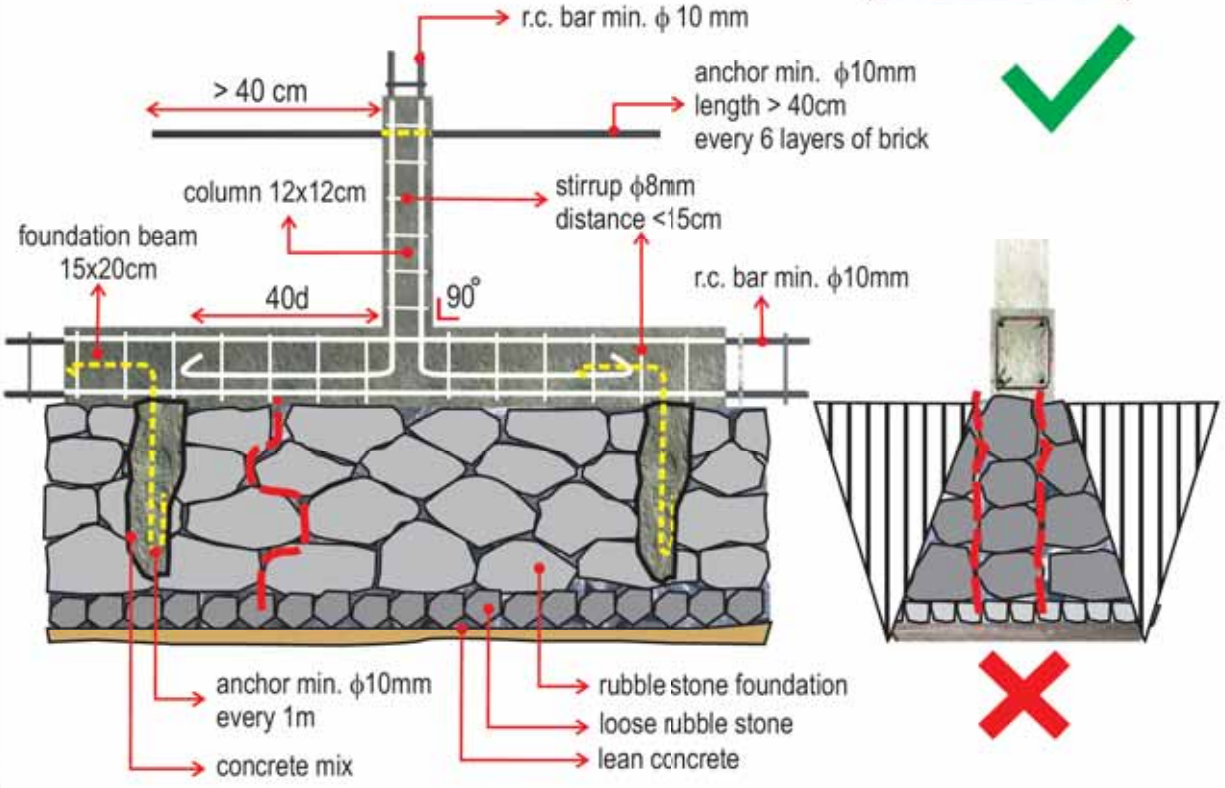
Detail A



6. RUBBLE (RIVER / QUARRY) STONE FOUNDATION

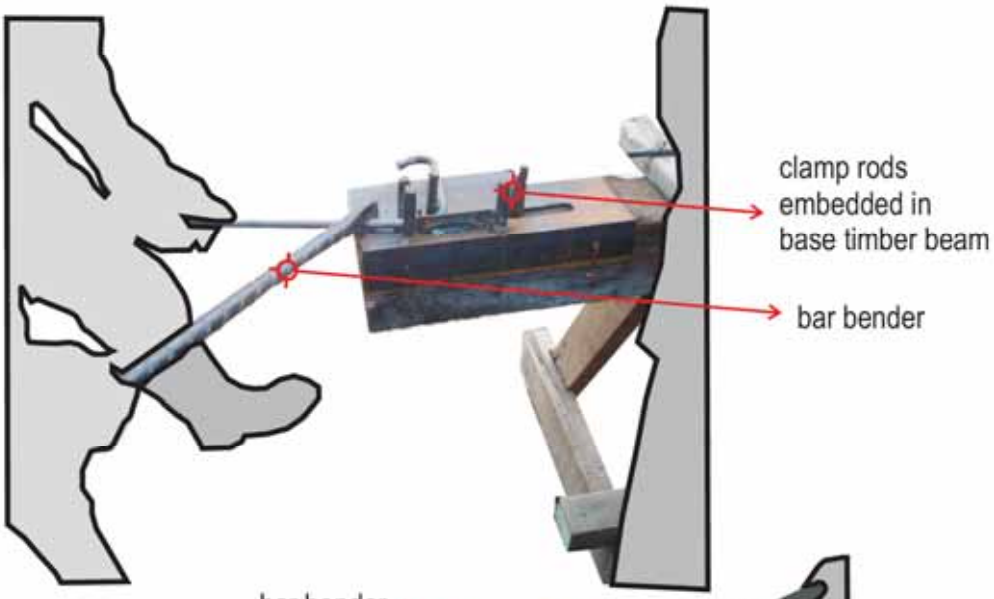


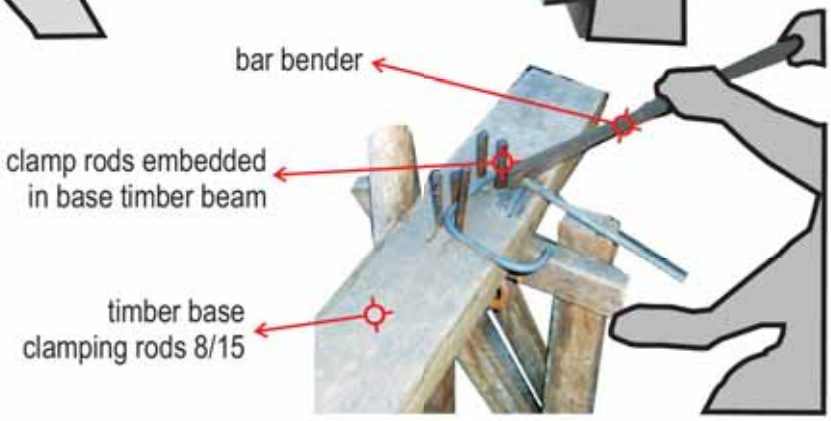


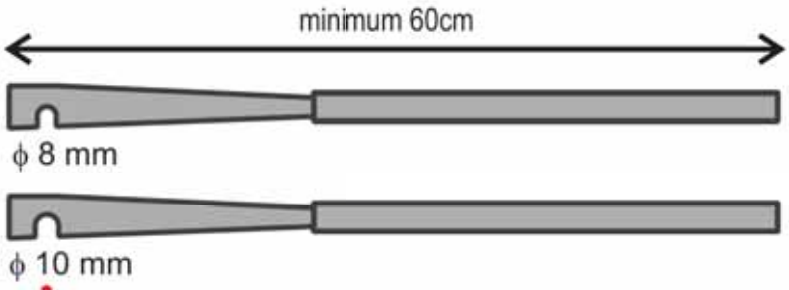


Note:
Loose rubble stone and sand is needed if the bottom is muddy.

7. REINFORCING BARS BENDING TOOL







the groove must be in accordance with the bar diameter to be bent

Notes:

- Prior to cutting reinforcing bars, the lengths of columns, beams reinforcing bars & stirrups and length of hooks must be determined from construction drawings.
- After the reinforcing bars are cut based on the necessary length, the reinforcing bars are bent with appropriate bar bending tool and shaped into columns, beams, stirrups.
- Bending bars after the reinforcing bars are assembled is not correct.

8. LENGTH AND BENDING OF REINFORCING BARS

8. A. BEAM REINFORCING BARS

1. OUTER BEAM REINFORCING BAR

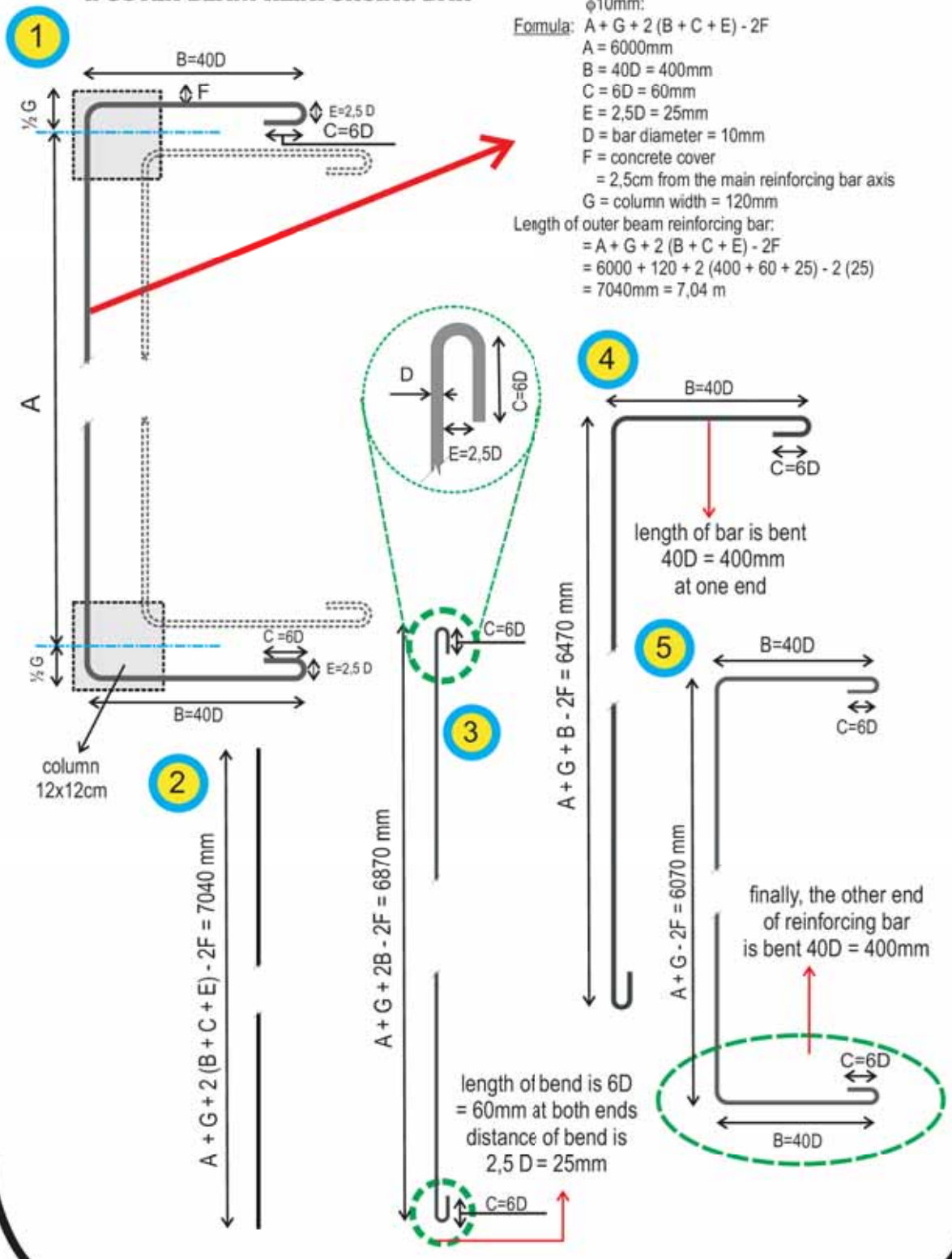
Prior to cutting, reinforcing bar length to be measured from construction drawings, including the bends & hooks.

Example: beam with 6m length from axis to axis, using bar ϕ10mm:

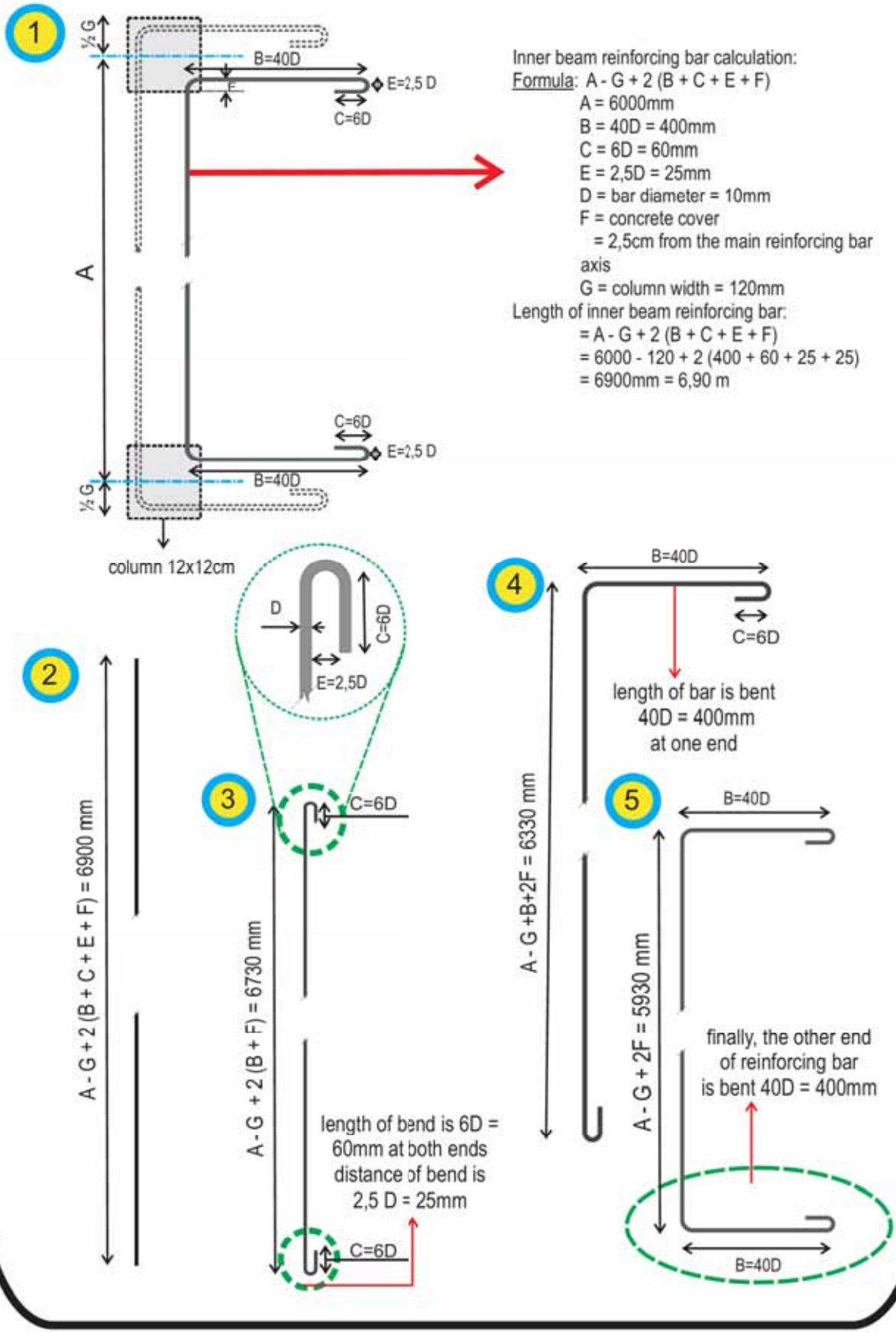
Formula: A + G + 2 (B + C + E) - 2F

A = 6000mm
B = 40D = 400mm
C = 6D = 60mm
E = 2,5D = 25mm
D = bar diameter = 10mm
F = concrete cover
= 2,5cm from the main reinforcing bar axis
G = column width = 120mm

Length of outer beam reinforcing bar:
= A + G + 2 (B + C + E) - 2F
= 6000 + 120 + 2 (400 + 60 + 25) - 2 (25)
= 7040mm = 7,04 m



2. INNER BEAM REINFORCING BAR



Inner beam reinforcing bar calculation:

Formula: A - G + 2 (B + C + E + F)

A = 6000mm

B = 40D = 400mm

C = 6D = 60mm

E = 2,5D = 25mm

D = bar diameter = 10mm

F = concrete cover
= 2,5cm from the main reinforcing bar axis

G = column width = 120mm

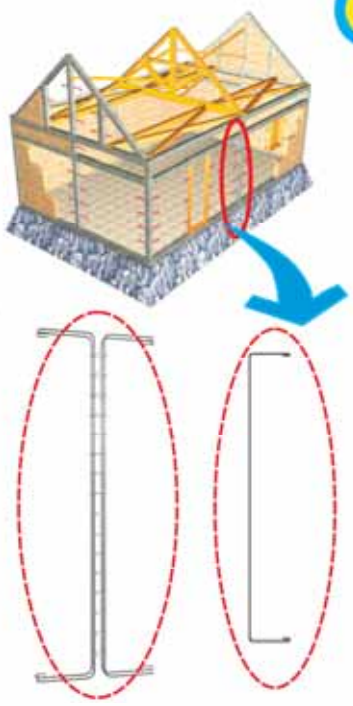
Length of inner beam reinforcing bar:

= A - G + 2 (B + C + E + F)

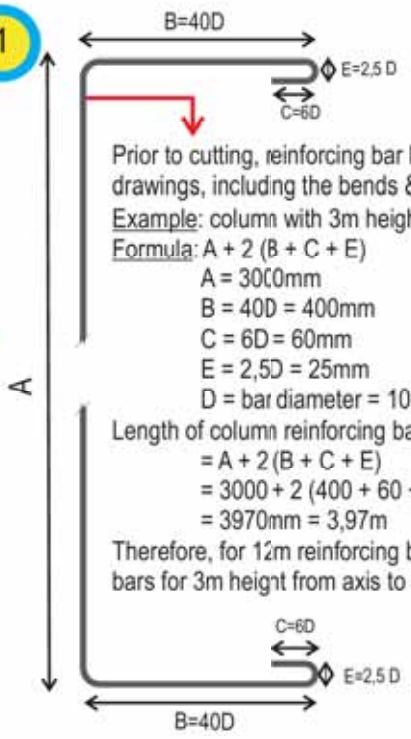
= 6000 - 120 + 2 (400 + 60 + 25 + 25)

= 6900mm = 6,90 m

8. B. COLUMN REINFORCING BARS



1



Prior to cutting, reinforcing bar length to be measured from construction drawings, including the bends & hooks.

Example: column with 3m height from axis to axis, using bar ϕ10mm:

Formula: A + 2 (B + C + E)

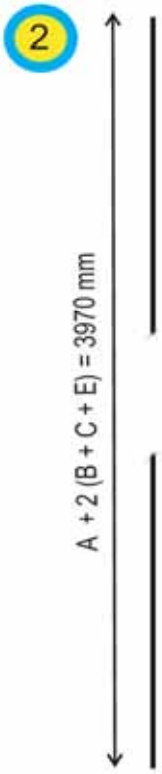
A = 3000mm
B = 40D = 400mm
C = 6D = 60mm
E = 2,5D = 25mm
D = bar diameter = 10mm

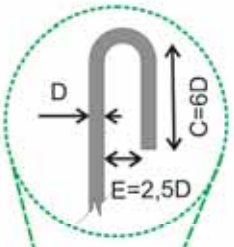
Length of column reinforcing bar:

= A + 2 (B + C + E)
= 3000 + 2 (400 + 60 + 25)
= 3970mm = 3,97m

Therefore, for 12m reinforcing bar, it can be obtained 3 column reinforcing bars for 3m height from axis to axis.

2





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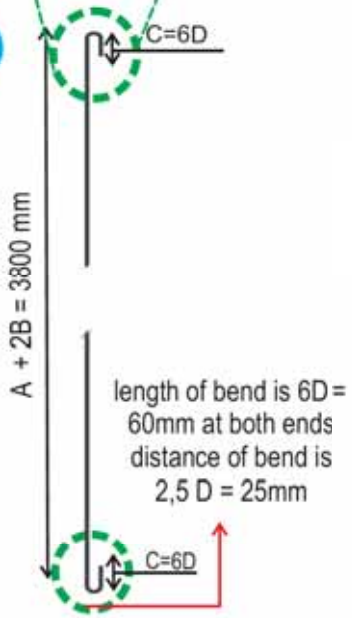

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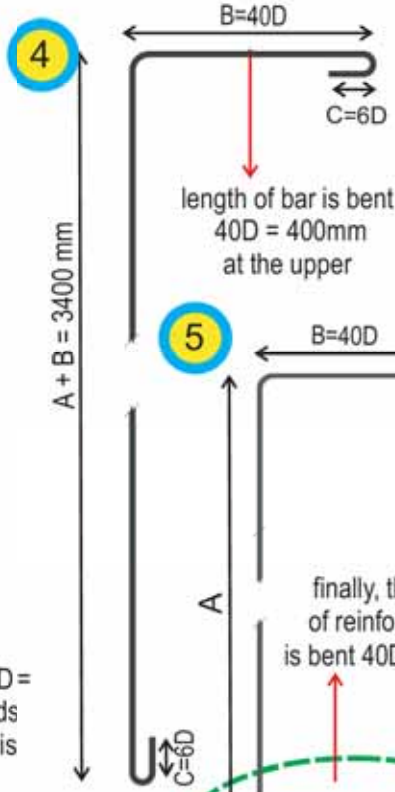

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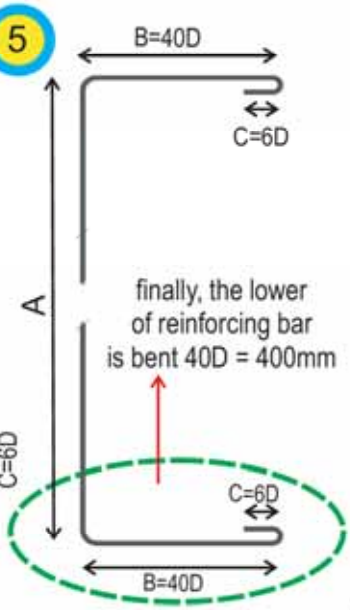
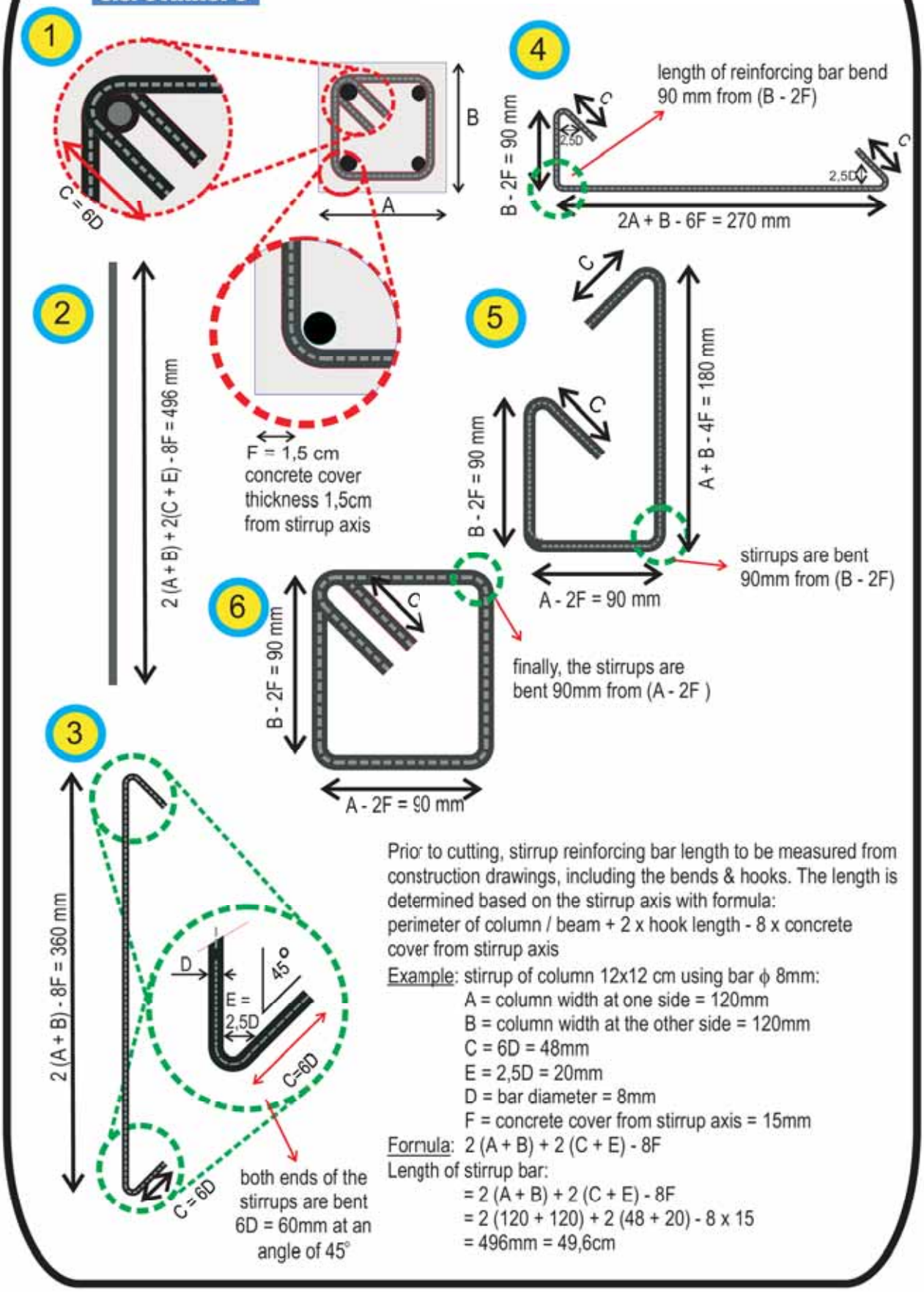


8.C. STIRRUPS



Prior to cutting, stirrup reinforcing bar length to be measured from construction drawings, including the bends & hooks. The length is determined based on the stirrup axis with formula:
perimeter of column / beam + 2 x hook length - 8 x concrete cover from stirrup axis

Example: stirrup of column 12x12 cm using bar ϕ 8mm:

A = column width at one side = 120mm
B = column width at the other side = 120mm
C = 6D = 48mm
E = 2,5D = 20mm
D = bar diameter = 8mm
F = concrete cover from stirrup axis = 15mm

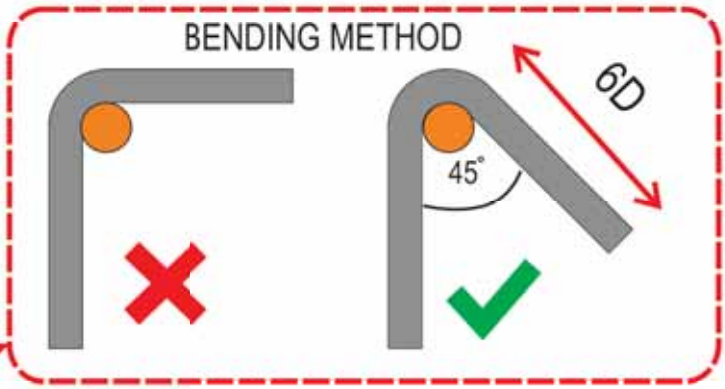
Formula: 2 (A + B) + 2 (C + E) - 8F

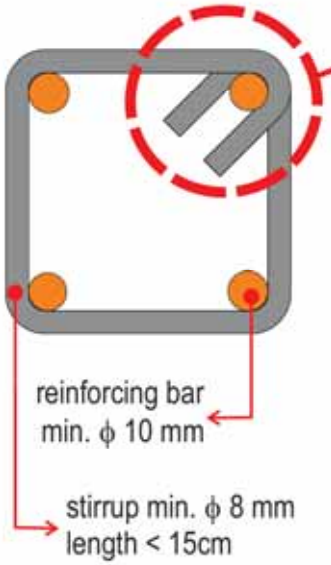
Length of stirrup bar:

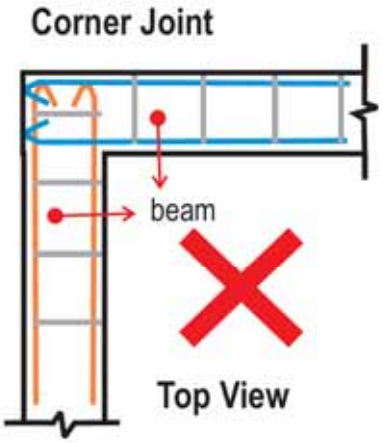
= 2 (A + B) + 2 (C + E) - 8F
= 2 (120 + 120) + 2 (48 + 20) - 8 x 15
= 496mm = 49,6cm

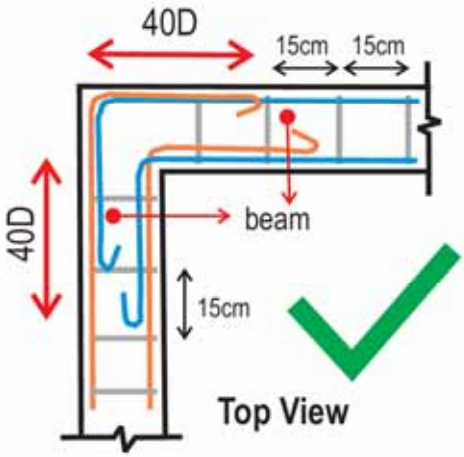
9. SEISMIC RESISTANT DETAILING OF JOINTS

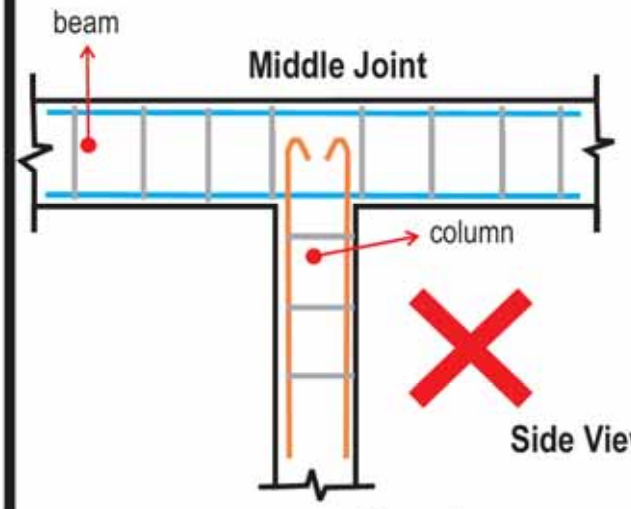
IMPORTANT:
- reinforcing bar diameter
- bending method
- joint detailing

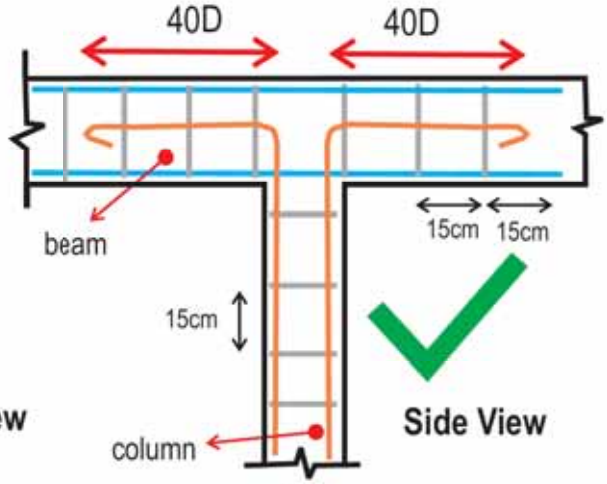




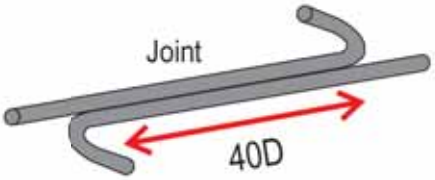






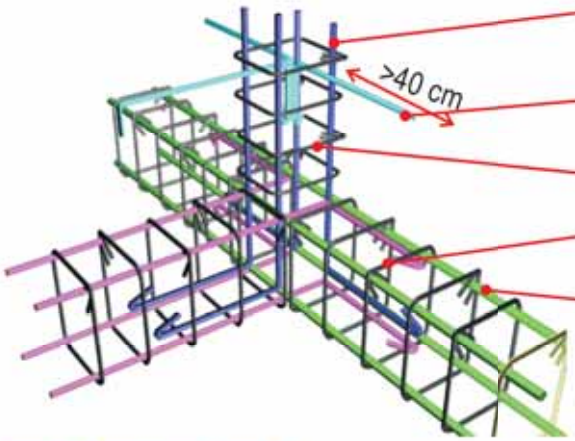


Example:
D = 10mm
40D = 400mm
40D = 40cm



10. FOUNDATION BEAM REINFORCING DETAILING

10.A. MIDDLE JOINT



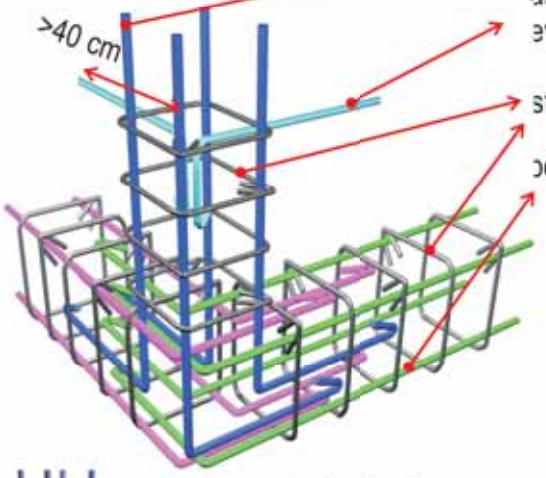
column reinforcing bar
min. ϕ 10mm

anchor min. ϕ 10mm,
length > 40cm
every 6 layers of brick

stirrups min. ϕ 8mm
distance < 15cm

beam reinforcing bars
min. ϕ 10mm

10.B. CORNER JOINT

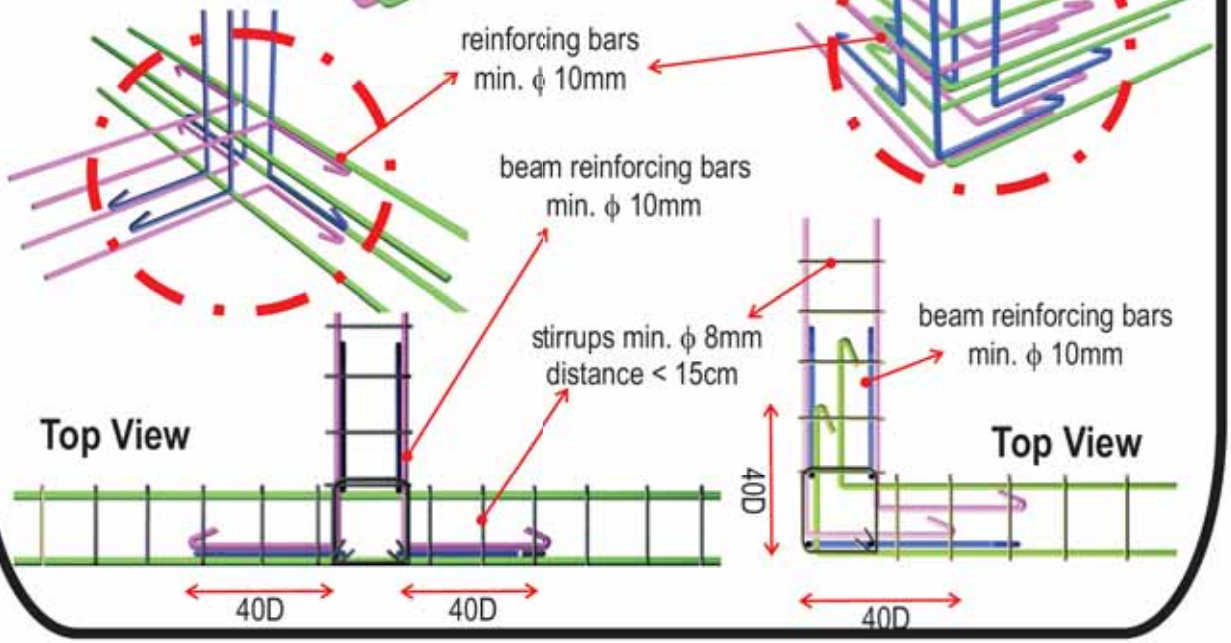


column reinforcing bar min. ϕ 10mm

anchor min. ϕ 10mm, length > 40cm
every 6 layers of brick

stirrups min. ϕ 8mm distance < 15cm

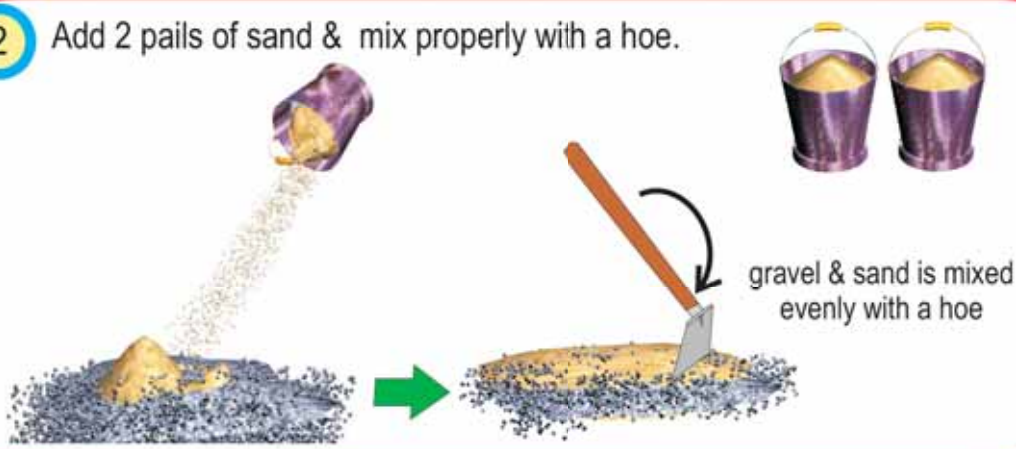
beam reinforcing bars min. ϕ 10mm



11. PREPARING CONCRETE MIX

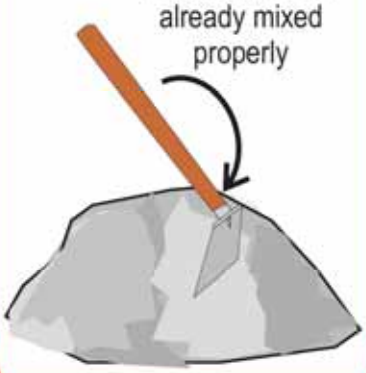
1 First step, pour 3 pails of gravel & mix properly with a hoe.

2 Add 2 pails of sand & mix properly with a hoe.



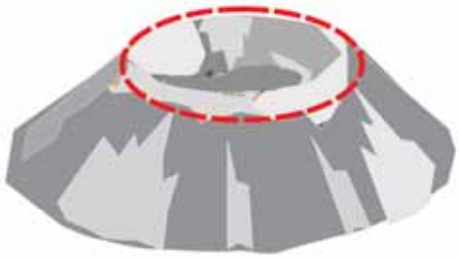
3 Subsequently ,add one pail of cement & mix properly with a hoe.

4 After the three ingredients are properly mixed.



11. PREPARING CONCRETE MIX

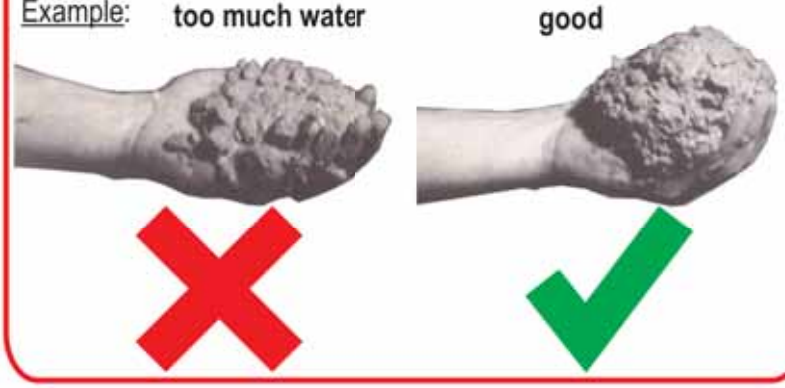
5 Form a depression in the center.



6 Add ½ pail of water & mix properly.

7 Finally test the concrete mix consistency by placing in your hand.

Example: **too much water** **good**



Concrete mix that meets standard requirement:
Materials needed for 1 m^3 of concrete:

- 0,125 m^3 water
- 0,250 m^3 cement
- 0,500 m^3 sand
- 0,750 m^3 gravel

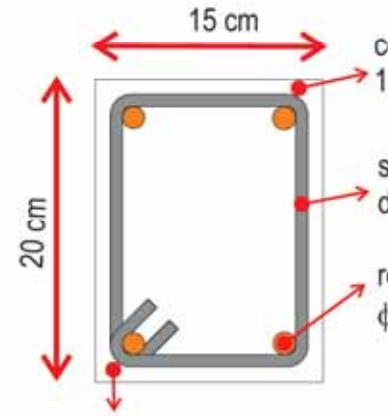
The ratio of water : cement : sand : gravel

1 : 2 : 4 : 6

or

½ : 1 : 2 : 3

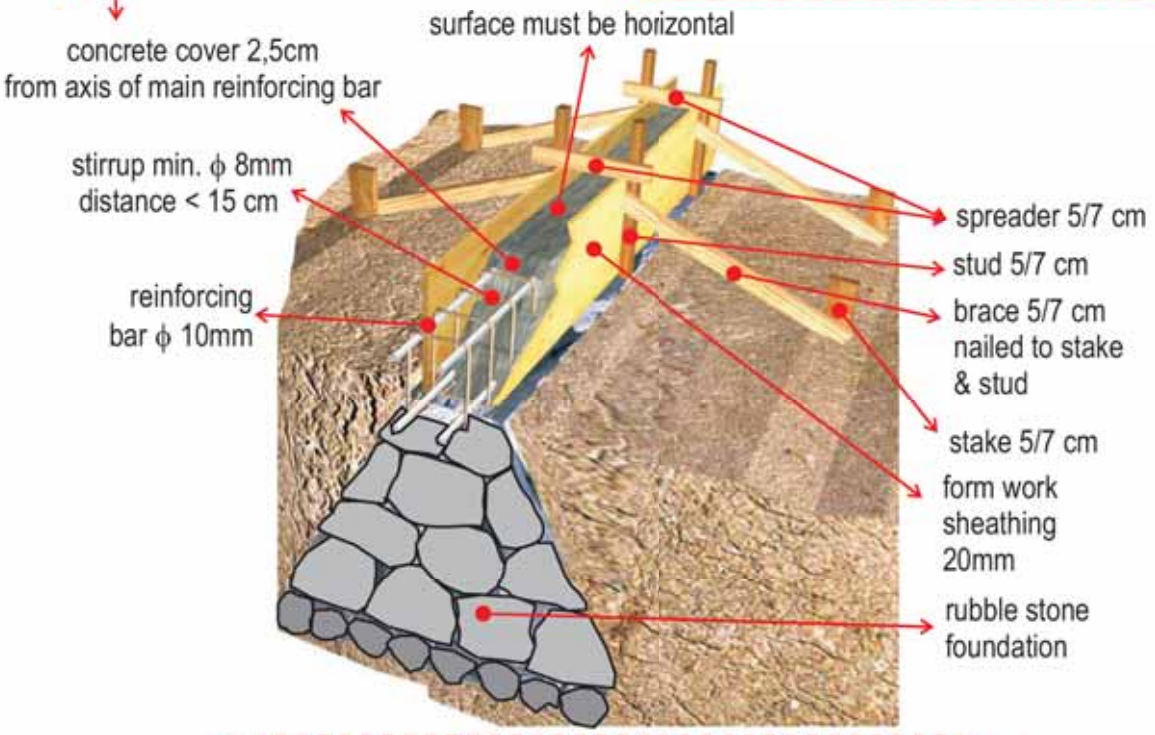
12. PLACING CONCRETE IN FOUNDATION BEAM



Mix properly with appropriate amount of water

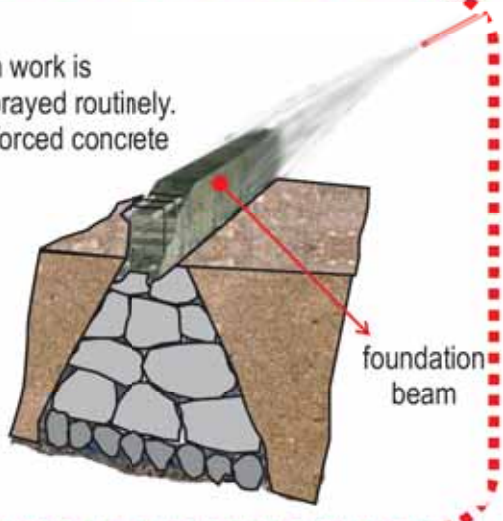
Concrete Mix:

Expected min. compressive strength:
= 150 kg/cm^2

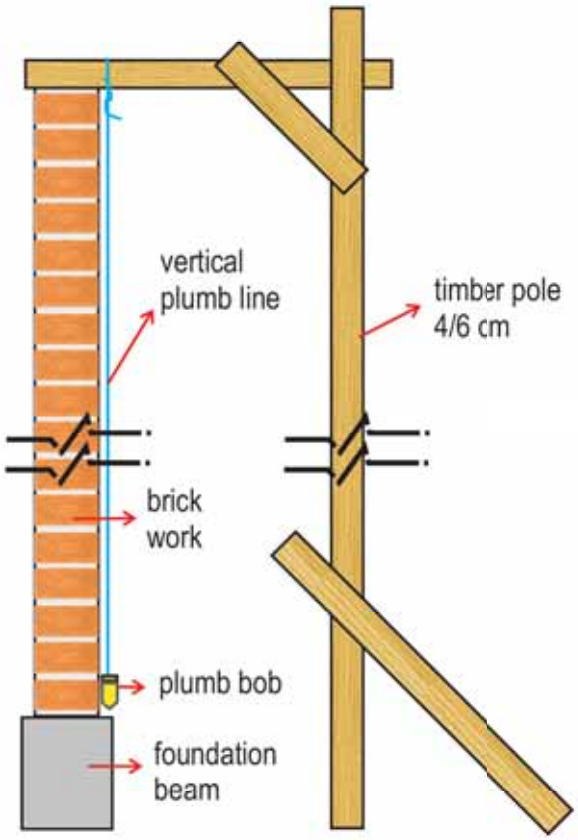


CURING:

- Before & after the form work is removed, it must be sprayed routinely.
- This applies to all reinforced concrete components.

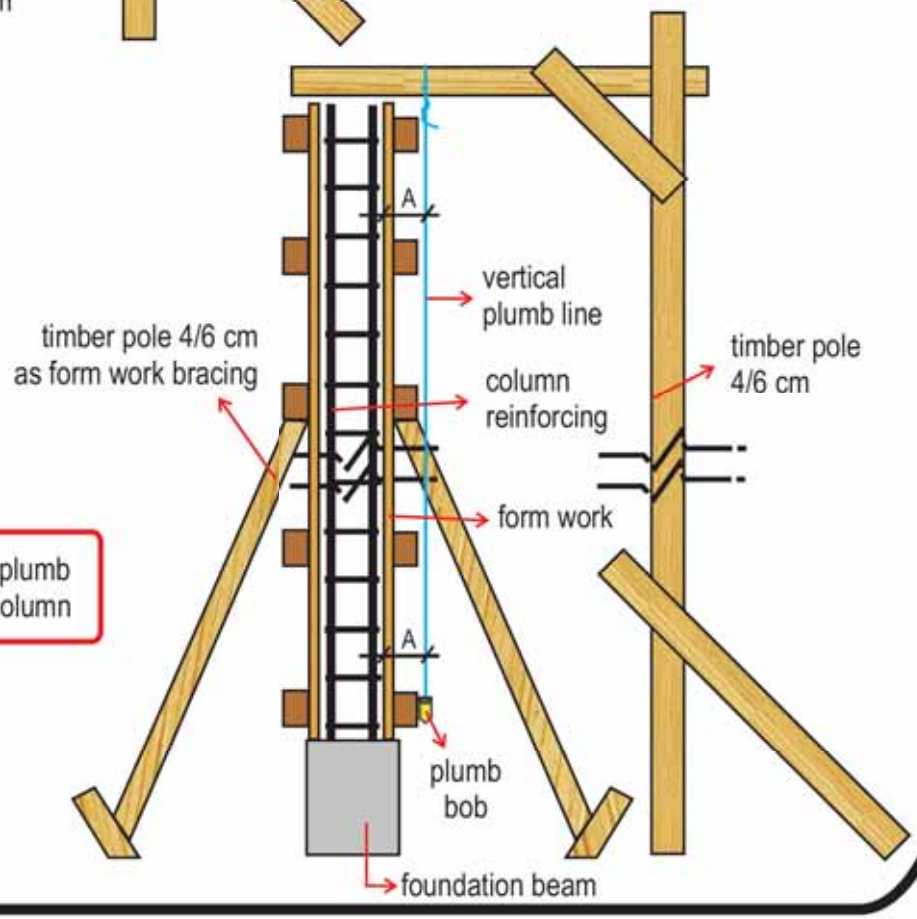


13. PLUMBNESS OF BRICK LAYING AND COLUMNS



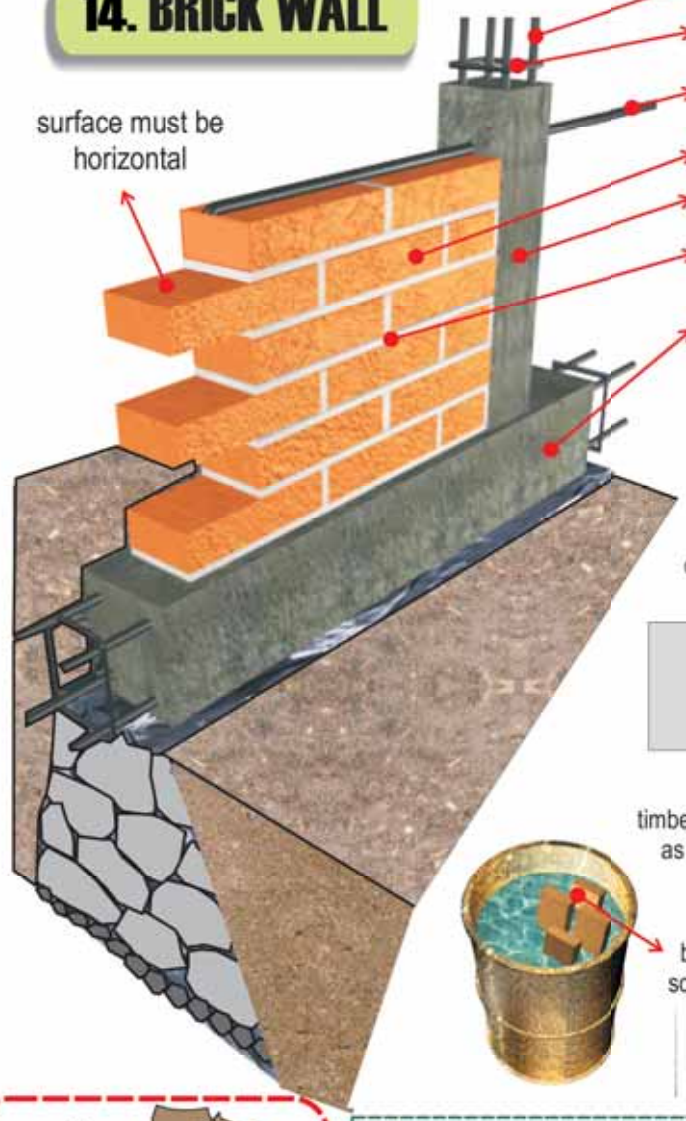
Walls and columns must be plumb and can be done using plumb lines and pins (cord & plumb bob).
Corners of walls must be perpendicular.

Note:
Columns form work must be supported on 4 sides to warrant plumbness.



A: distance of plumb line to the column

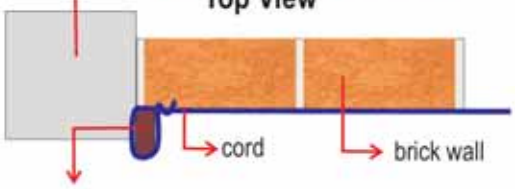
14. BRICK WALL



Mortar Mix:

1 pc (cement) 4 sand

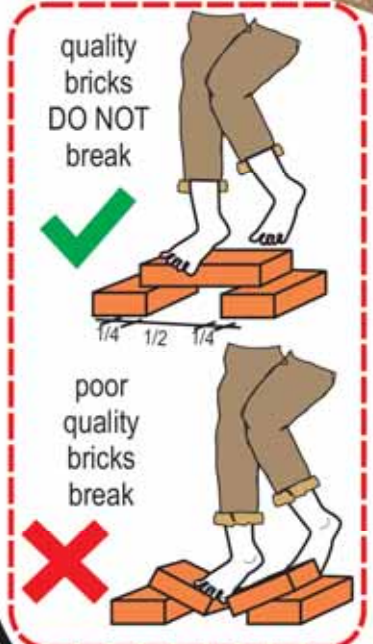
mixed properly & add water appropriately

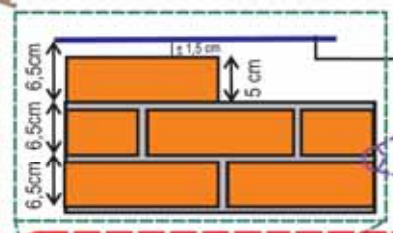


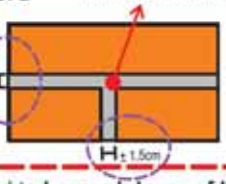
timber pole 5/7 cm along wall height erected to act as pilot for brick laying in the vertical direction

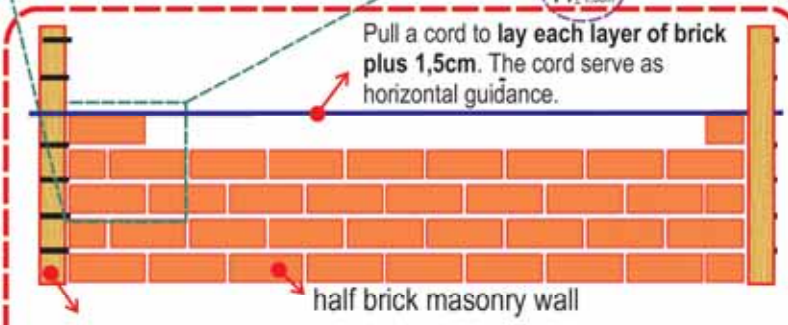
bricks must be soaked minimum

Curing: brick wall must be sprayed periodically



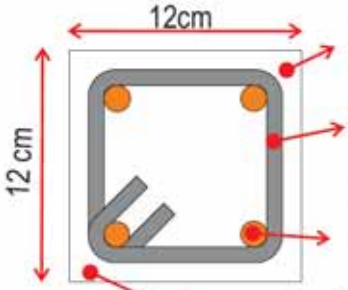






Timber pole to fix the cord is marked for every level of brick plus 1,5cm. The string is removed if the brick layer is completed.

15. REINFORCING BAR DETAILING AND PLACING CONCRETE IN COLUMNS



concrete cover 2,5cm from axis of main reinforcin

stirrup min. ϕ 8mm distance < 15 cm

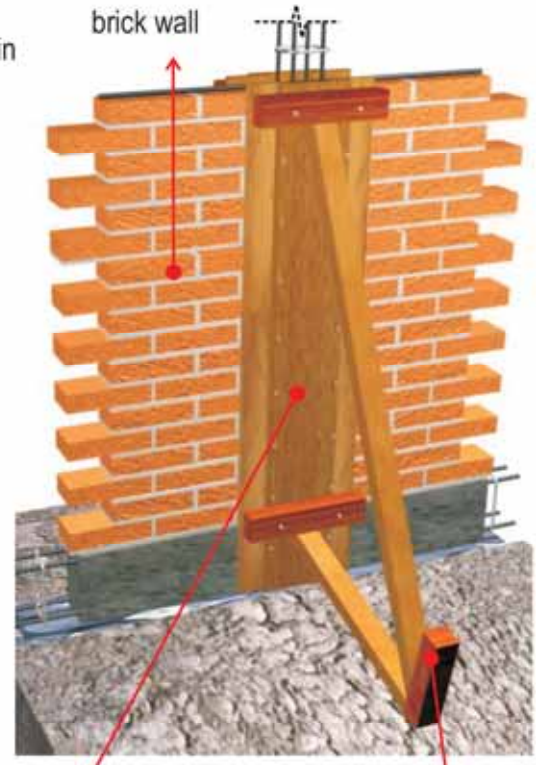
reinforcing bar min. ϕ10mm

concrete mix:
1 cement : 2 sand : 3 gravel

Concrete Mix:

1 pc (cement) 2 sand 3 gravel

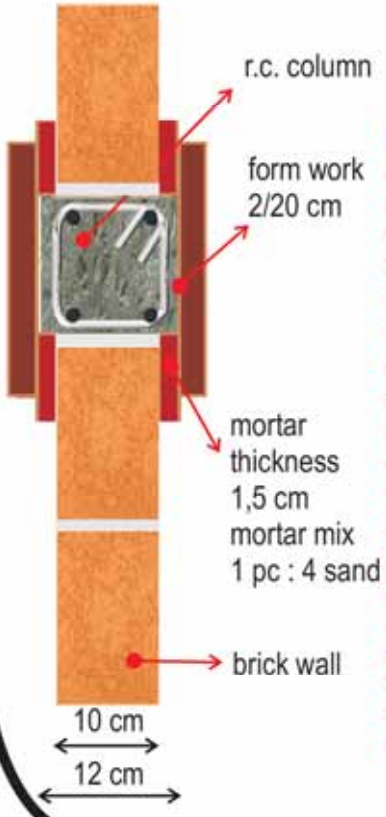
Mix properly; add water appropriately. Expected min. compressive strength of concrete = 150 kg/cm^2



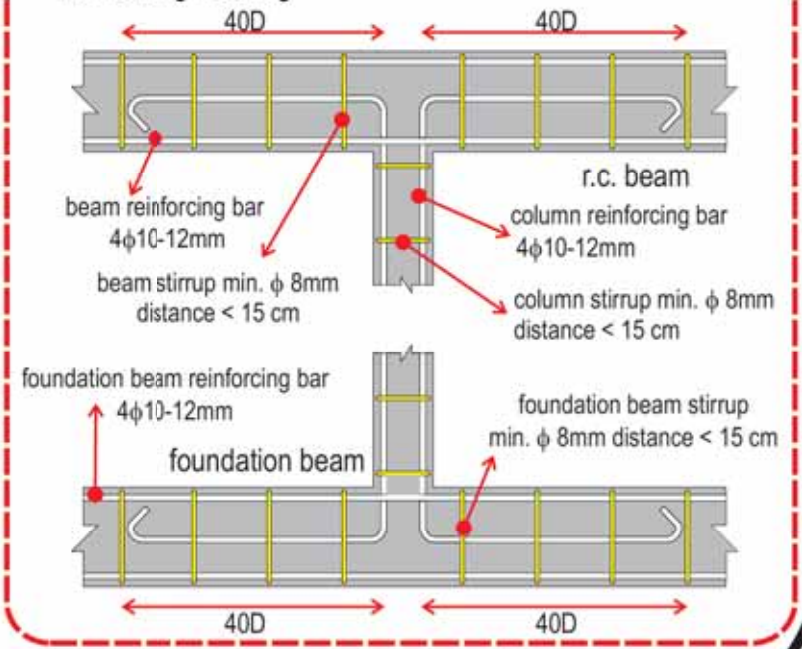
all form work must be tailored made & shall not use arbitrary planks

stake 4/6 cm

Top View

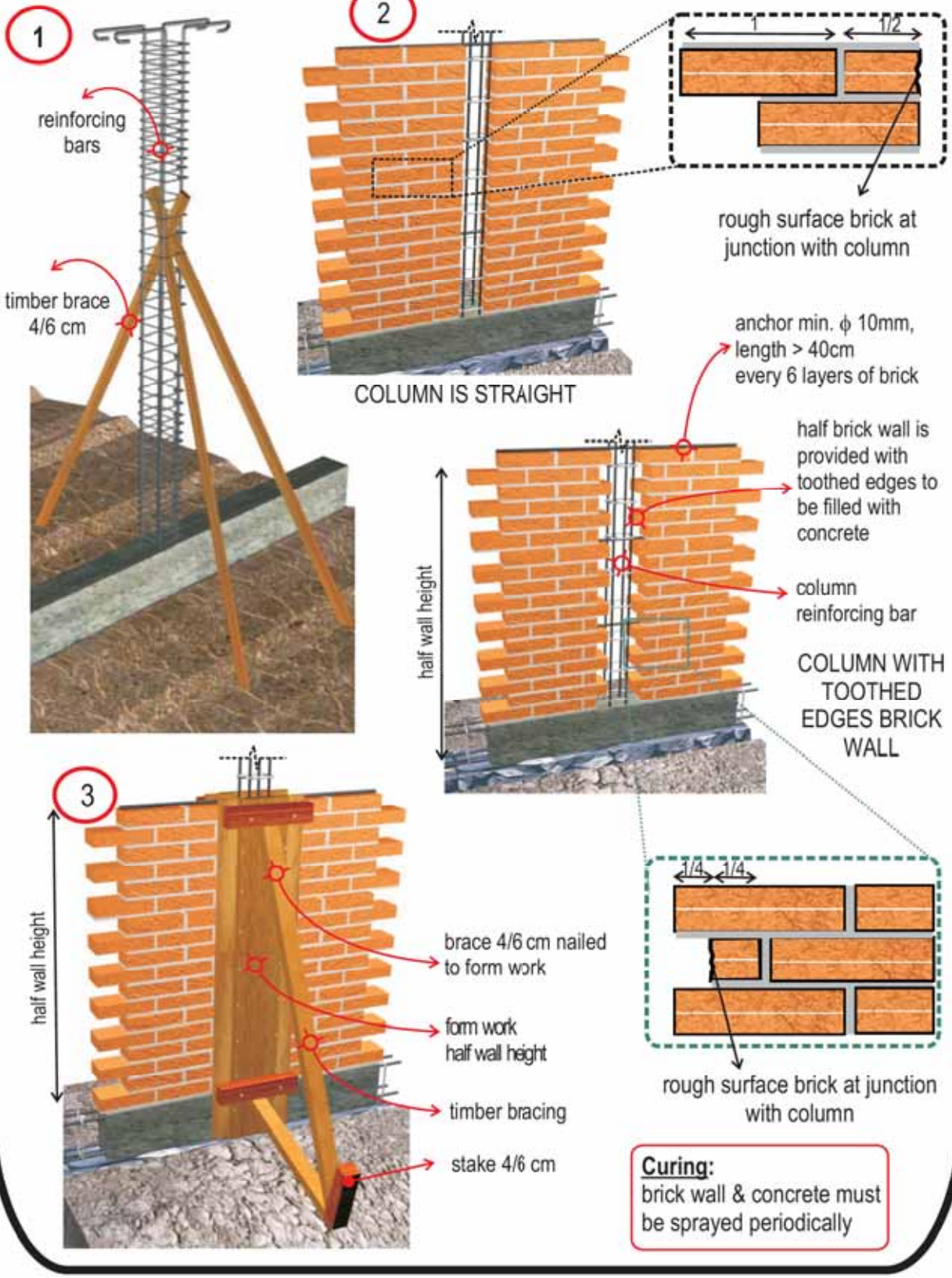


Reinforcing Detailing



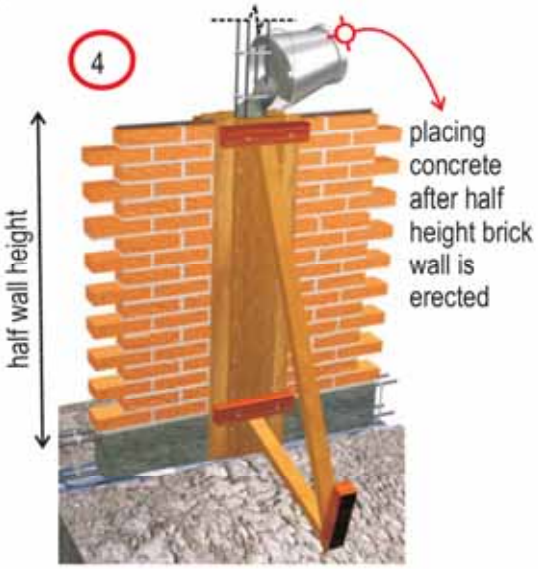
15.A. PLACING CONCRETE IN COLUMN SIMULTANEOUSLY WITH BRICK LAYING

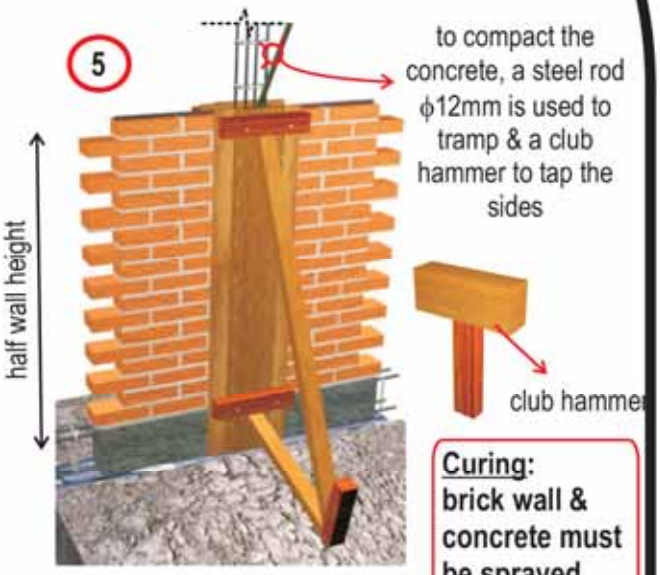
I. COLUMN REINFORCING BARS SUPPORTED BY TIMBER BRACING TO PREVENT BENDING/LEANING



Curing:
brick wall & concrete must be sprayed periodically

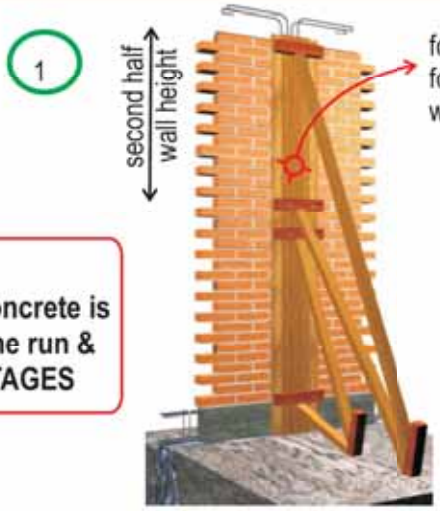
II. PHASE I PLACING CONCRETE IN COLUMN AFTER THE HALF HEIGHT BRICK WALL IS ERECTED

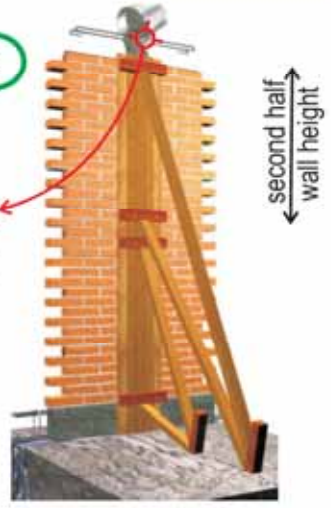




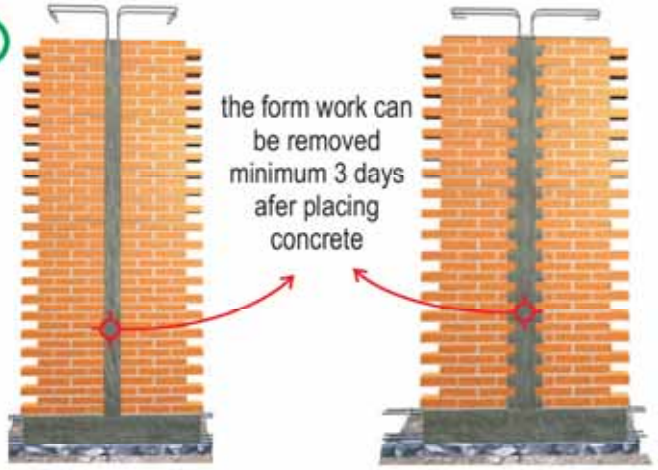
Curing:
brick wall & concrete must be sprayed periodically

III. PHASE II PLACING CONCRETE IN COLUMN



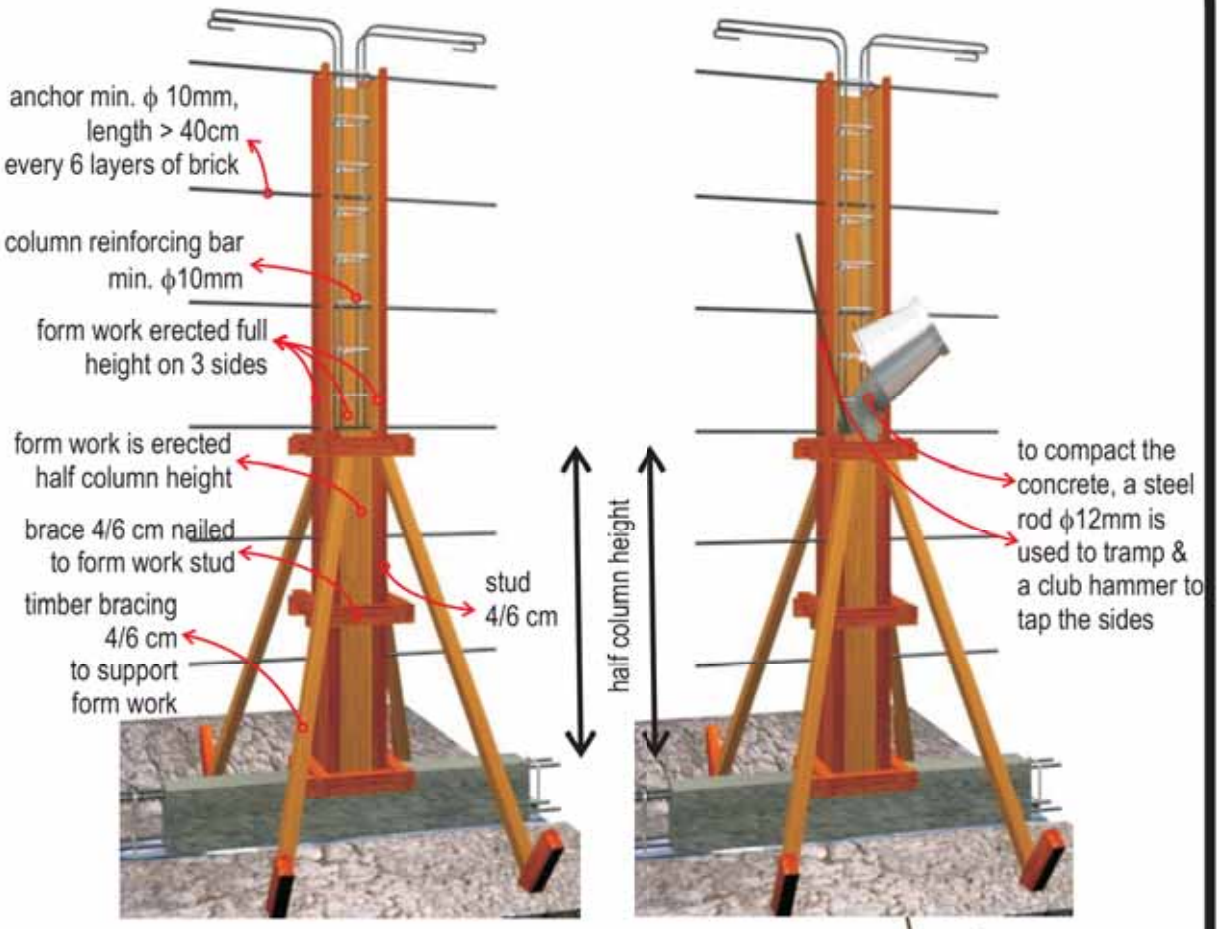


Note:
placing concrete is done in one run & NOT IN STAGES

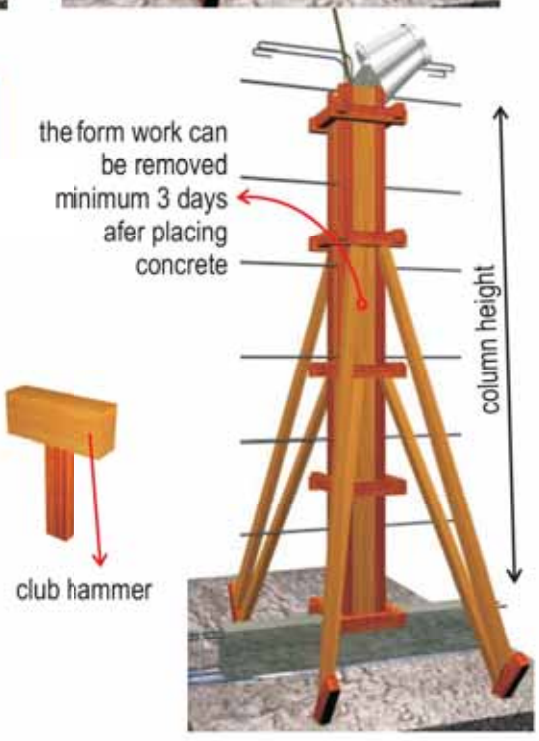


15.B. PLACING CONCRETE IN COLUMNS IN STAGES PRIOR TO THE BRICK LAYING

I. PLACING CONCRETE LOWER HALF OF THE COLUMN



II. PLACING CONCRETE UPPER HALF OF THE COLUMN

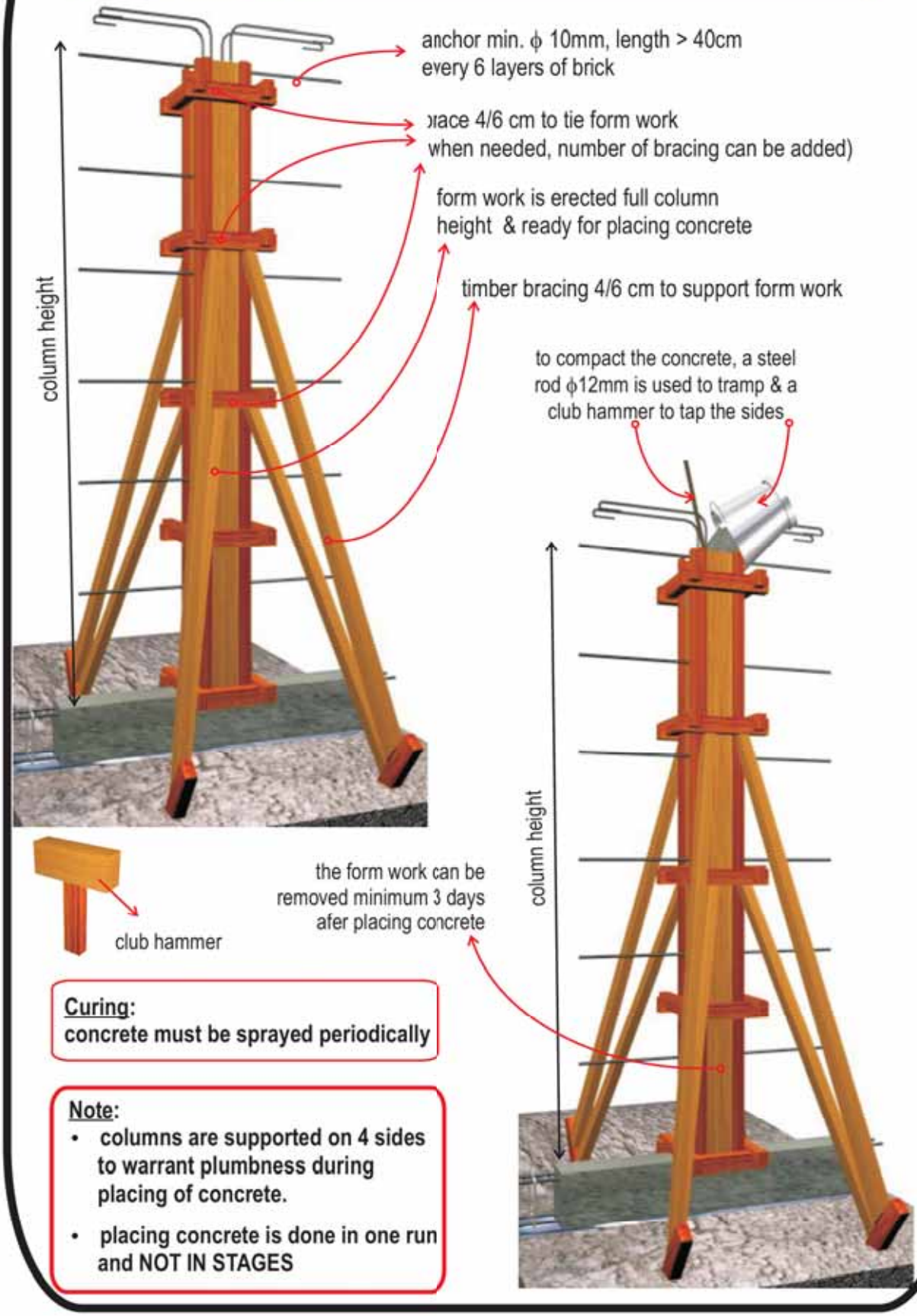


Curing:
concrete must be sprayed periodically

Note:

- **columns are supported on 4 sides to warrant plumbness during placing of concrete.**
- **placing concrete is done in one run and NOT IN STAGES**

15.C. PLACING CONCRETE IN FULL HEIGHT COLUMNS PRIOR TO BRICK LAYING

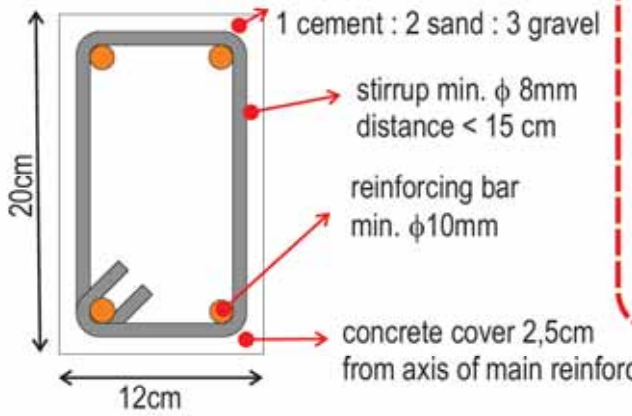


Curing:
concrete must be sprayed periodically

Note:

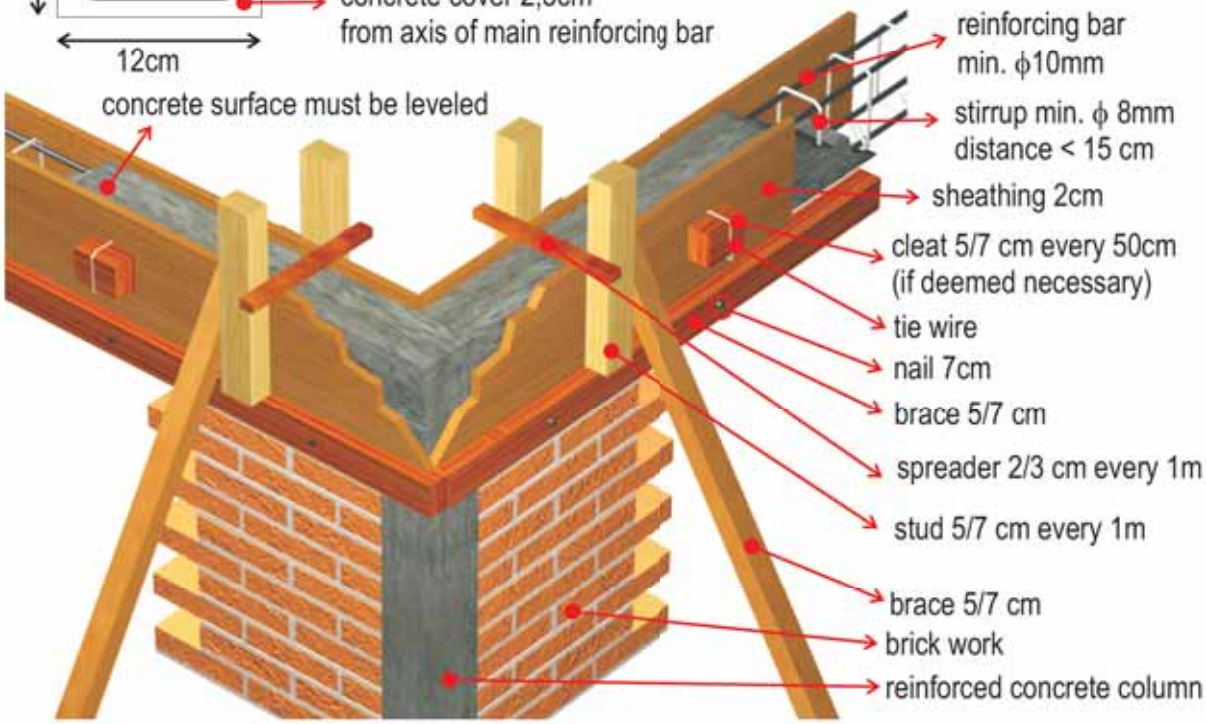
- **columns are supported on 4 sides to warrant plumbness during placing of concrete.**
- **placing concrete is done in one run and NOT IN STAGES**

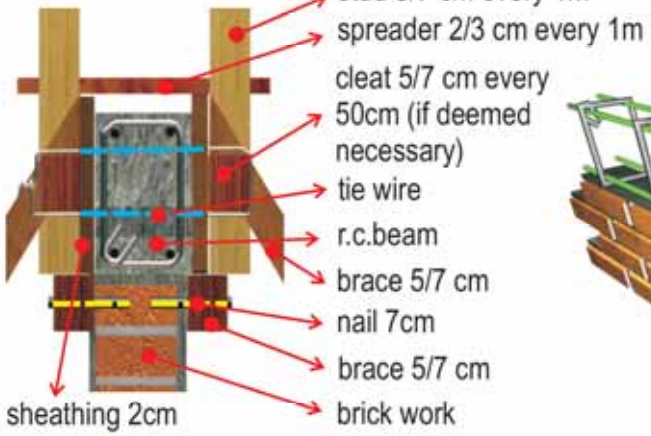
16. JOINT DETAILS AND PLACING CONCRETE IN BEAMS

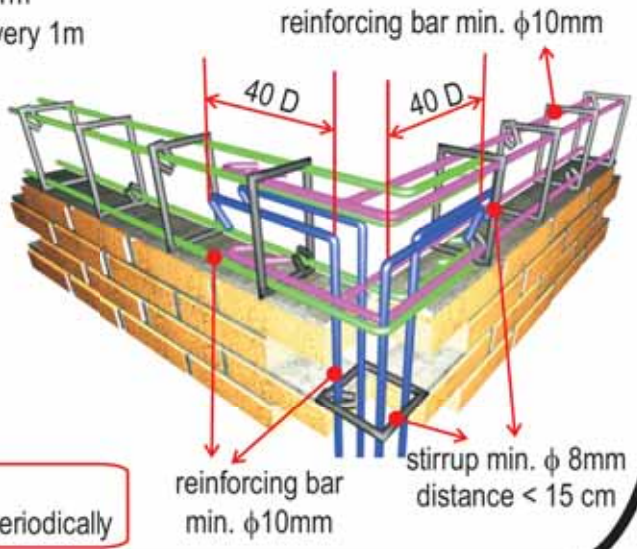


Concrete Mix:

Mix properly; add water appropriately.
Expected min. compressive strength of concrete = 150 kg/cm^2





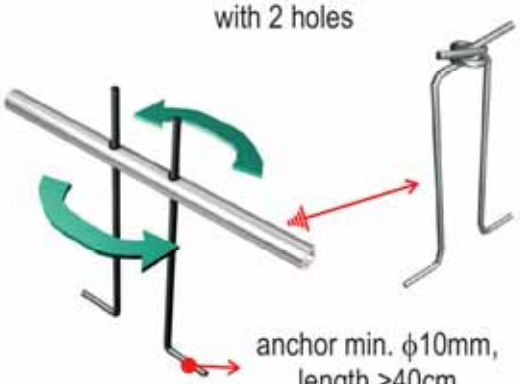


Curing:
brick wall & concrete must be sprayed periodically

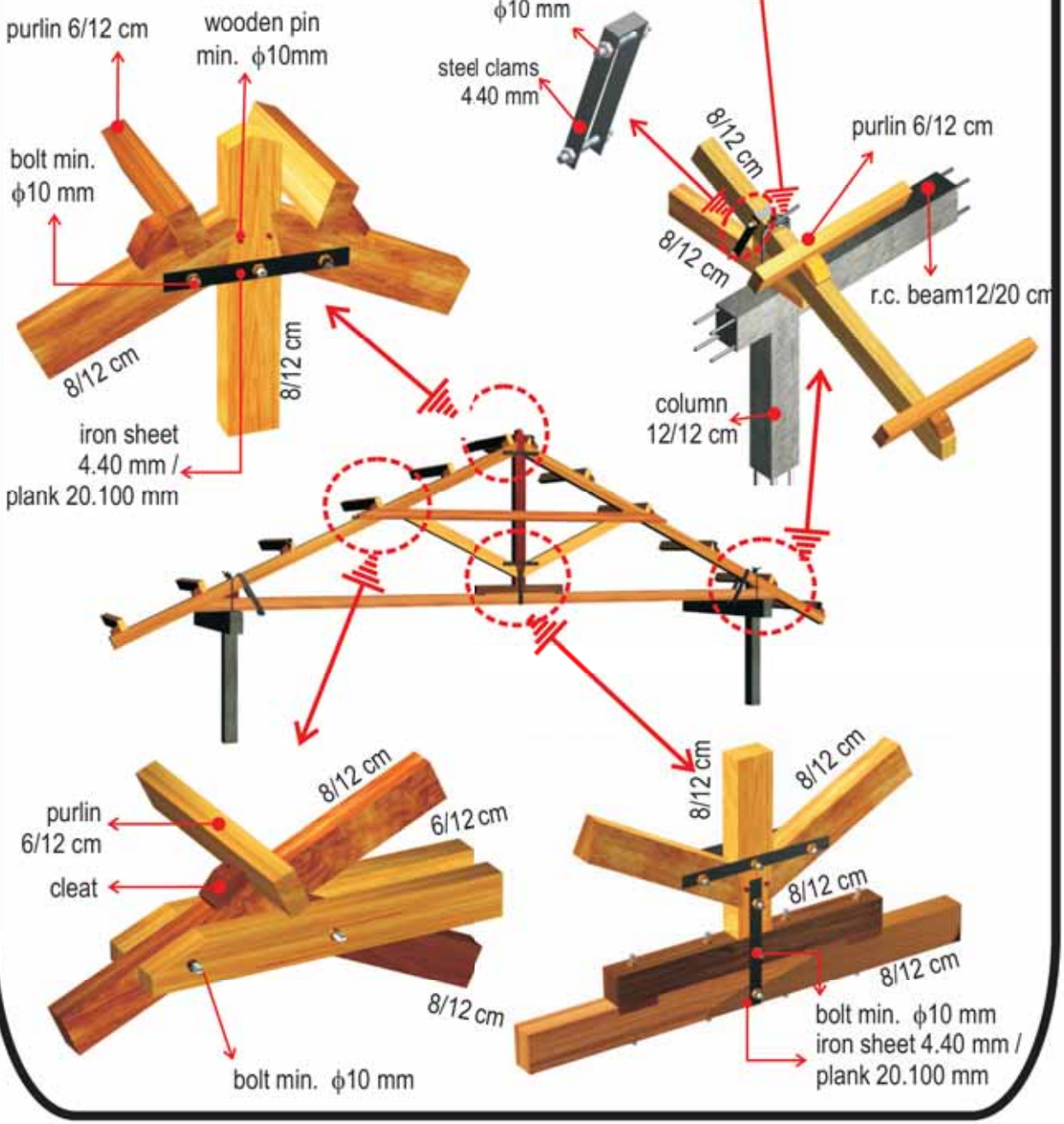
17. TIMBER ROOF TRUSSES

timber bracing to tie trusses 6/12 cm

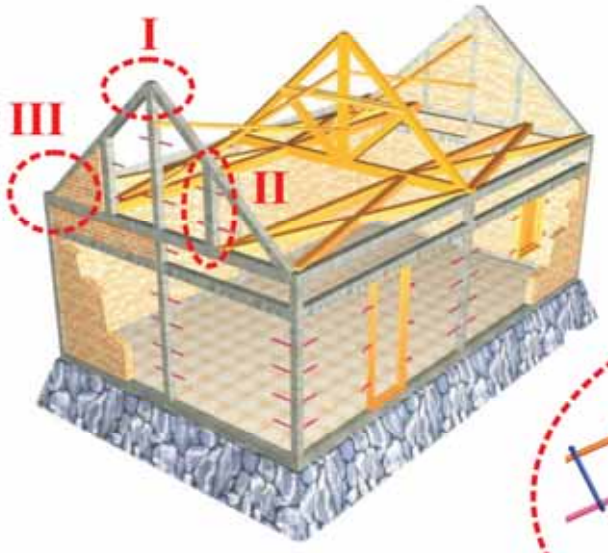
tool to twist anchor bars made of galvanized iron pipe > ϕ 3" with 2 holes

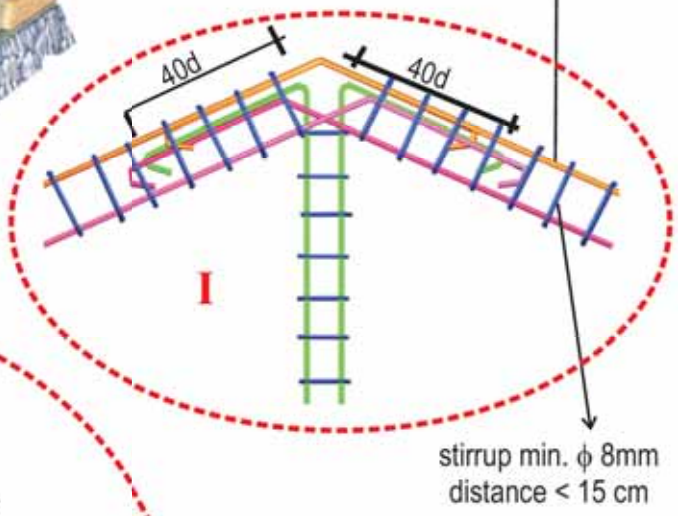


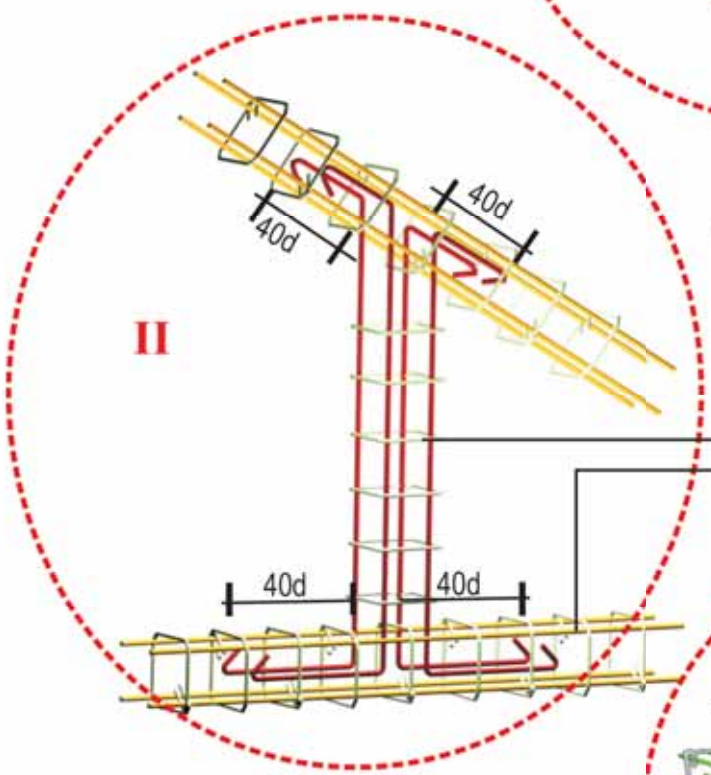
anchor min. ϕ10mm, length >40cm

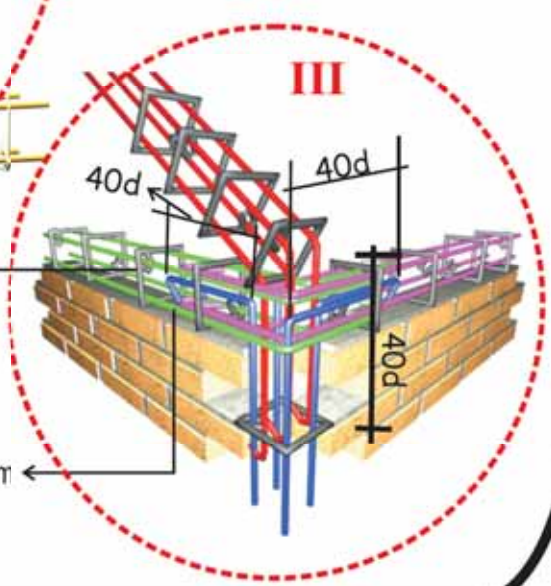


18. GABLE WALL

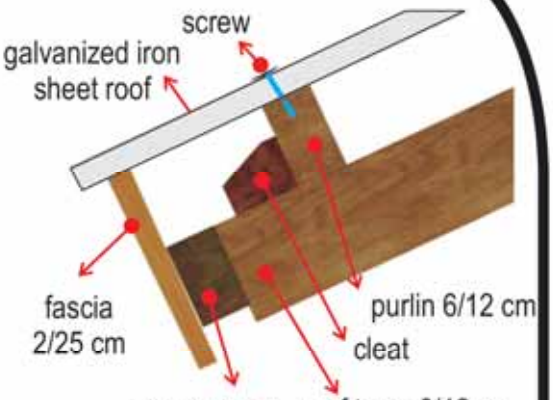


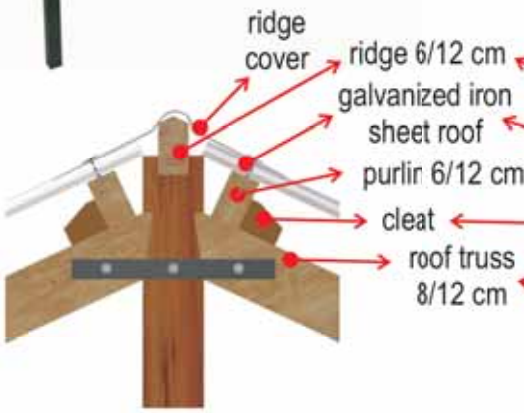


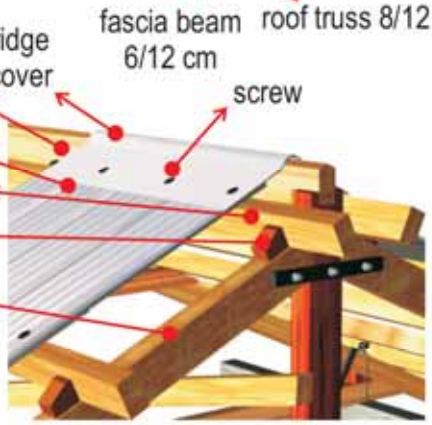


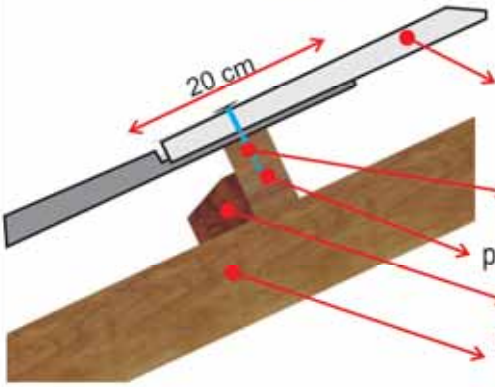


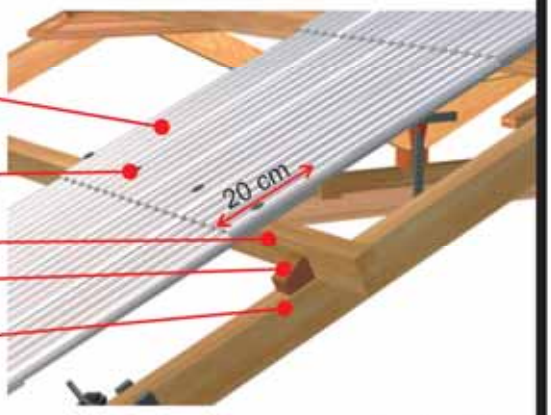
19. ROOF COVERING

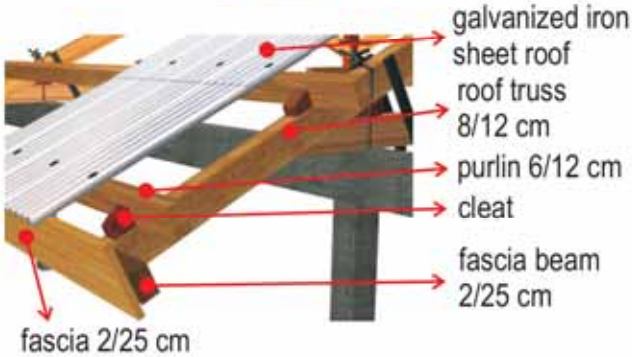












Advantage of galvanized iron sheet roofing:

- Light in weight
- Easy to install

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