



Constructing Seismic Resistant Masonry Houses in Indonesia

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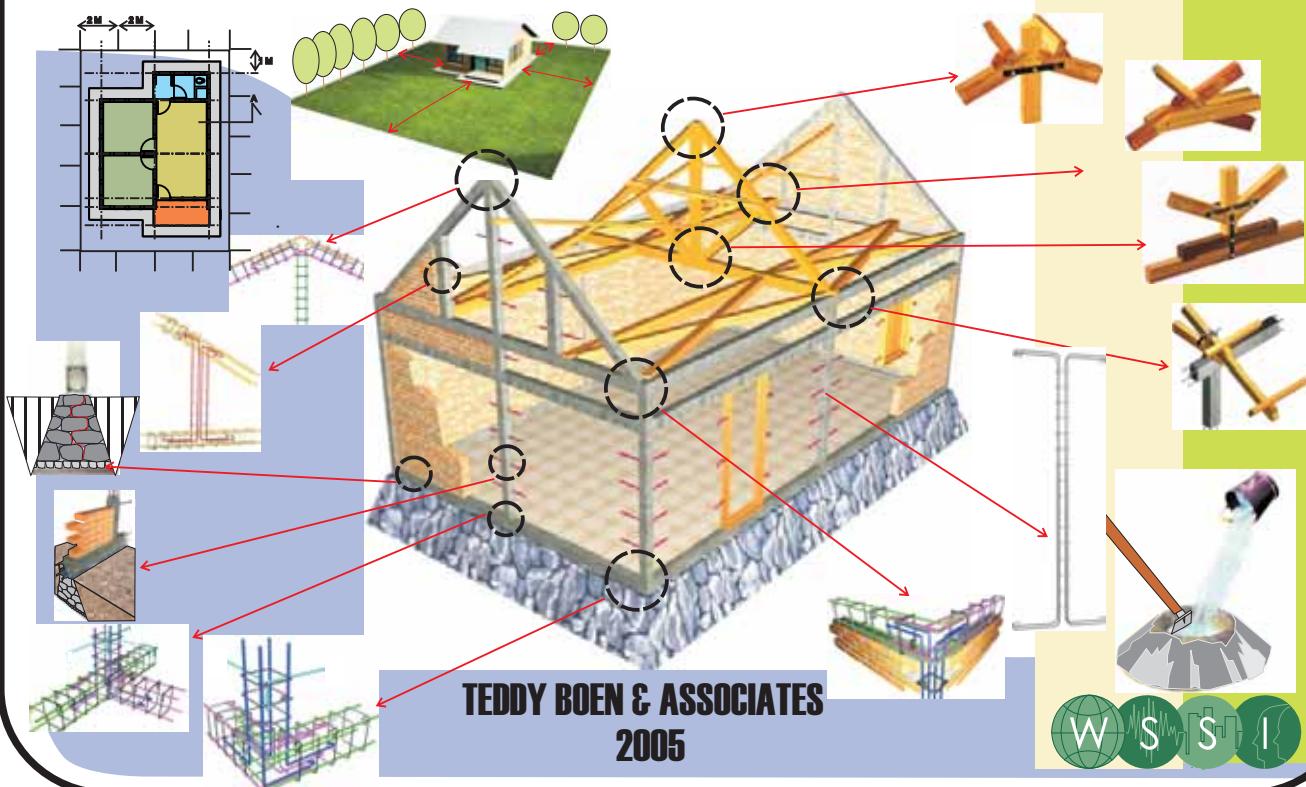
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CONSTRUCTING SEISMIC RESISTANT MASONRY HOUSES



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Second Edition



WORLD SEISMIC SAFETY INITIATIVE

TEDDY BOEN

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I

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 prone.

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.

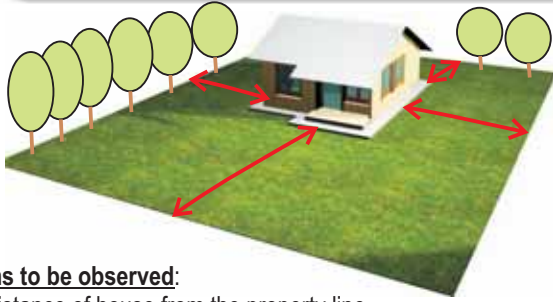
It is hoped that this guideline is useful for the common people in earthquake prone areas and for stakeholders involved in reducing the impact of future earthquakes.

Jakarta, April 2005

Teddy Boen & Associates

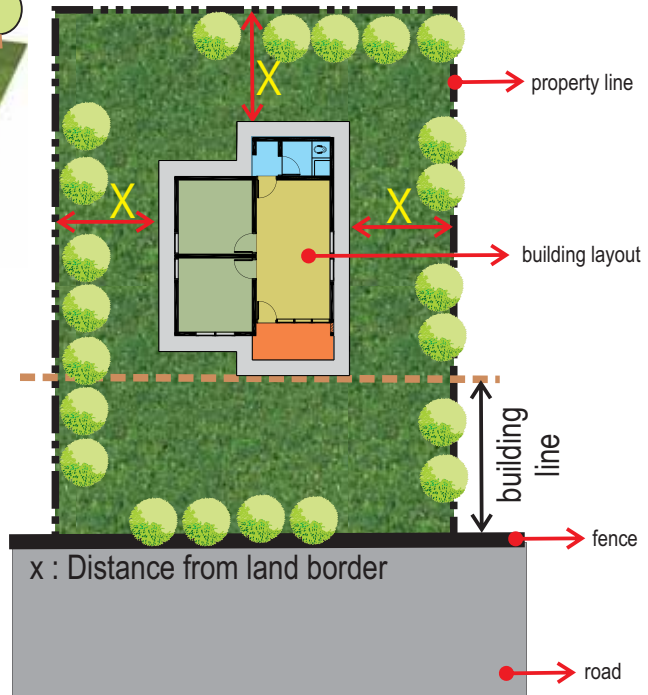
II

1. GENERAL REQUIREMENTS AND LAYOUT OF HOUSES



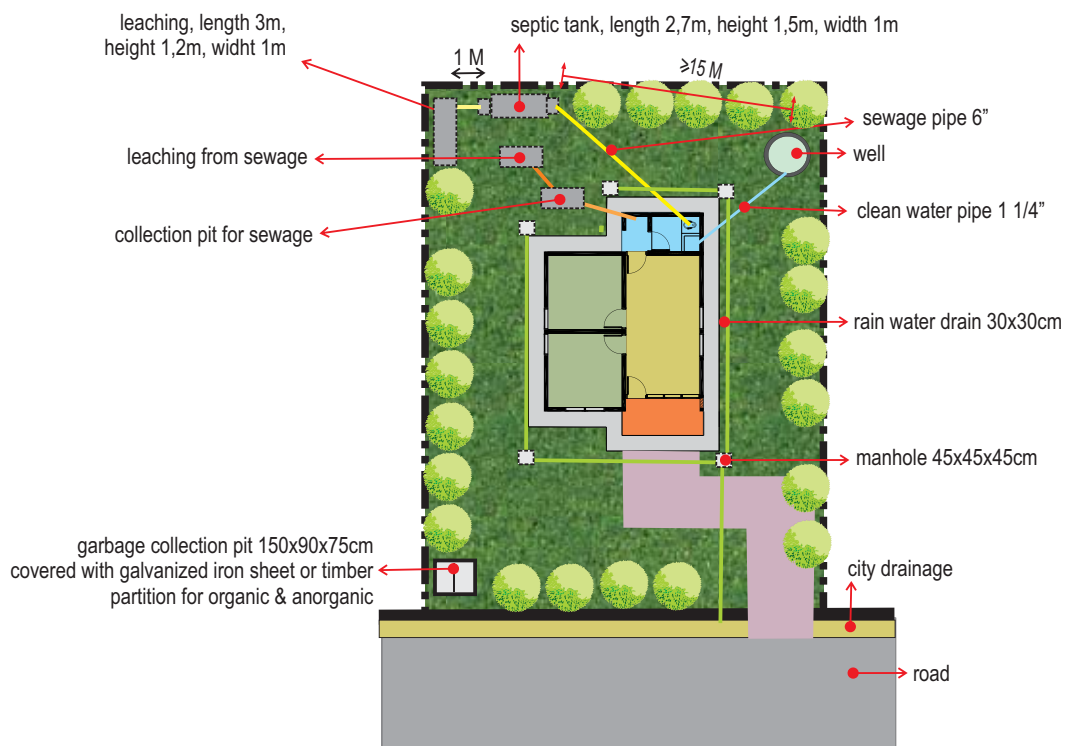
Items to be observed:

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



1

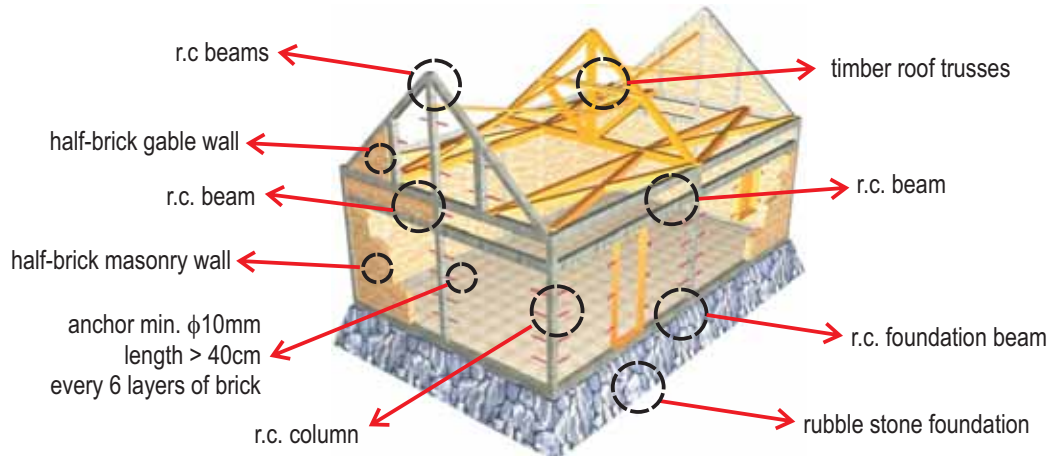
2. CLEAN WATER AND SEWERAGE



2

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**.



3

4. BUILDING MATERIALS

SAND:

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



GRAVEL:

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



CEMENT:

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

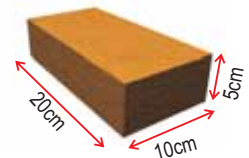


WATER :

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

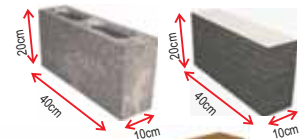
BRICKS:

- 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

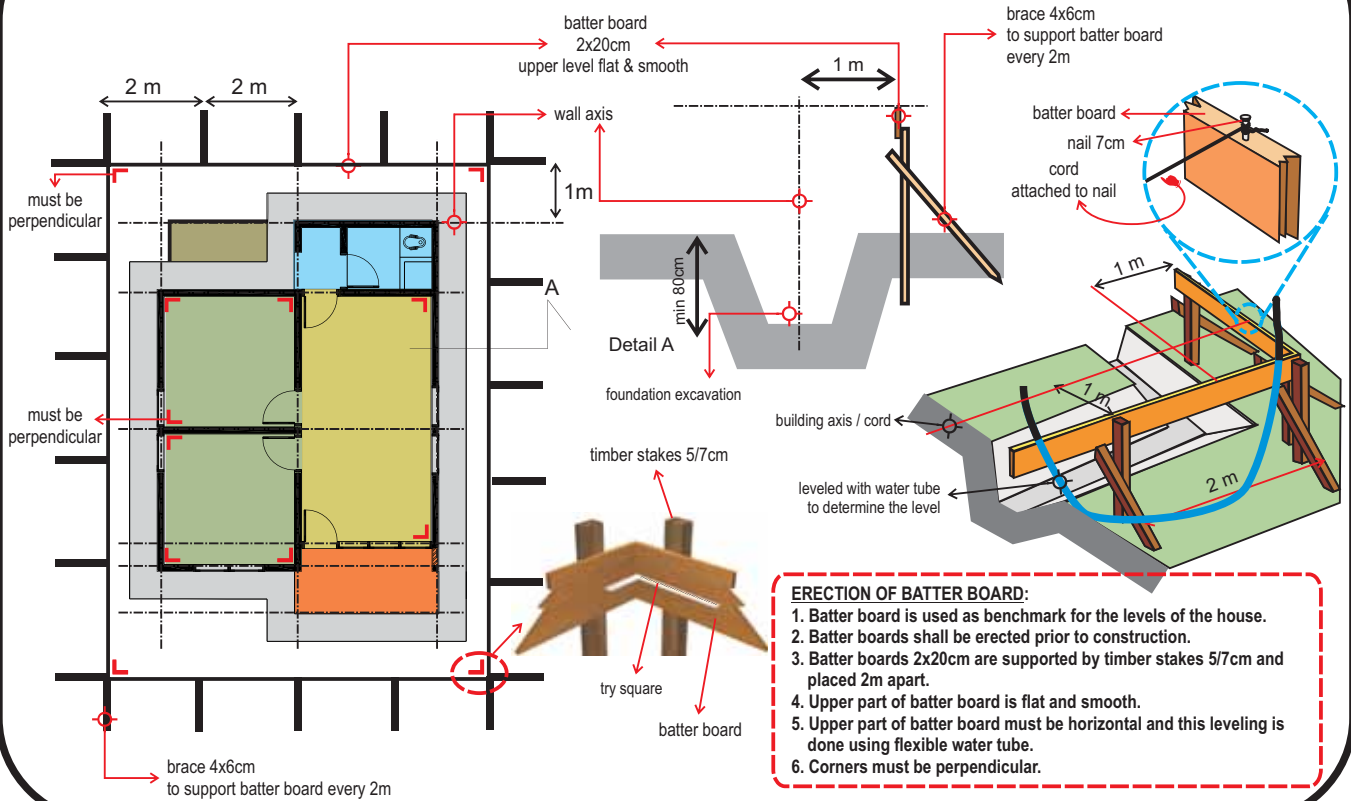


R.C. BARS:

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

4

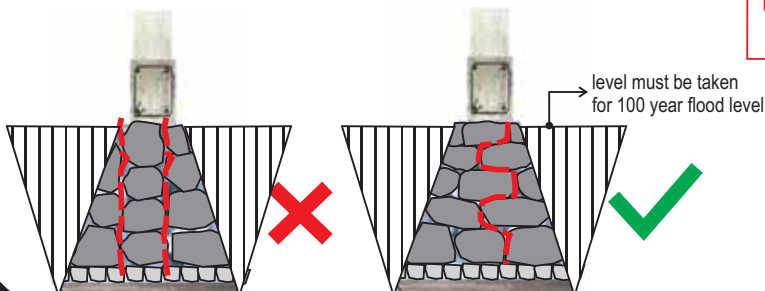
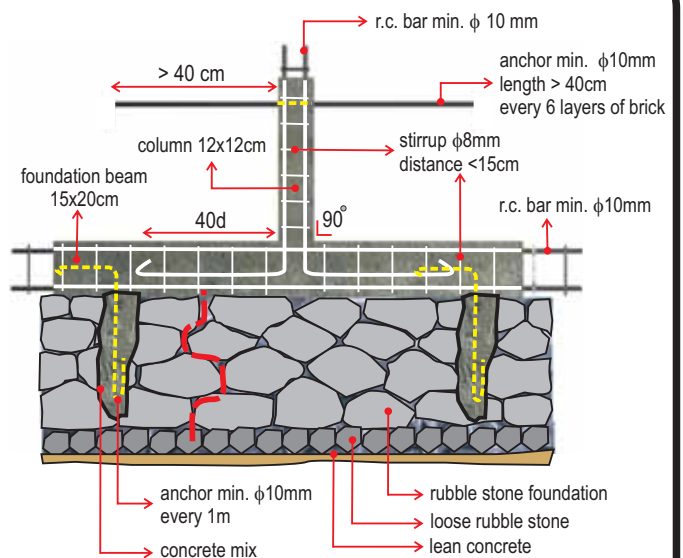
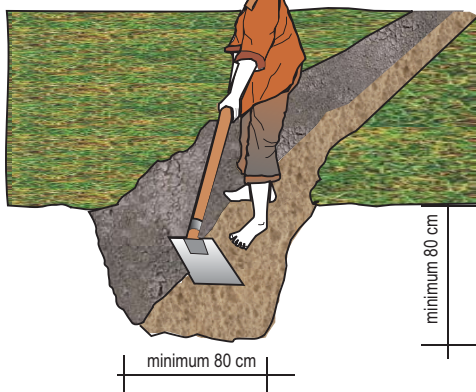
5. ERECTION OF BATTER BOARDS



5

6. RUBBLE (RIVER / QUARRY) STONE FOUNDATION

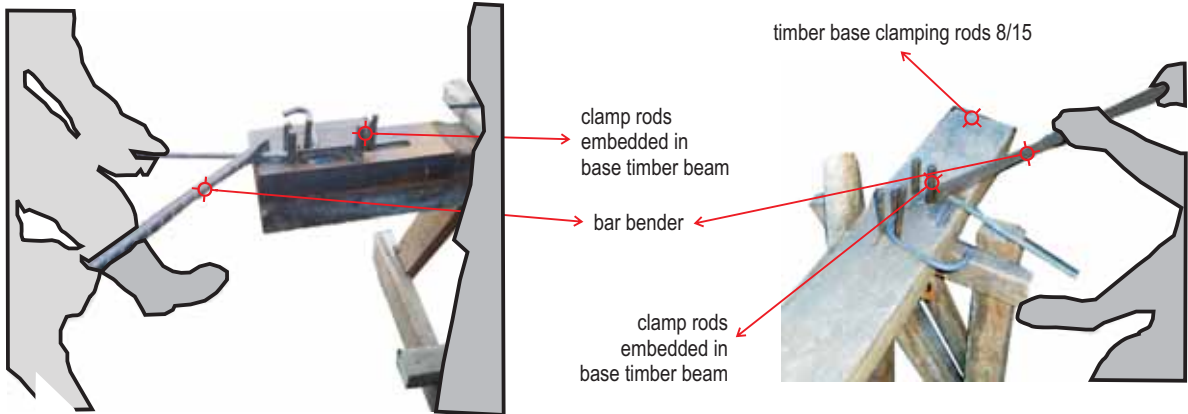
foundation excavation



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

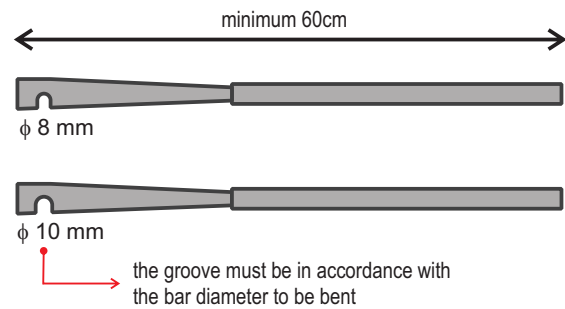
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7. REINFORCING BARS BENDING TOOL



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.

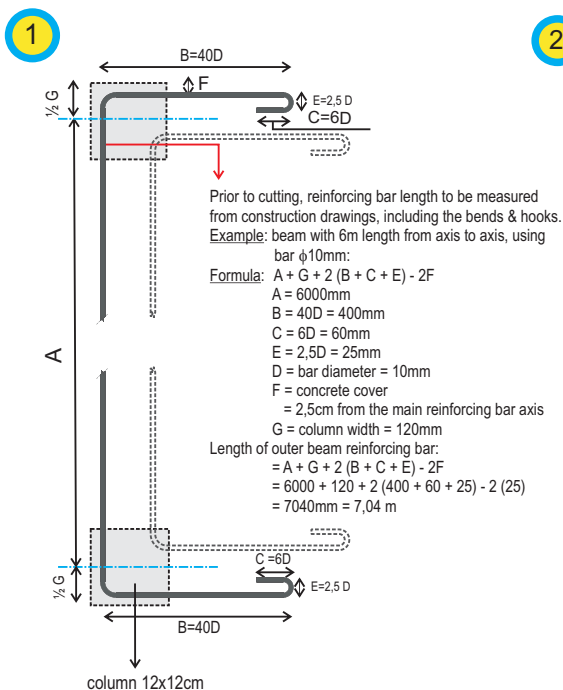


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8. LENGTH AND BENDING OF REINFORCING BARS

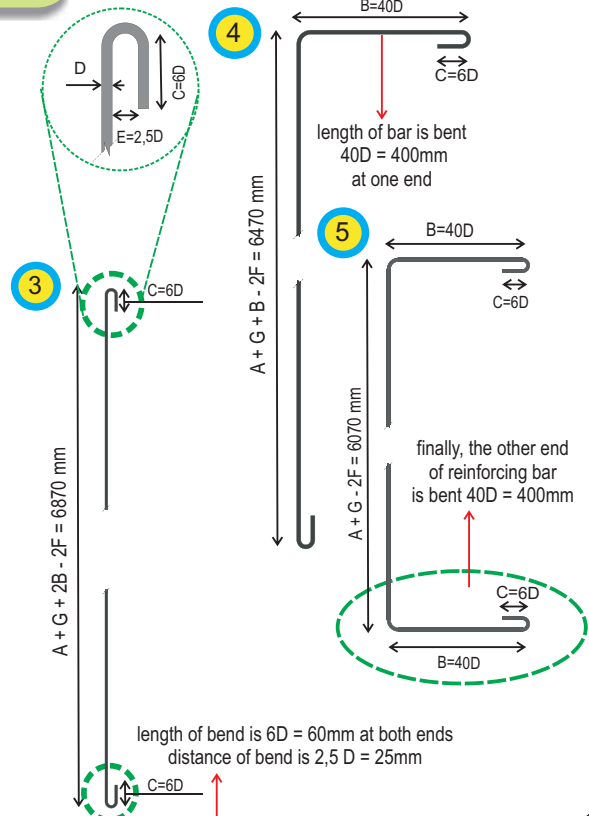
8. A. BEAM REINFORCING BARS

1. OUTER BEAM REINFORCING BAR



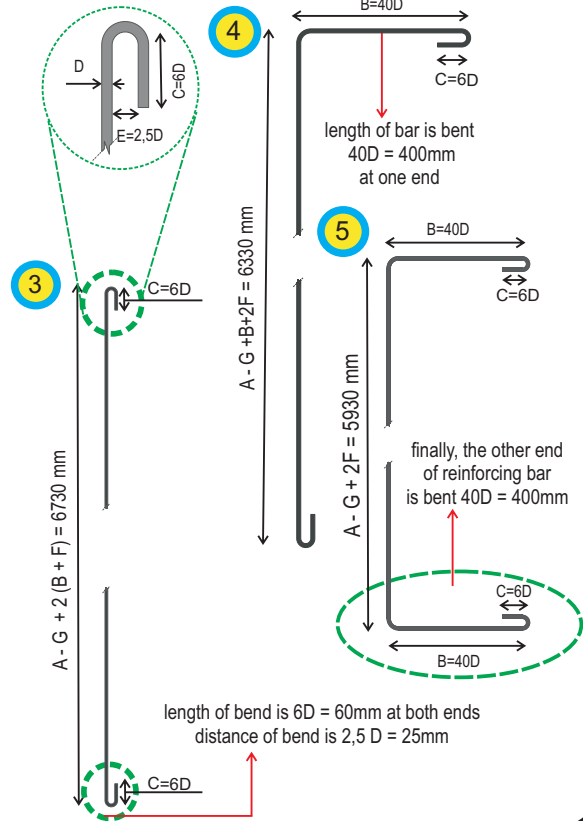
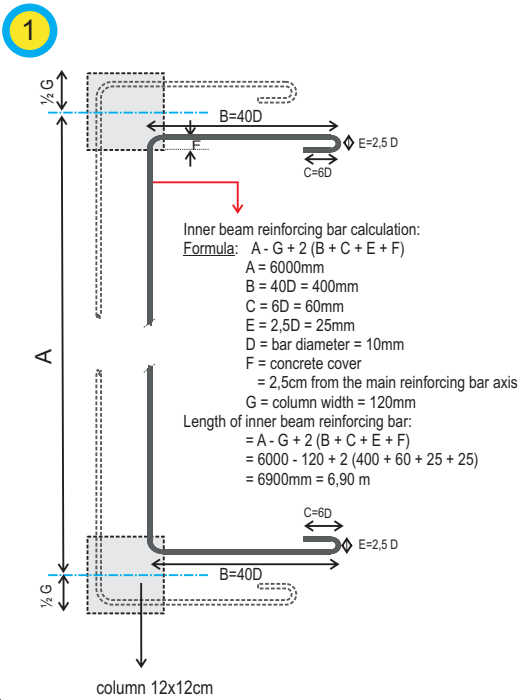
2

$$A + G + 2(B + C + E) - 2F = 7040\text{ mm}$$



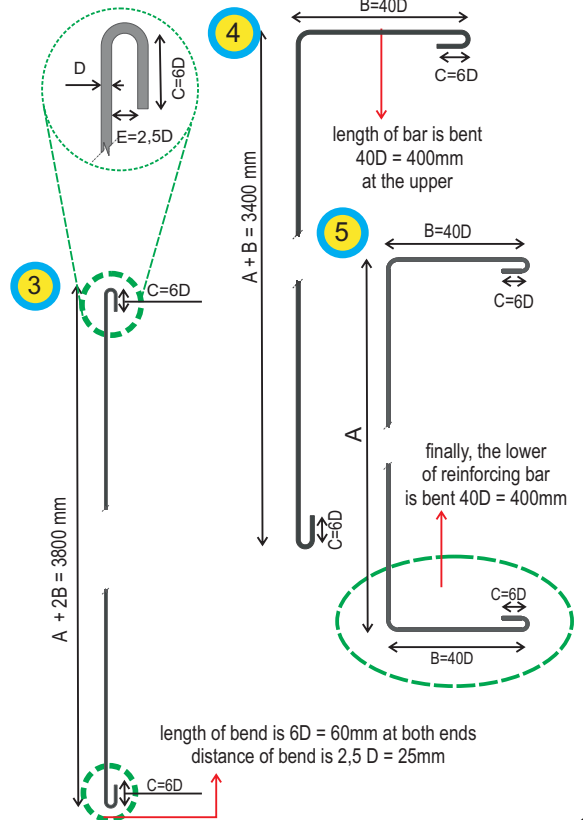
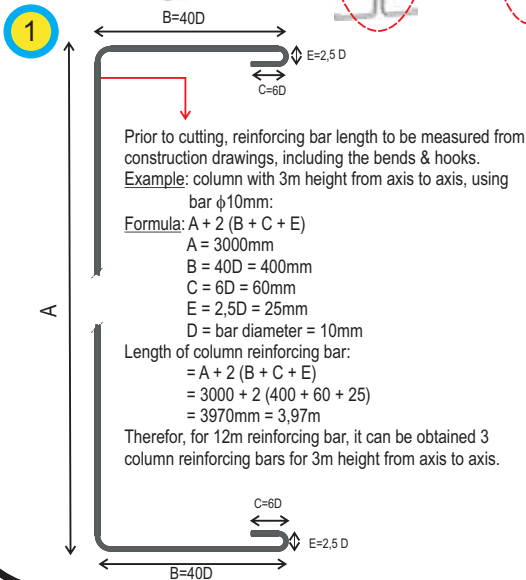
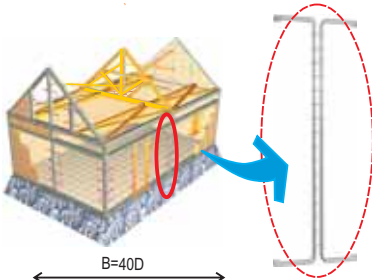
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2. INNER BEAM REINFORCING BAR



9

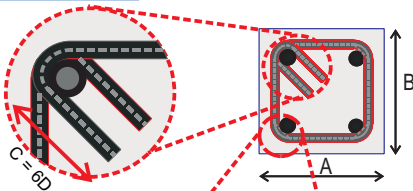
8. B. COLUMN REINFORCING BARS



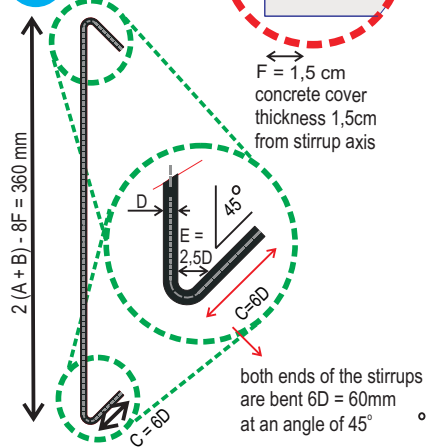
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8.C. STIRRUPS

1



3



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

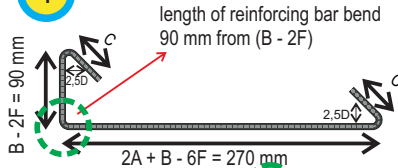
Example: stirrup of column 12x12 cm using bar ϕ 8mm:
A = column width at one side = 120mm
B = column width at the other side = 120mm
C = 6D = 48mm
E = 2,5D = 20mm
D = bar diameter = 8mm
F = concrete cover from stirrup axis = 15mm

Formula: $2(A+B) + 2(C+E) - 8F$
Length of stirrup bar:
 $= 2(120+120) + 2(48+20) - 8 \times 15$
 $= 496\text{mm} = 49,6\text{cm}$

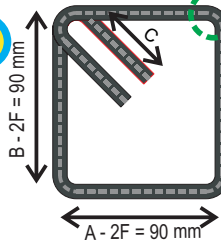
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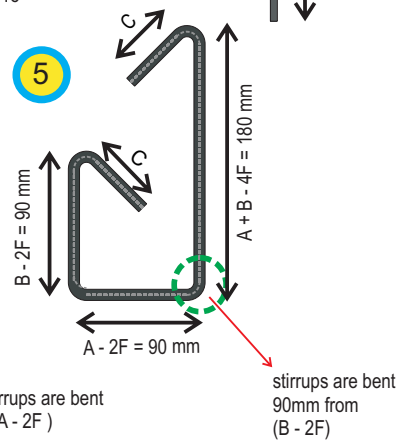
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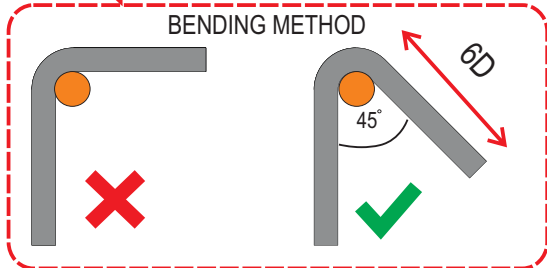
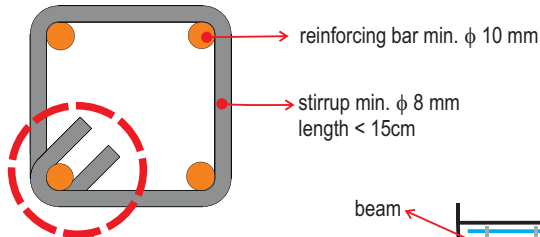
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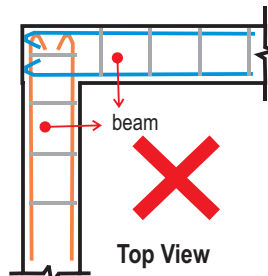
9. SEISMIC RESISTANT DETAILING OF JOINTS

IMPORTANT:

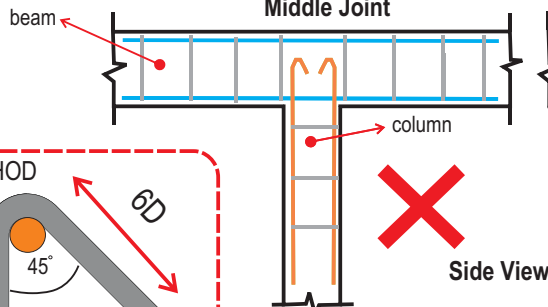
- reinforcing bar diameter
- bending method
- joint detailing



Corner Joint

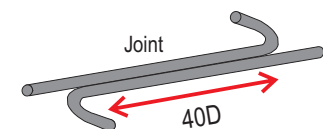


Middle Joint



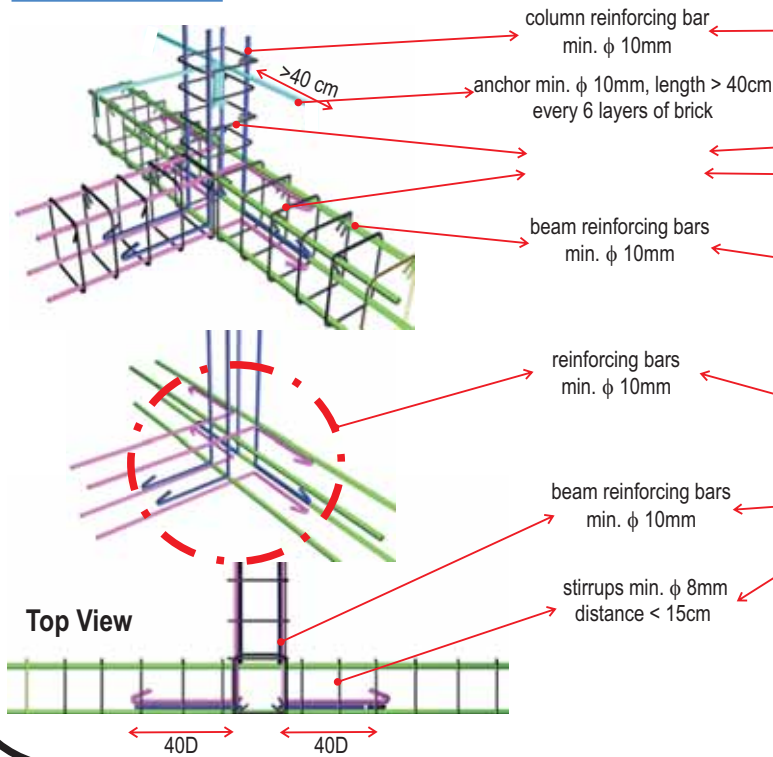
Example:

D = 10mm
40D = 400mm
40D = 40cm

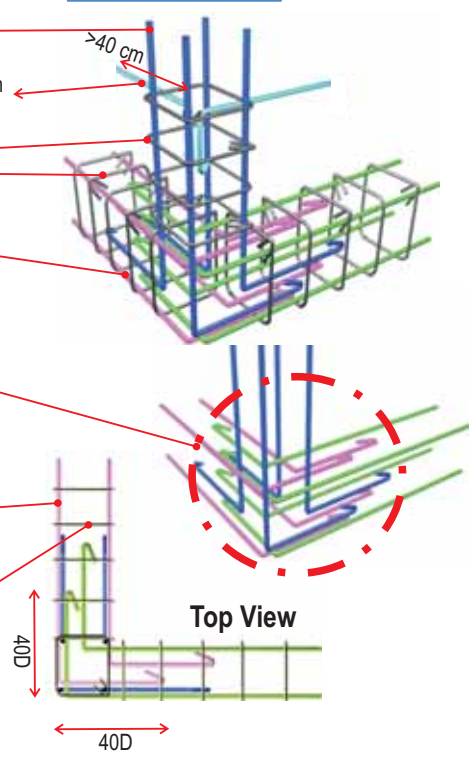


10. FOUNDATION BEAM REINFORCING DETAILING

10.A. MIDDLE JOINT



10.A. CORNER JOINT



11. PREPARING CONCRETE MIX

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

mix properly with a hoe

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

gravel & sand is mixed evenly with a hoe

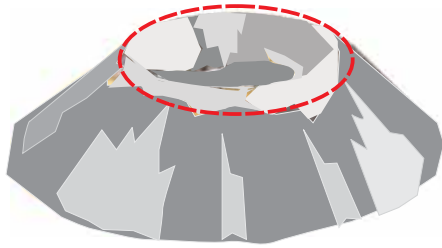
3 Subsequently, add one pail of cement & mix properly with a hoe.

gravel, sand & cement is mixed properly with a hoe

4 After the three ingredients are properly mixed.

gravel, sand & cement that are already mixed properly

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.



Concrete mix that meets standard requirement:

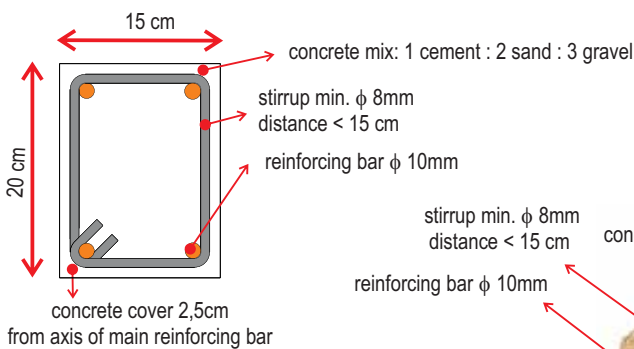
Materials needed for 1 m³ of concrete:

- 0,125 m³ water
- 0,250 m³ cement
- 0,500 m³ sand
- 0,750 m³ gravel

The ratio of water : cement : sand : gravel

1 : 2 : 4 : 6
or
½ : 1 : 2 : 3

12. PLACING CONCRETE IN FOUNDATION BEAM



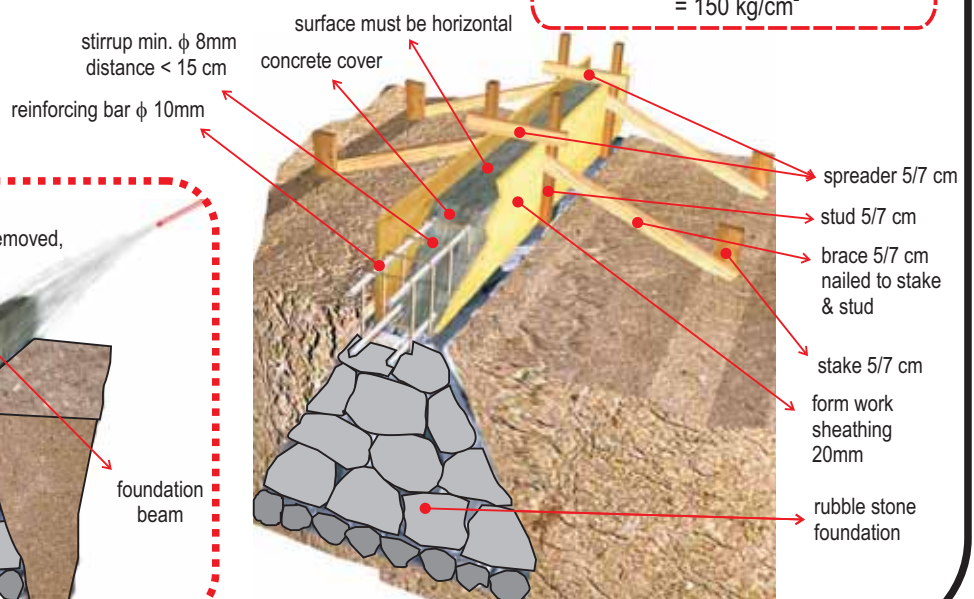
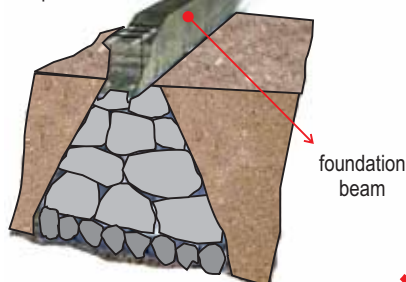
Mix properly with appropriate amount of water

Concrete Mix:

- 1 pc (cement)
 - 2 sand
 - 3 gravel
- Expected min. compressive strength:
= 150 kg/cm²

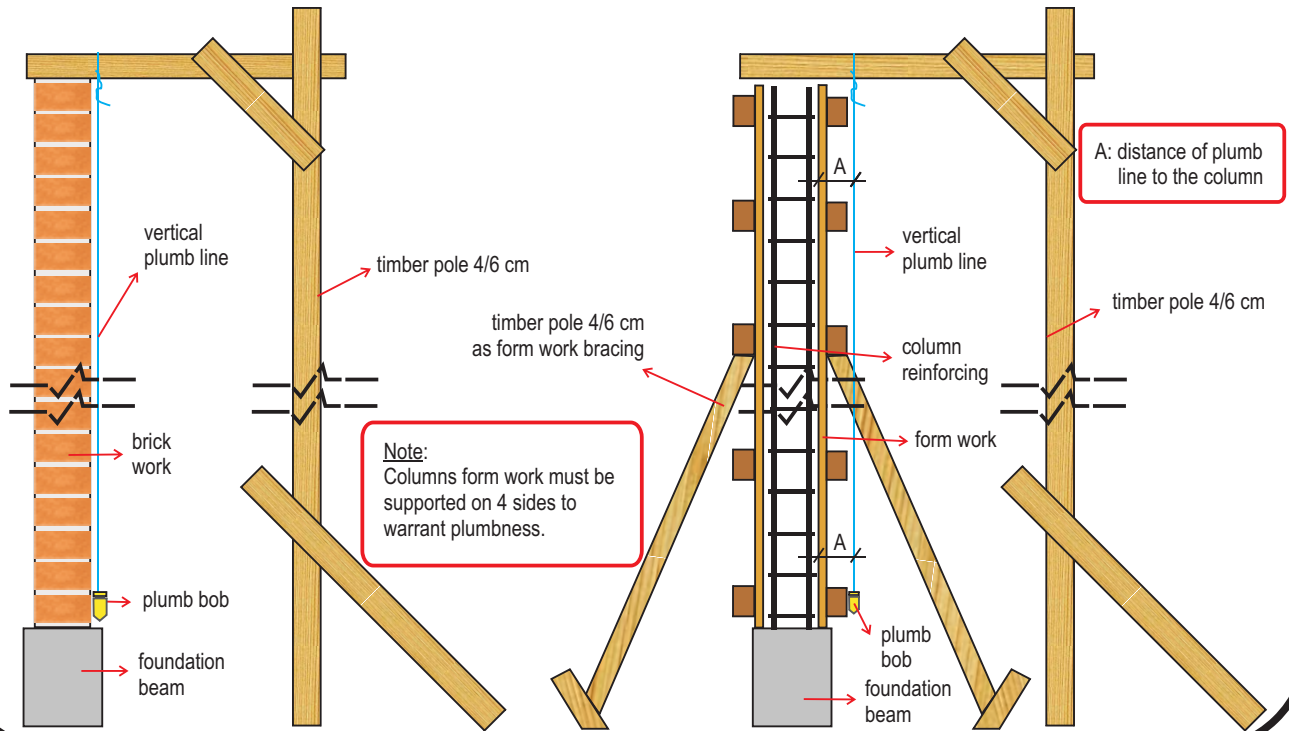
CURING:

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



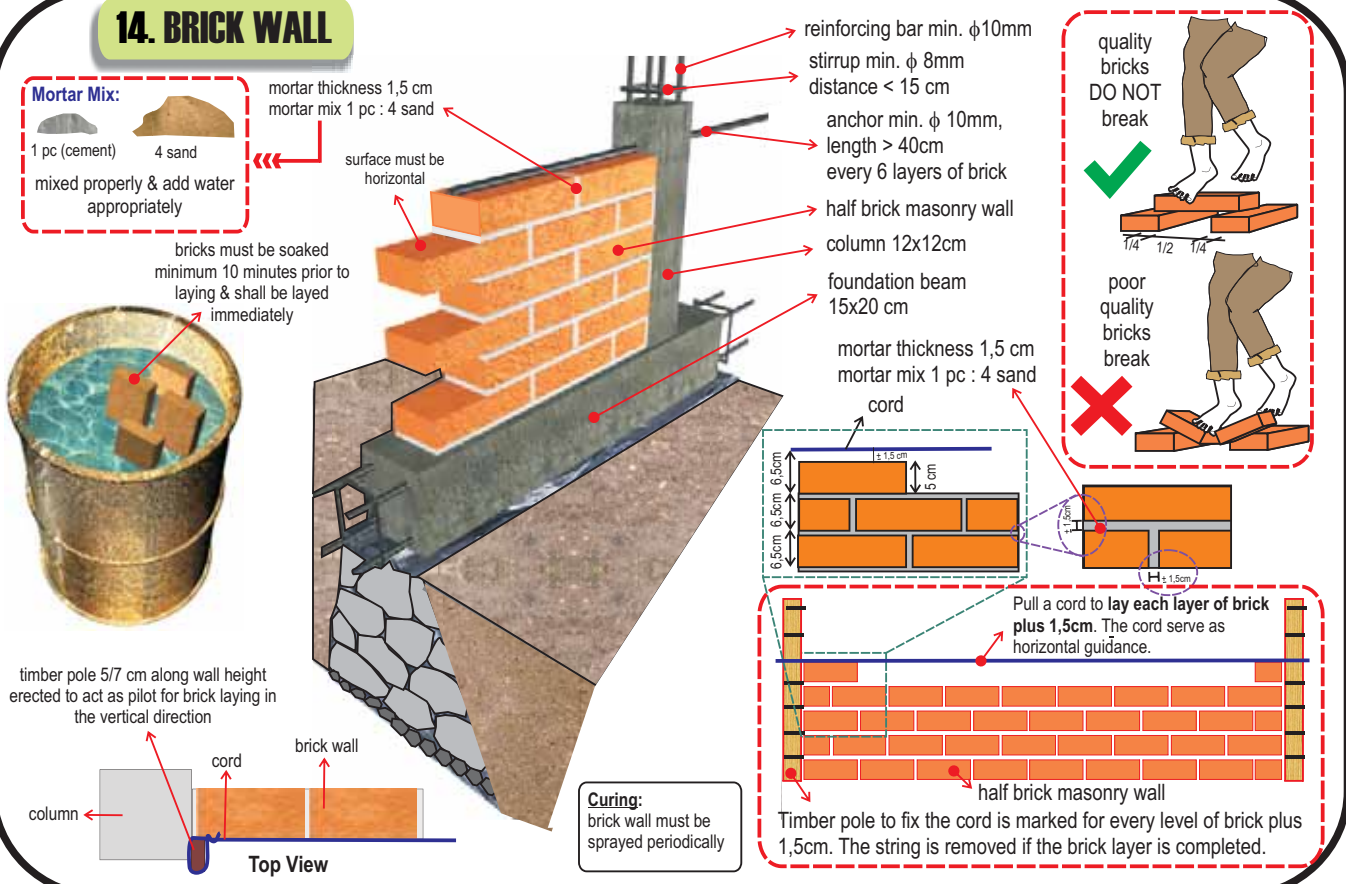
13. PLUMBNESS OF BRICK LAYING AND COLUMNS

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



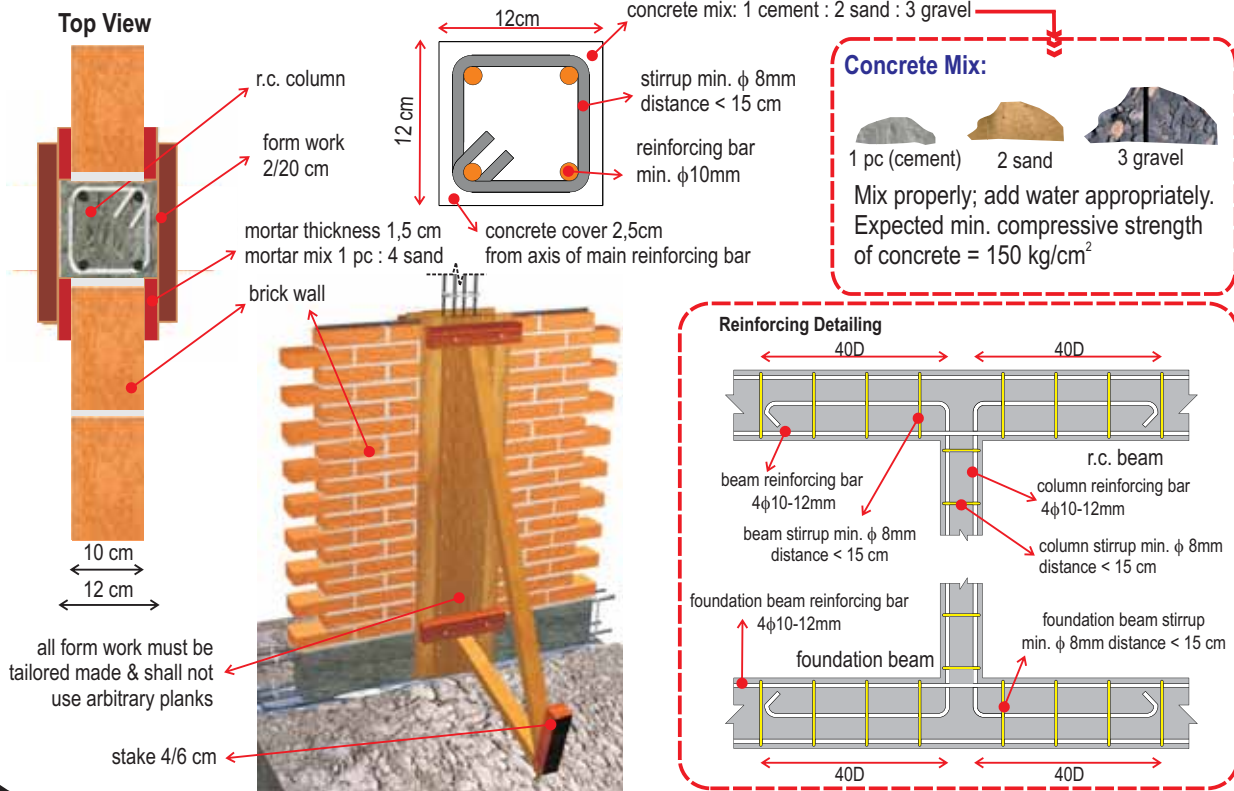
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14. BRICK WALL



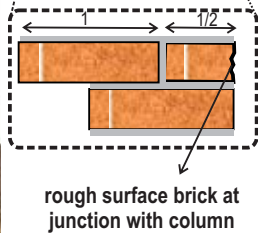
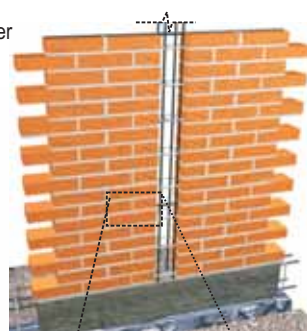
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15. REINFORCING BAR DETAILING AND PLACING CONCRETE IN COLUMNS

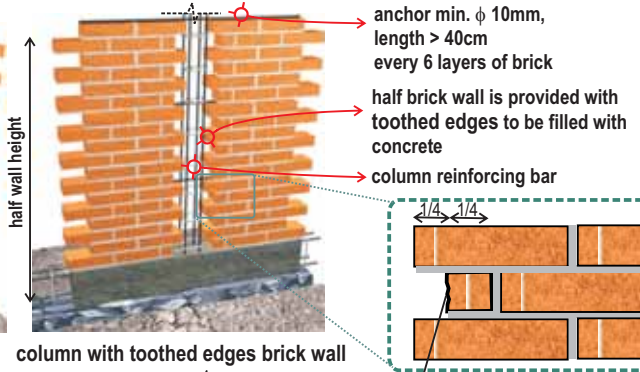


15.A.I. PLACING CONCRETE IN COLUMN SIMULTANEOUSLY WITH BRICK LAYING

Column reinforcing bars supported by timber bracing to prevent bending/leaning



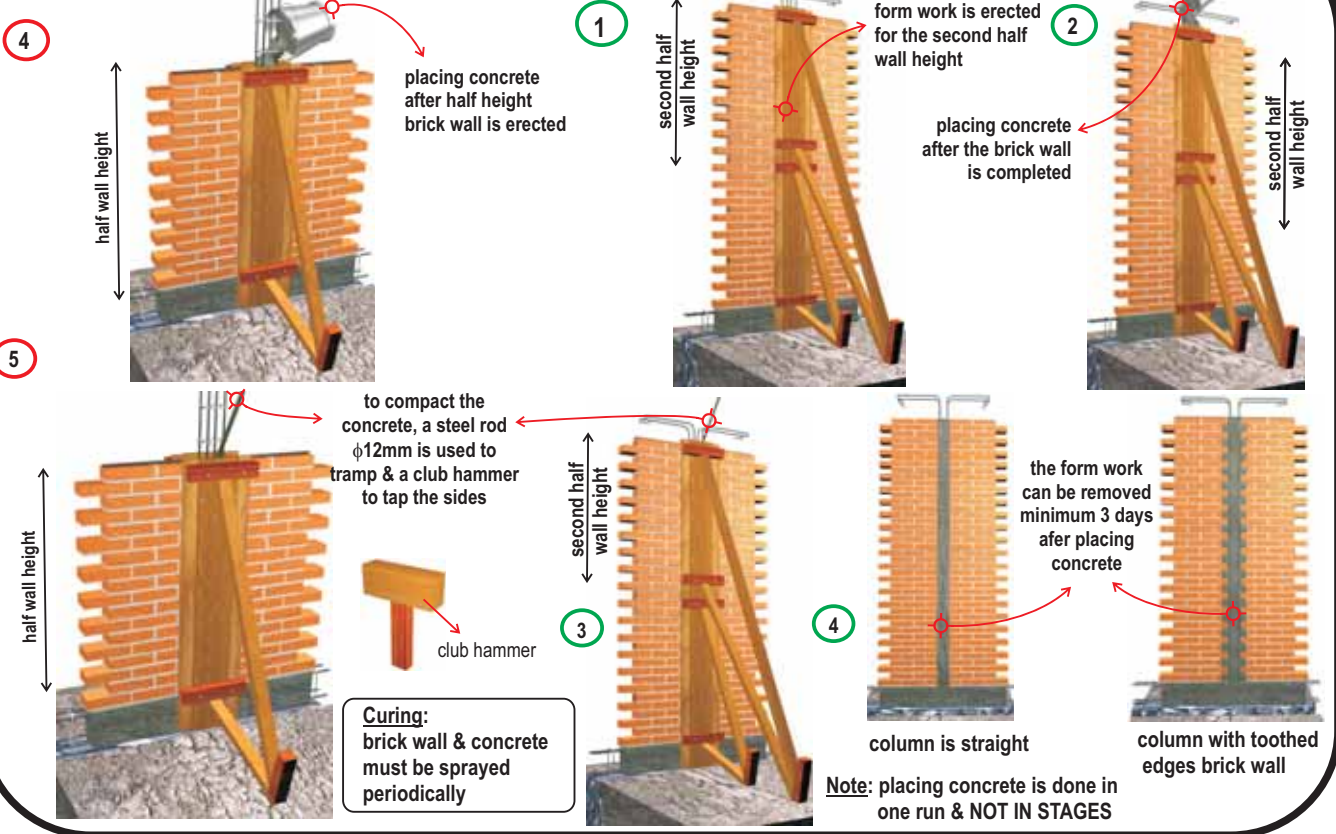
II. PHASE I PLACING CONCRETE IN COLUMN AFTER THE HALF HEIGHT BRICK WALL IS ERECTED



Curing:
brick wall & concrete must be sprayed periodically

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

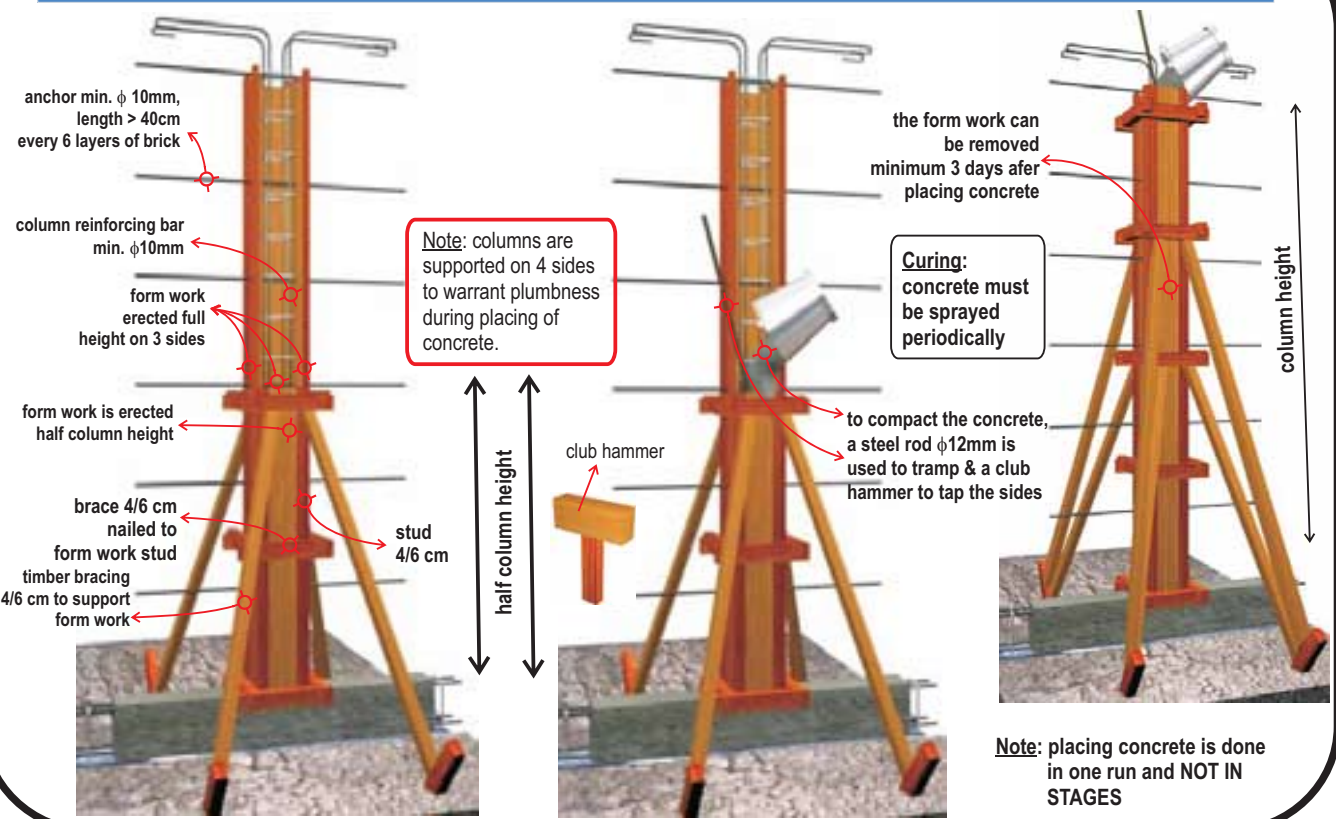
III. PHASE II PLACING CONCRETE IN COLUMN



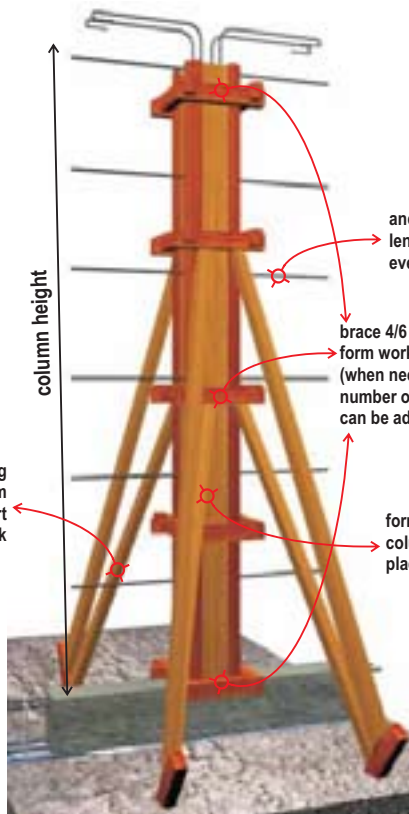
15.B.I. PLACING CONCRETE IN COLUMNS IN STAGES PRIOR TO THE BRICK LAYING

II. PLACING CONCRETE LOWER HALF OF THE COLUMN

III. PLACING CONCRETE UPPER HALF OF THE COLUMN



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



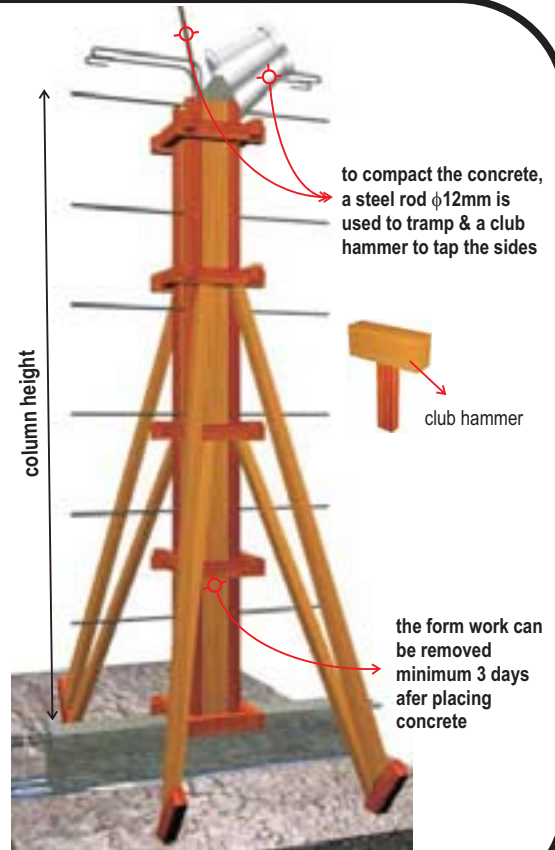
Note: columns are supported on 4 sides to warrant plumbness during placing of concrete.

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

brace 4/6 cm to tie form work (when needed, number of bracing can be added)

form work is erected full column height & ready for placing concrete

Curing: concrete must be sprayed periodically



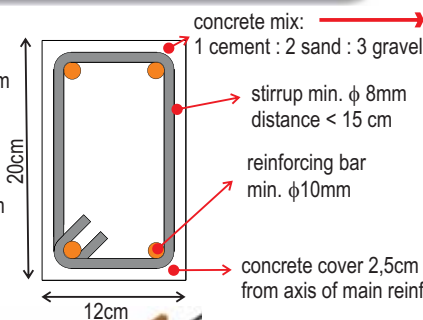
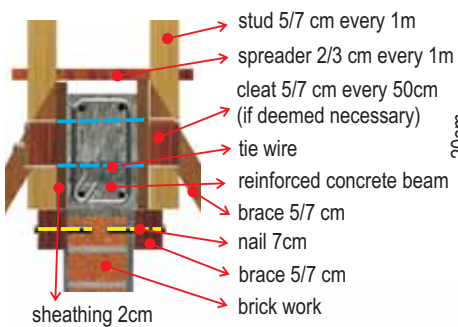
to compact the concrete, a steel rod ϕ 12mm is used to tramp & a club hammer to tap the sides



the form work can be removed minimum 3 days after placing concrete

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

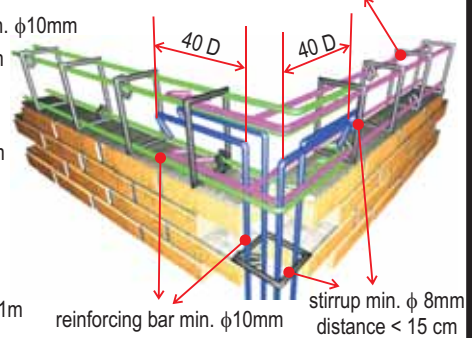
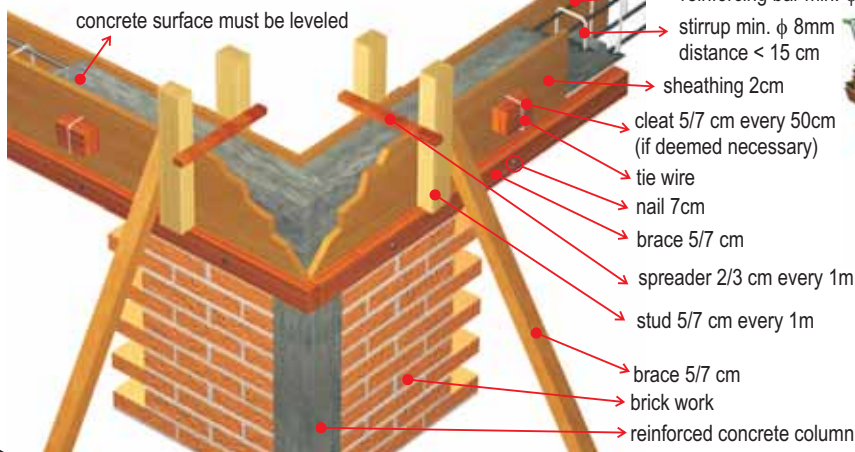
16. JOINT DETAILS AND PLACING CONCRETE IN BEAMS



Concrete Mix:

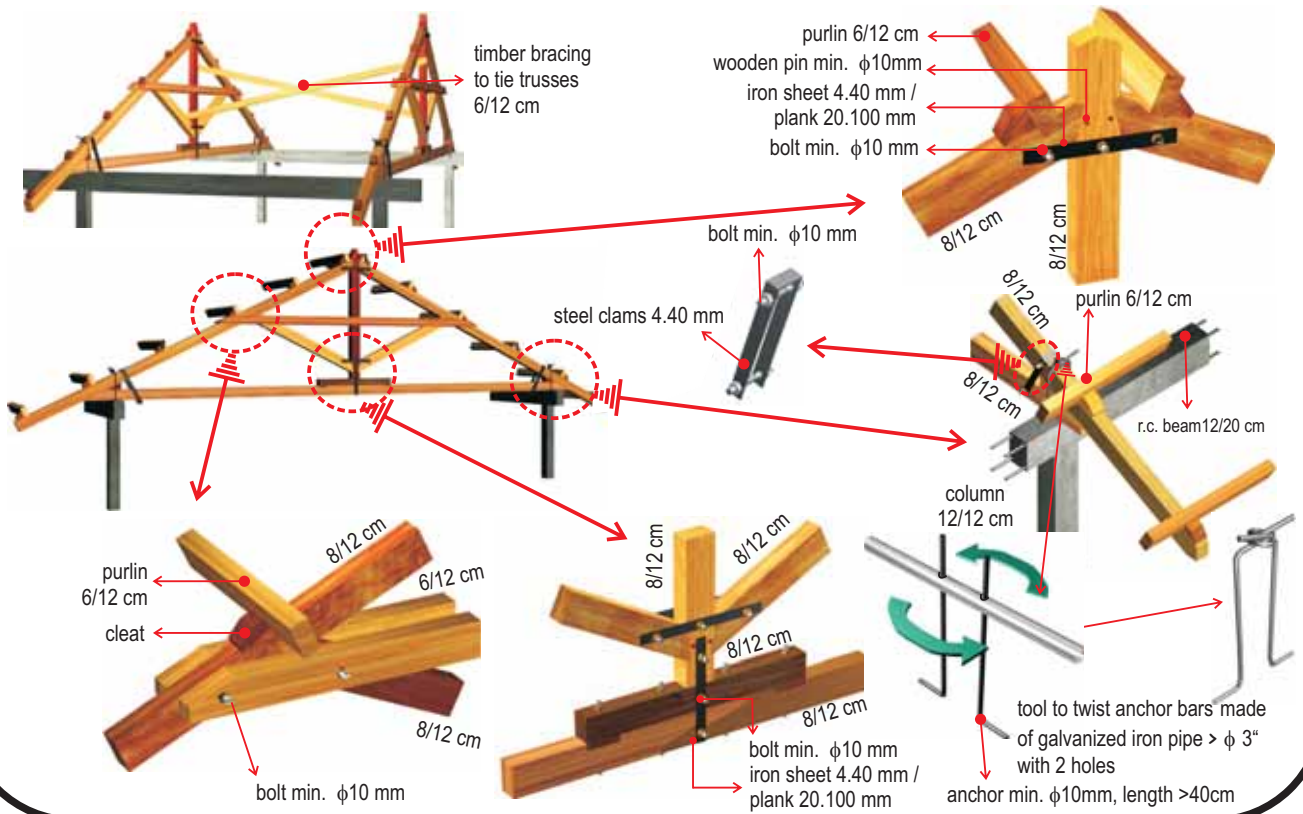
1 pc (cement) 2 sand 3 gravel

Mix properly; add water appropriately. Expected min. compressive strength of concrete = 150 kg/cm²



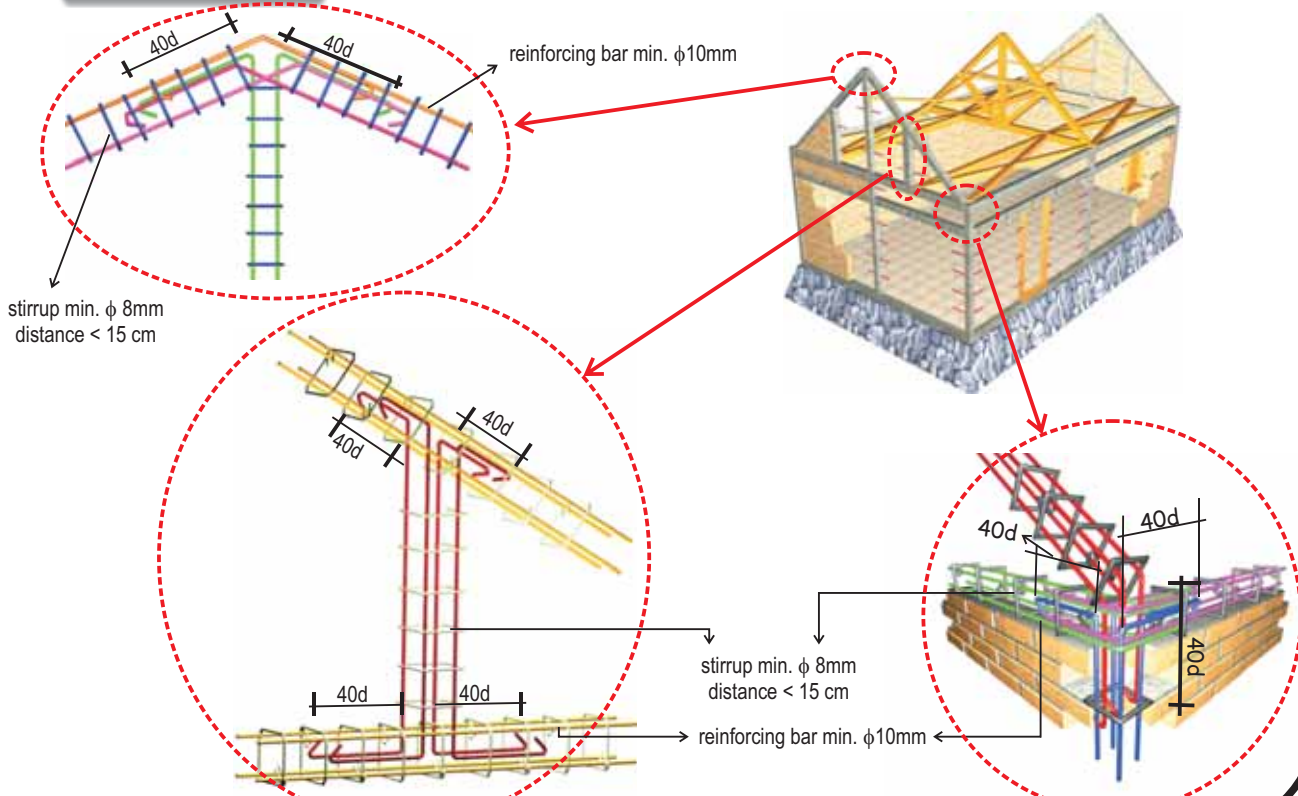
Curing: brick wall & concrete must be sprayed periodically

17. TIMBER ROOF TRUSSES



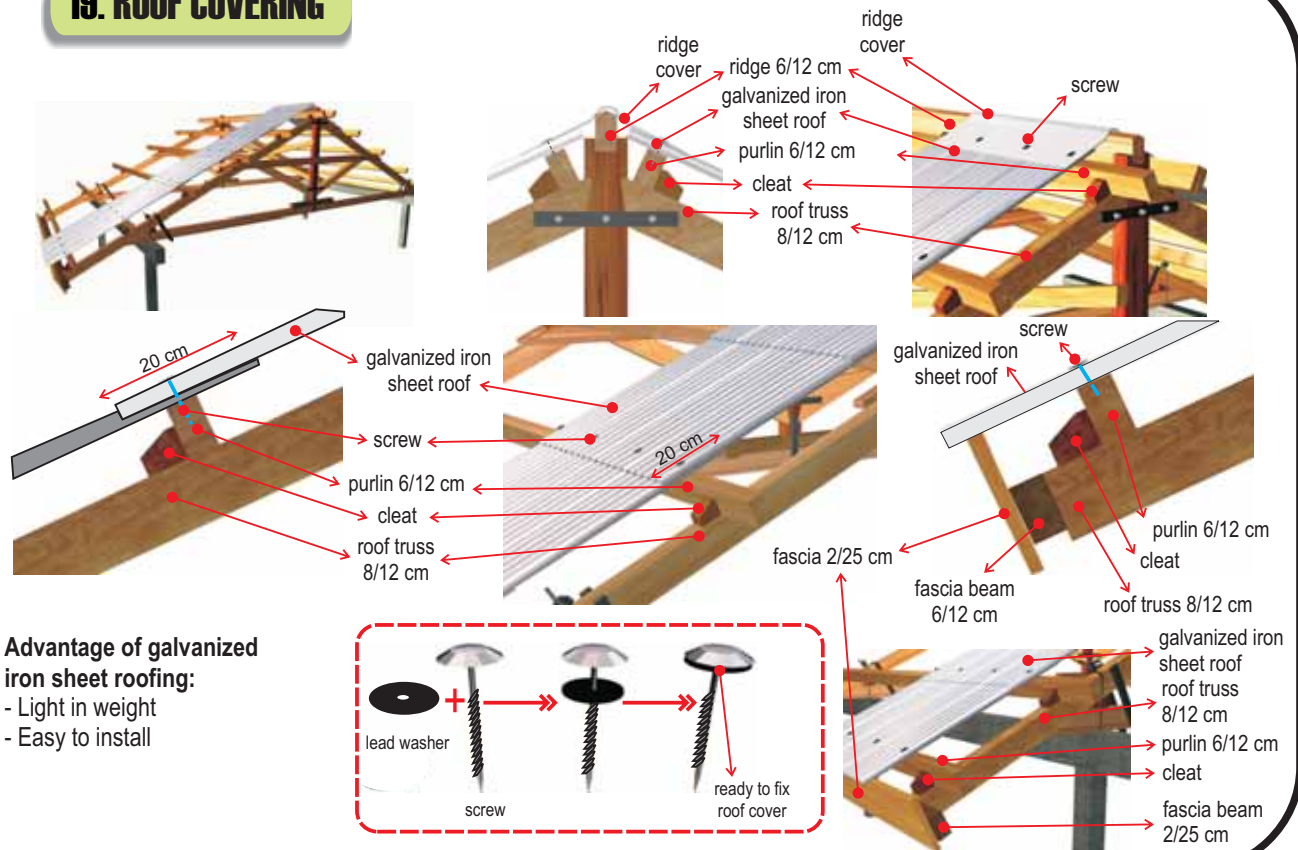
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18. GABLE WALL



26

19. ROOF COVERING



Advantage of galvanized iron sheet roofing:

- Light in weight
- Easy to install

27

REFERENCES

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