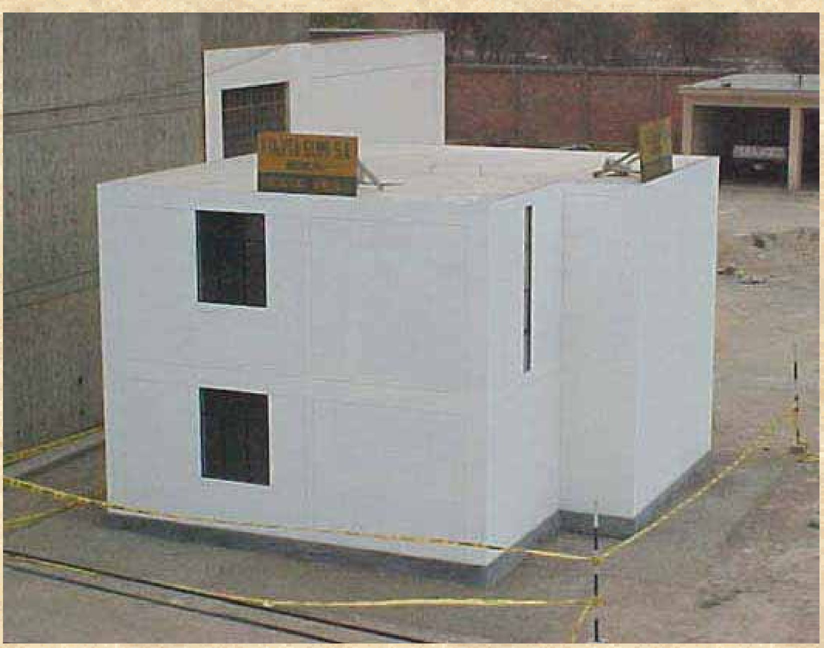
UNIVERSIDAD NACIONAL DE INGENIERIA

STRUCTURAL LABORATORY FULL SCALE TESTING DIVISION CISMID

MASONRY CONSTRUCTION GUIDE



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IDI Infrastructure Development Institute-Japan

CONSTRUCTION OF MASONRY BUILDINGS WITH APPROPRIATED TECHNOLOGIES

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This Guide has been produced upon the basis of the skills and knowledge acquired through the execution of the Construction Technology Development and Promotion Program in semi-developed and developing countries, which is under the supervision of the Ministry of Land, Infrastructure and Transport of Japan.

The program is aimed at introducing to and establishing in developing countries those construction technologies developed by these countries with the adaptation of the state of the art technologies that have been developed in Japan and bear the likely traditional methodologies, after their effectiveness having been certified in the pilot construction work in the local places, and also through its related experiments.

The execution of the program was entrusted to Infrastructure Development Institute-Japan (IDI) by the Ministry of Land, Infrastructure and Transport of Japan, and CISMID compiled the guide with the financial and technological support extended from Japan. A specially organised experts committee discussed and was involved in the technological assistance.

In Peru masonry building with clay brick and adobe is the likely used system in house construction. Those houses suffered severe damages in the past when earthquakes hit them due to insufficient structural resistance to seismic shocks and unsatisfactory quality control of construction work and building materials.

Under the circumstances the program was planned to improve the situation. The project is intended to contribute to the mitigation of earthquake damages by improving the earthquake-resisting capacity (seismic performance) of confined masonry construction. Such improvement is to be achieved in a way that is easy to Peruvian people, which becomes possible through adequate selection of materials, devices in detail of reinforcing steel and adequate construction and its control without effecting drastic changes to the Peruvian conventional construction methods. Experiments for checking the resisting forces of houses and walls will also be carried out by applying force to unit walls and a real-size 2 story house constructed especially for the experiment. And local engineers will profit by seeing and being involved in their construction process. Its ultimate target is to disseminate such improved house construction methods widely helped by the construction guide derived from the program.

This guide represents the accomplishments of the Construction Technology Development and Promotion Program of Japan that can be expected to contribute a lot to the improvement to seismic resistance of the houses in Peru.

I hereby express my heartfelt appreciation to the Ministry of Land, Infrastructure and Transport of Japan, and also to The Infrastructure Development Institute - Japan for their contribution to the improvement of the construction methods of houses in Peru.

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INITIAL REMARK

Masonry houses with good structural performance may be constructed by appropriate construction procedures, good structural detailing and good quality control. This guide has been divided in fourteen sections following the construction procedure. Structural detailing and quality control are discussed between the Japanese Advisor Committee and CISMID considering the Peruvian construction system and the Japanese concept on structural detailing, such as anchorages of reinforcements, and quality control. This guide should be used for two or single story house, because our experiment was performed with a real size 2 story house.

Each section presents questions of how to execute the construction works and also recommendations to assure the quality in the construction site. When an item is very important signal with a small man appear and shows the recommendation in green color. Also if crucial note appear, a signal of stop will appear showing in red color the recommendation. These kinds of recommendations must be follows if the quality wants to be reach on the construction site.

We hope you enjoy the reading of this guide and also spread the knowledge and recommendations among your colleagues. It will help to improve our construction technology on masonry houses.

CONTENTS

THE CONSTRUCTION OF A MASONRY HOUSE

1. Introduction

Clay brick masonry building is the most likely used type of structural system on housing in Peru and South America. More than 43% of housing are built using this system. In last 2001 Atico (Southern Peru) quake housing build with masonry experimented damage. Main reason of this damage is the non quality control on the construction and improper structural configuration. Building a house without following the National Standards of Earthquake design, the Masonry design standard and this Masonry Construction guide could produce damage on the house.

2. Which Materials we use?

- Cement
  Coming in bags of 42.5 kg. It must be protected from humidity for not harden before its use. Storage space should be insulate from soil humidity through plastic sheets or wood stands.

- Sand (fine aggregates: fine and thick sand)
  It will use on the mix with cement, stone and water. Its mission is to reduce voids between stones. Sand shouldn't contain earth (soil), mica, salt, organic filthy, odor, iron compounds, blackish appearance. Don't damp sand before use.

You can prove if sand is bad putting sand in a recipient with water. If too much soil or dust is present, it will separate from the mix.

- Crushed Stone (thick aggregates)
  Stone should be crushed or angular (sharp). Should be hard and compact. Stones easily breakable are not good.

- **Sand & Gravel (natural mix of aggregates)**
  Sand & Gravel is a natural mix of stone of different sizes and thick sand. It is used to prepare concrete of low resistance or quality like run foundation, over-footing, false floor.

- **Water**
  Water shouldn't contain filthy elements, should be clean, drinkable and fresh.

Do not use dirty water

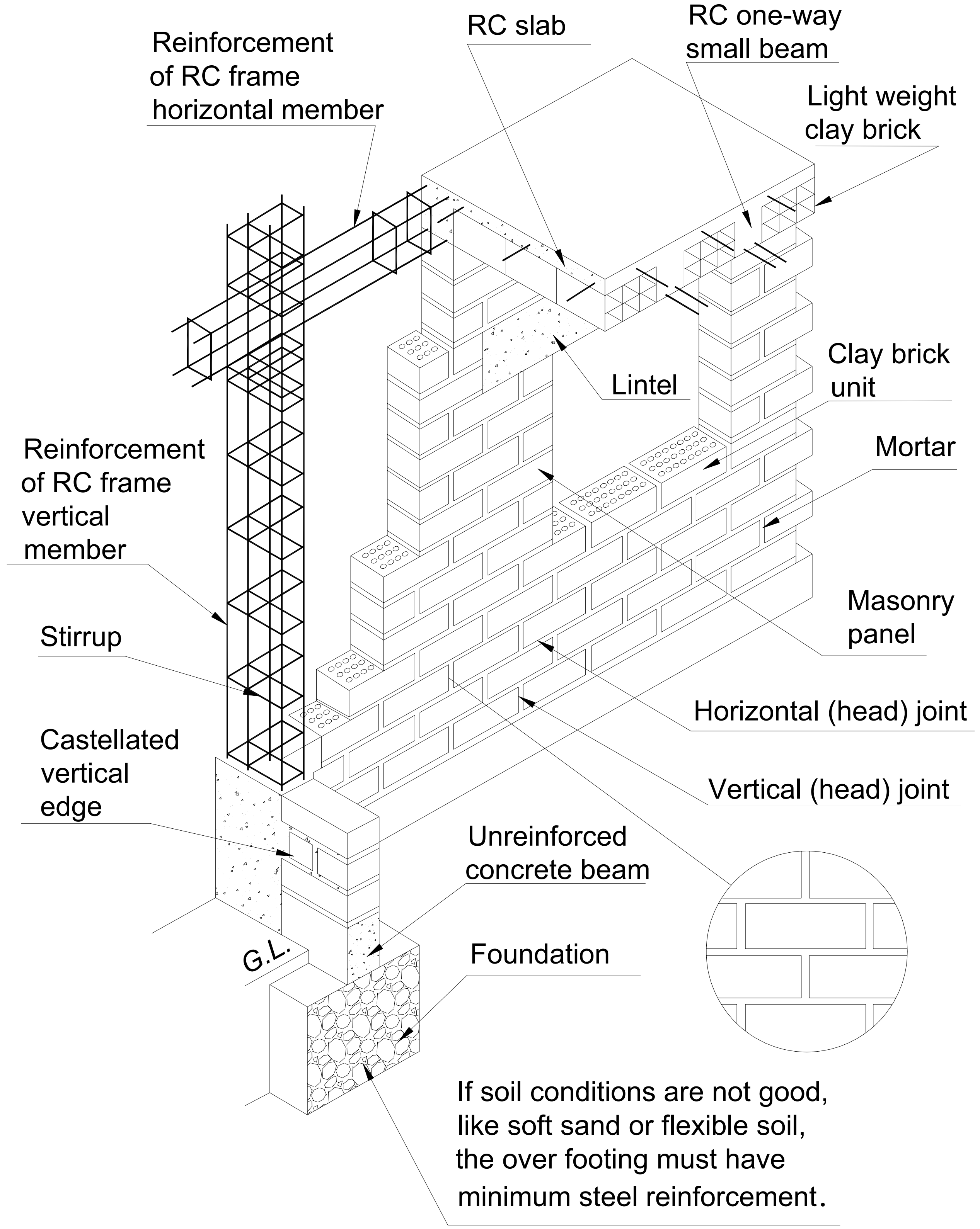
- **Masonry units**
  They are clay bricks and lime-siliceous bricks. Masonry units can be solid, hollow or tubular. To consider solid section without holes must more than 75% of the geometrical area. The minimum compression stress of bricks is 50 kgf/cm^2.

Do not use uncooked clay bricks or irregular bricks. Clay bricks which are so white must not be used.

- **Steel Reinforcement**
  For confined reinforced concrete elements corrugated bars of 9.15m length and diameters of 3/8" and 1/2" should be used. For stirrups or hoops can be used flat bars of 1/4" diameter. For tying reinforcement bars black wire n° 16 is used.
  To prevent oxidation storage of bars can be cover by plastic sheets of wood boards.

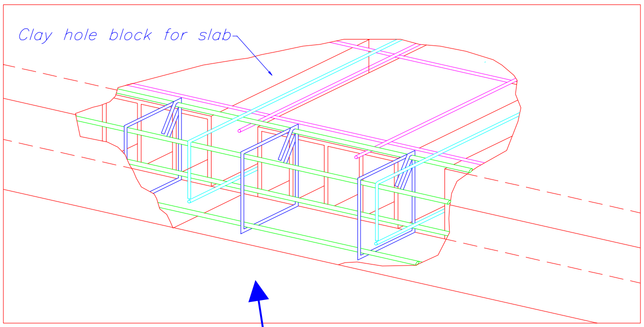
- **Wood**
  Wood boards and braces are used as form (mold). Forms should be dry and protected from water; otherwise it remains humid (wet), swells up and becomes soft. It is used to apply a cover of oil (petroleum) in the surface of wood board before its use as a form.

3. Which elements are part of the structural system ?

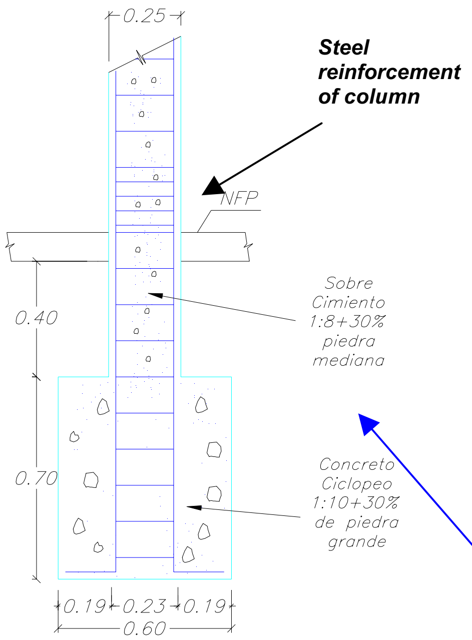


4. Where are these elements and materials in a real house ?

Beam and slab (light block slab)

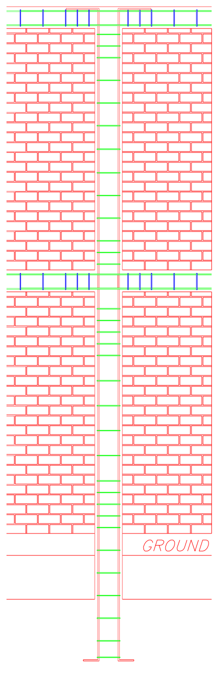


Confining column detail



Continuous (run) foundation
And over-footing
(vertical extension of foundation before layering of masonry units in order to protect them from humidity of ground)

Detail of the Confined Column in its whole length.



Main structural element:
Masonry Bearing Walls
(Masonry and its confining
Elements: beams and columns work jointly)

5. How do you know if walls amount is enough?

Structural design project is necessary to compute the reinforce elements, confinement elements, walls amount, footings and others.

A preliminary computation usually used in the design phase of the project is the procedure known as wall density ratio. This procedure is very simple and consists in finding the ratio between walls area and story area. The ratio should be examined on each floor. It should also be examined severally in the vertical direction and in the horizontal direction. A wall whose length is under 30 cm. shouldn't be counted because it isn't effective enough.

As a result value the ratio must be compare with a threshold value proposed by the Peruvian committee of masonry standards, which are as follows:

Soil Type	Zone-3	Zone-2	Zone-1
S1	4%	3%	1%
S2	4%	3%	2%
S3	5%	4%	2%

Here the minimum wall density ratio is presented as a percent and is given for each soil type and each earthquake zone in Peru.

- **Example of how to check wall density**

As an example we will consider the two story masonry house experimented in CISMID/FIC/UNI, during this project.

In the Figure on the next page the plan of each story is presented. We will developed the first story wall density requirement as example.

a) Check in the vertical direction on the 1st floor

Each wall is named with two nearest horizontal axis and is own vertical axis. Then each wall is identified its length, which is length of the wall including confined columns and the effective thickness of the wall (without finishing). We already know the area of the story is 51 m2, and the results of the computations are presented in the following table:

Block in	Material	Wall	L (m)	L(cm)	t (cm)	e (cm)	h (m)	h(cm)	Awall(m2)
Side	Masonry	AB1	1.50	150.00	15.00	13.00	2.50	250.00	0.20
Side	Masonry	B'C1	0.50	50.00	15.00	13.00	2.50	250.00	0.07
width	Masonry	AB2	2.50	250.00	25.00	23.00	2.50	250.00	0.58
Side	Masonry	AA'3	0.70	70.00	15.00	13.00	2.50	250.00	0.09
side	Masonry	CD'1	2.70	270.00	15.00	13.00	2.50	250.00	0.35
side	Masonry	DD'3	0.80	80.00	15.00	13.00	2.50	250.00	0.10
side	Masonry	D'E3	0.80	80.00	15.00	13.00	2.50	250.00	0.10
width	Masonry	D'E2	1.20	120.00	25.00	23.00	2.50	250.00	0.28

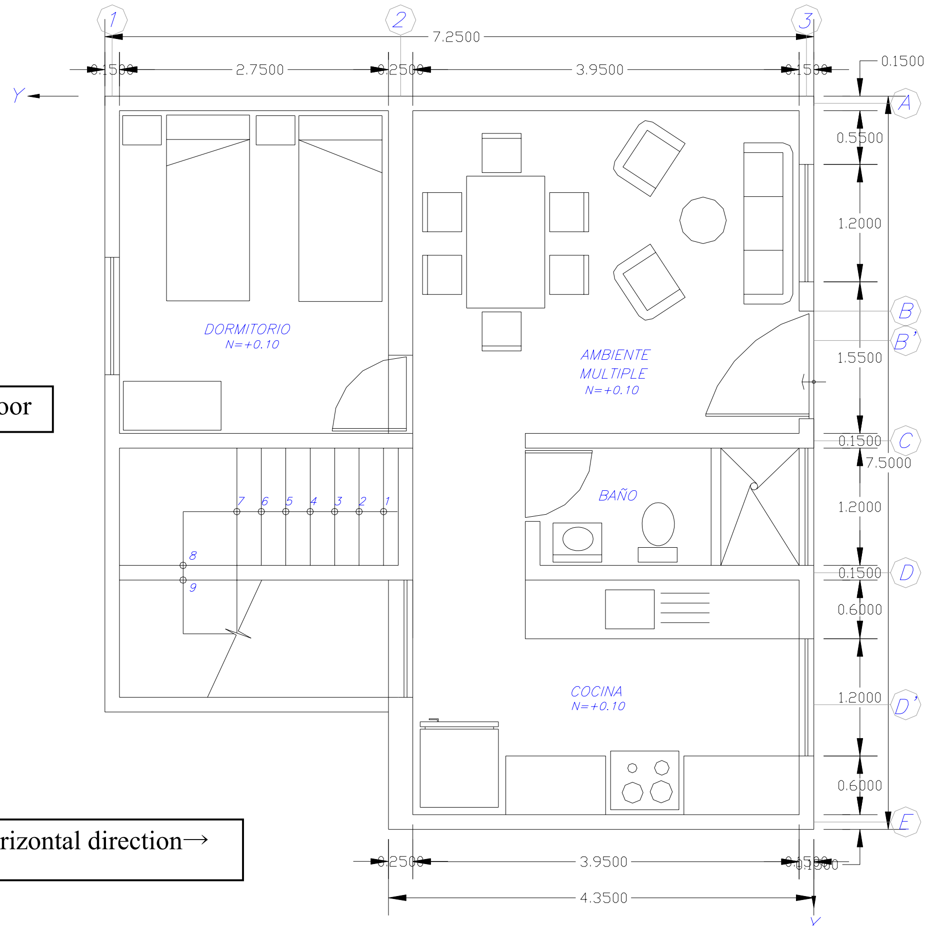
If wall density is less than the minimum required, wall density can be increase increasing the thickness of the wall or increasing stiffness replacing a masonry wall by a concrete wall.

ΣAwall= 1.76 m2
Ahouse(m2)= 51.00 m2

Wall Density= 3.5% ≥ 4.0%
Fail

From the results in the vertical direction we found a wall density ratio of 3.5% which is not enough for our requirement in zone 3 with soil type 2, who need a minimum of 4% ratio. For this reason, if we build it in zone 3 with soil type 2, we need to increase the amount of walls in this direction or we need to replace one of the walls by a concrete shear wall.

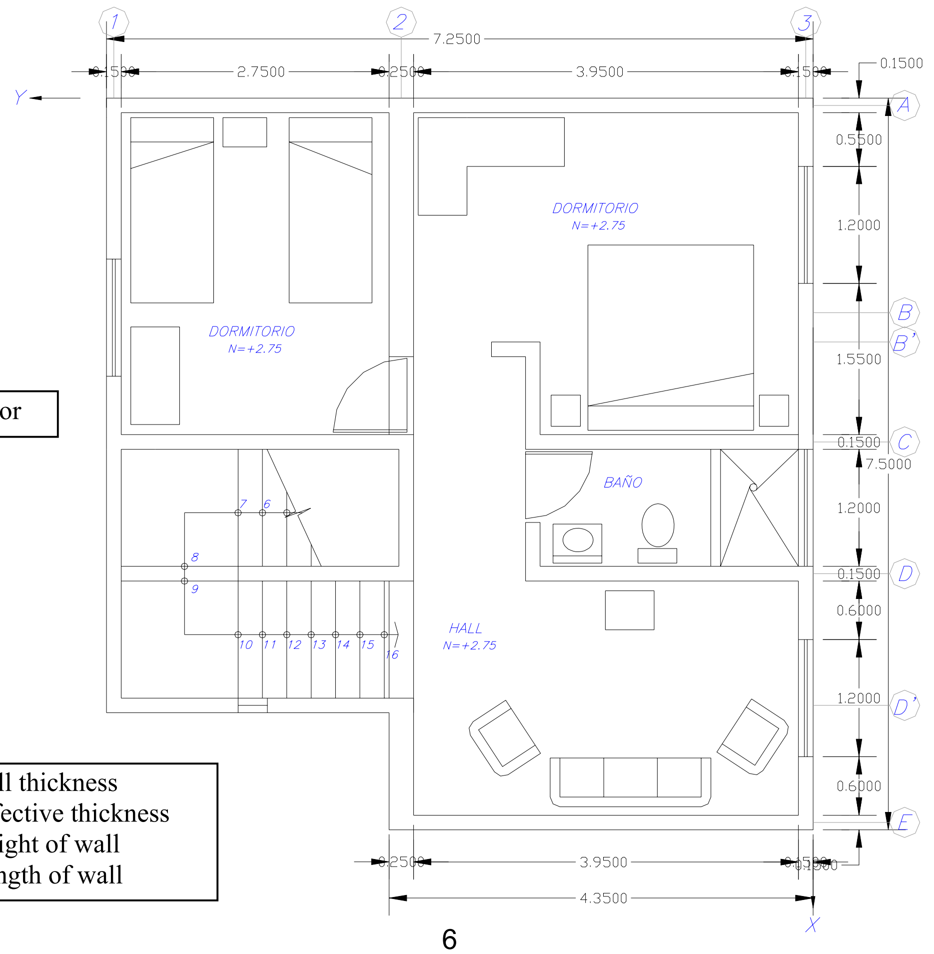
1st floor



←Horizontal direction→

← Vertical direction →

2nd floor



t = wall thickness
e = effective thickness
h = height of wall
L = length of wall

b) Example of replacing by a concrete shear wall

In our example we take this last alternative and replace the wall D'E2 by a shear wall of concrete with the same dimensions. Because material is different, we must find the equivalent thickness in masonry wall for the concrete wall. Then the thickness of the concrete wall is multiply by the ration Ec/Em (ratio between elastic modulus of the concrete and elastic modulus of masonry) to make our computation.

Block in	Material	Wall	L (m)	L(cm)	t (cm)	e (cm)	h (m)	h(cm)	Awall(m2)
Side	Masonry	AB1	1.50	150.00	15.00	13.00	2.50	250.00	0.20
Side	Masonry	B'C1	0.50	50.00	15.00	13.00	2.50	250.00	0.07
width	Masonry	AB2	2.50	250.00	25.00	23.00	2.50	250.00	0.58
Side	Masonry	AA'3	0.70	70.00	15.00	13.00	2.50	250.00	0.09
side	Masonry	CD'1	2.70	270.00	15.00	13.00	2.50	250.00	0.35
side	Masonry	DD'3	0.80	80.00	15.00	13.00	2.50	250.00	0.10
side	Masonry	D'E3	0.80	80.00	15.00	13.00	2.50	250.00	0.10
width	Concrete	D'E2	1.20	120.00	25.00	212.38	2.50	250.00	2.55

ΣAwall= 4.03 m2

Ec= 217000 kg/cm2

Em= 23500 kg/cm2

Ahouse(m2)= 51.00 m2

Wall Density= 7.9% ≥ 4.0%
OK

Concrete wall properties are transformed to masonry wall equivalence

Finally, replacing wall D'E2 by a concrete wall provides a wall density ratio of 7.9% value, which is over the 4% required; this value will assure good behavior against quakes as test results shown.

c) Check in the horizontal direction on the 1st floor

In similar way as on the vertical direction, walls are named with two nearest vertical axes and it's own horizontal axis. Then each wall is identified its length, which is length of the wall including confined columns and the effective thickness of the wall (without finishing). The results of the computations are presented in the following table:

Block in	Material	Wall	L (m)	L(cm)	t (cm)	e (cm)	h (m)	h(cm)	Awall(m2)
Side	Masonry	12A	2.35	235.00	15.00	13.00	2.50	250.00	0.31
Side	Masonry	23A	3.45	345.00	15.00	13.00	2.50	250.00	0.45
Side	Masonry	12C	2.35	235.00	15.00	13.00	2.50	250.00	0.31
Side	Masonry	2'3C	2.30	230.00	15.00	13.00	2.50	250.00	0.30
Side	Masonry	2'3D	2.30	230.00	15.00	13.00	2.50	250.00	0.30
Side	Masonry	12D'	2.35	235.00	15.00	13.00	2.50	250.00	0.31
Side	Masonry	23E	3.45	345.00	15.00	13.00	2.50	250.00	0.45

ΣAwall= 2.41 m2

Ahouse(m2)= 51.00 m2

Wall Density= 4.7% ≥ 4.0%
OK

The wall density in this direction is over the required 4%, and assures a good behavior of the structural system.

d) Check in the vertical direction on the on the 2nd floor

In order to find the wall density ratio for this direction, we must consider the walls who came from the lower level. It means, only the walls who start on the foundation are consider for this computation. Therefore, amount of walls for this direction is the same as the one on the first floor because wall BC3 is not consider. Then, if replacement of wall D'E2 remains on the second floor, wall density is computed in the following table:

Block in	Material	Wall	L (m)	L(cm)	t (cm)	e (cm)	h (m)	h(cm)	Awall(m2)
Side	Masonry	AB1	1.50	150.00	15.00	13.00	5.00	500.00	0.20
Side	Masonry	B'C1	0.50	50.00	15.00	13.00	5.00	500.00	0.07
width	Masonry	AB2	2.50	250.00	25.00	23.00	5.00	500.00	0.58
Side	Masonry	AA'3	0.70	70.00	15.00	13.00	5.00	500.00	0.09
side	Masonry	CD'1	2.70	270.00	15.00	13.00	5.00	500.00	0.35
side	Masonry	DD'3	0.80	80.00	15.00	13.00	5.00	500.00	0.10
side	Masonry	D'E3	0.80	80.00	15.00	13.00	5.00	500.00	0.10
width	Concrete	D'E2	1.20	120.00	25.00	212.38	5.00	500.00	2.55

ΣAwall= 4.03 m2
Ec= 217000 kg/cm2 Ahouse(m2)= 51.00 m2
Em= 23500 kg/cm2

Wall Density= 7.9% ≥ 4.0%
OK

e) Check in the horizontal direction on the on the 2nd floor

In this direction wall 12D' has an opening, and is divide into two: wall 11'D' (before the opening) and 1'2D' (after the wall). Therefore for this direction wall density become:

Block in	Material	Wall	L (m)	L(cm)	t (cm)	e (cm)	h (m)	h(cm)	Awall(m2)
Side	Masonry	12A	2.35	235.00	15.00	13.00	5.00	500.00	0.31
Side	Masonry	23A	3.45	345.00	15.00	13.00	5.00	500.00	0.45
Side	Masonry	12C	2.35	235.00	15.00	13.00	5.00	500.00	0.31
Side	Masonry	2'3C	2.30	230.00	15.00	13.00	5.00	500.00	0.30
Side	Masonry	2'3D	2.30	230.00	15.00	13.00	5.00	500.00	0.30
Side	Masonry	11'D'	0.93	93.00	15.00	13.00	5.00	500.00	0.12
Side	Masonry	1'2D'	0.93	93.00	15.00	13.00	5.00	500.00	0.12
Side	Masonry	23E	3.45	345.00	15.00	13.00	5.00	500.00	0.45

ΣAwall= 2.35 m2
Ahouse(m2)= 51.00 m2

Wall Density= 4.6% ≥ 4.0%
OK

Then, wall density shows a reduction in this direction but is enough to satisfied the required minimum of 4%

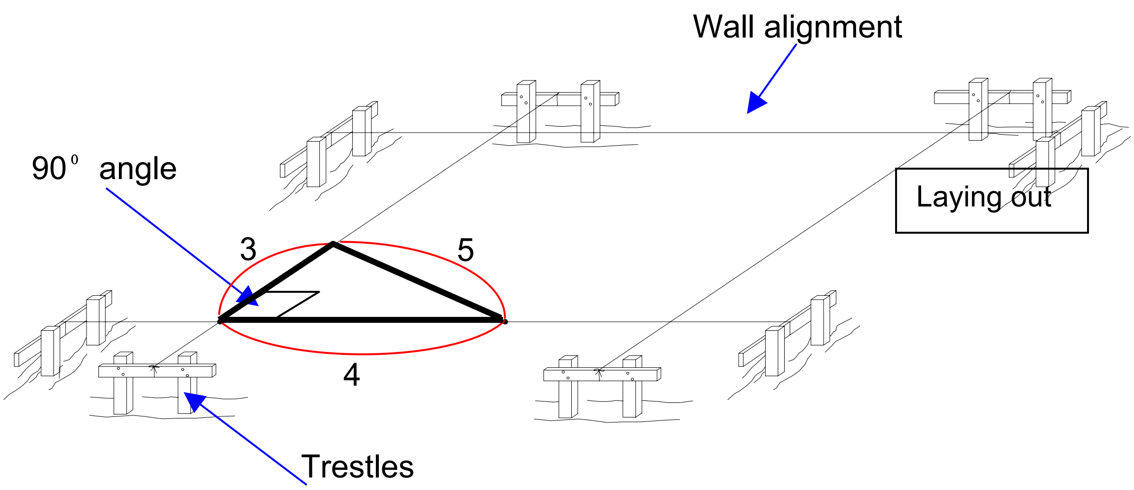
6. What should I do before starting the construction?

- **Preparing the ground**

Ground should be clean, without rubbish neither organic material nor any odd element to the ground.

- **Drawing the structure on the ground**

Ropes (cord) are tightened, using trestles made by wood poles nailed to a transversal stick and embedded to the ground, as shown in the figure. Trestles are placed at external part of build. Check the angle of 90° at the corners making triangle of 3-4-5 length sides, as shown here.



Level of the ground should be verified to know how are the unevenness. It can be used level, theodolite or transparent hose level. Trace of building axis and wall alignment or laying out should be made using gypsum powder, chalk, or similar, marking the trenches for foundation.

7. How should I build the foundation?

- **Site conditions**

The behavior of any foundation depends of the ground condition. Dense gravel, compact sand or silt or rigid clay are example of good ground. Foundations settled on these soils are expected not to experience any problem.

However, if non-controlled landfill or garbage deposits compose the ground, large settlements are expected on the foundation. Therefore construction on these kinds of soils is prohibited.

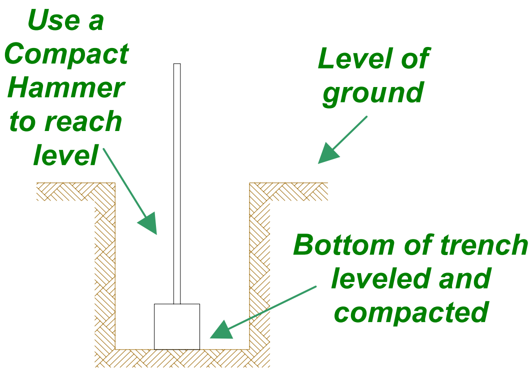
- **Digging of trench**

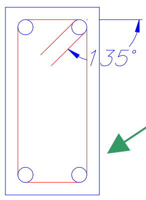
A trench digging for continuous foundation should be made following the structural plans and details.

It is important that foundation to be leveled below the ground level, on natural soil at a depth not less than 1.0 m. If thickness of the shallow landfill is greater than 1.0 m the trench should be over excavated until it reach the natural soil and refilled with simple concrete.

- **Prepare bottom of foundation**

Bottom of trench should be compacted and leveled. Foundation dimensions should consider future expansion of the building like the increasing of the stories, at the time of the design.





Hoops with hooks at 135º angle. The minimum diameter of hoop confinement is with 6 mm.

- **Place the reinforcement of the columns for walls**

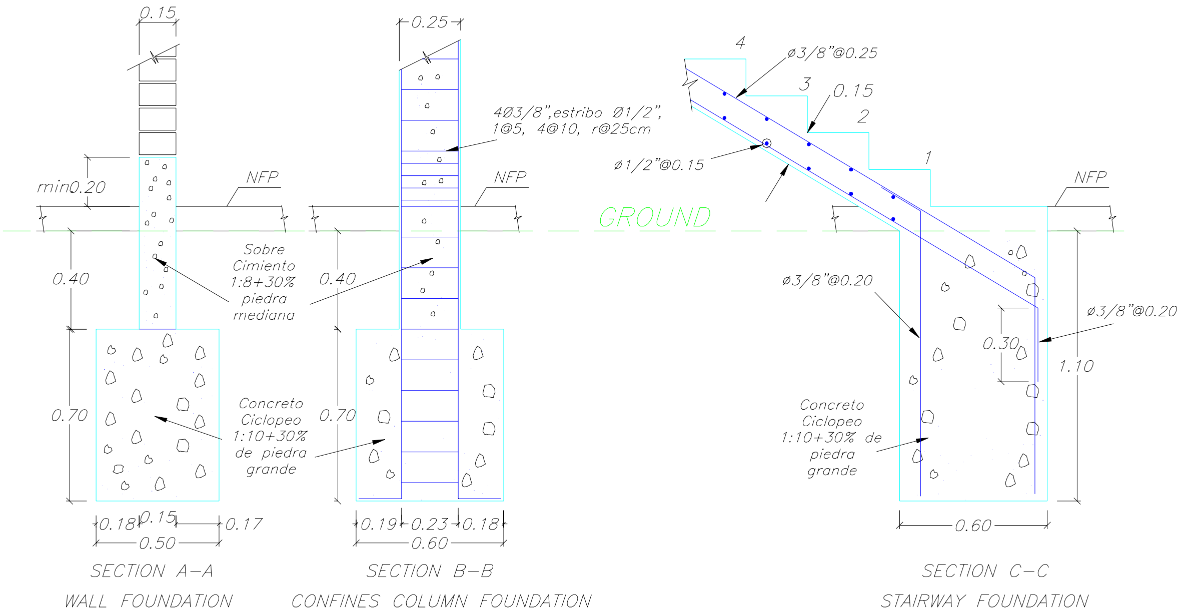
Reinforcement bars of columns -previously assembled as a basket- are placed and fixed into the foundation.

The basket of hoops must have enough space to let in concrete vibrator device into the column

- ## Place the simple concrete in the foundation

With reinforcement of all columns placed and provisionally fixed, continuous foundation is filled with simple concrete. For foundation the mix of simple concrete contains a cement-(sand-gravel) ratio of 1:10 plus 30% of big stones. For the over footing the cement-(sand-gravel) ratio for the mix is 1:8 plus 30% of medium stones.

- ## Detail example of foundation



The upper Figure shows examples for good soil condition of likely used types of foundation: Section A-A: 0.50x0.70m foundation for 15-cm thickness wall.
Section B-B: 0.60x0.70m foundation for confined column on 25-cm thickness wall.
Section C-C: 0.60x1.10m foundation for staircase.
When soil condition is not good, increase of width or depth of the foundation is required.

Care should be taken when transporting fresh concrete from mixer discharge to the trench, and also in placing concrete in order to not separate stones from fresh concrete. A good curing should be performed, allowing the concrete to reach enough strength, imperme-ability and durability. Lack of curing causes low resistance and it could appear cracks due to the contraction for drying of concrete.

8. How to build the over footing?

Over the run foundation continues the over-footing to be used as support for the wall. The main purpose is to isolate the wall from the soil and provides protection against humidity. Here it is used wood boards as a form or mold the over footing.

If soil conditions are not good, like soft sand or flexible soil, the over footing must have minimum steel reinforcement to work as a foundation connection beam.

It is recommended to use a mixture ratio of cement, sand and gravel for the over footing of 1:8 plus 30% of medium stones. Also vibrator or rods are required to reach a good mixture.

9. How to build a wall?

To build the wall we must prepare the mortar and prepare the bricks before start the process. Above the over-footing, it starts layering of brick units over mortar bed, forming masonry walls.

- **Preparation of the bricks**
  Bricks should be wet before layer them so they don't absorb water from mortar and obtaining a good adherence mortar-brick

- **Preparation of the mortar**
  To make the mortar, the mix will have thick sand - cement ratio of 5:1. Sand and cement should be mixed dry, out from the tray. Next this dry mix is put in the tray mixing it with water.

- **The construction process**

1

Masonry units (bricks)

Bricks should be wet before layer them, so they don't absorb water from mortar, and obtaining a good adherence mortar-brick

Cement
Thick sand
Water

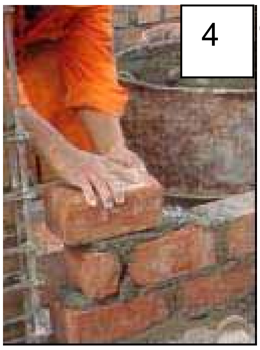
2

To make the mortar, sand and cement should be mixed dry, out from the tray. Next, this dry mix is put in the tray mixing them

3

Using a palette or brick layer's trowel mortar are placed over bricks in a way mortar penetrate bricks holes

4



Over mortar bed are placed the bricks.

5

Each layer of brick, should be checked vertically using a lead weight

6

Bricks at lateral edges of wall will be the "master brick". With the help of a screed board and a cord fixed between master bricks it is verified horizontal level and the thick of mortar joint, which should be the same for all bricks in the layer.

7

The wall reaches its final height

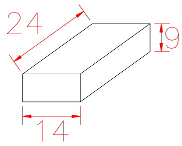
Verify the vertical level of the wall after each layer. Do not build more than 1.2-m height of wall per day.

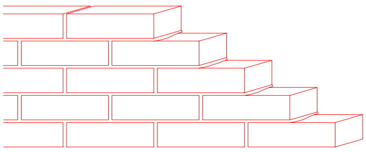
- **Additional Notes**

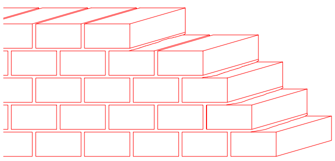
For the next layers this procedure is repeated. It is important the thick of mortar layer, if excceds1.5cm, resistant of resulting wall will be lower.

To cut a brick unit, it is used the small pick ("picota"). The pointed edge is used to mark and the opposite side is used to cut and clean the lateral surface of brick. Up to 1.50m high, worker can be stand and making the placing of bricks. Higher than this, it should be used scaffold where place materials and tools.

Considering as example handmade bricks with dimensions of 14x24x9, the bricks can be layered longitudinally (wall thick of 14cm), or layered transversally (thick of wall is 24cm).







When bricks are hand-made, there are variability in its size, obtaining a non uniform wall thick.

Wall shouldn't be picked or broken to make pipe installation inside. It should be left needed space to contain water, drainage, or electric piping. It means that in the place projected to cross a pipe, it should be left a space without brick, place the pipe and then the space will be filled with concrete. Piping should always run vertically, never diagonally.

The ratio between the product of wall length by its thickness in reinforced walls and the area of the floor is named wall density ratio. For Housing on flexible soil wall density ratio must be at least 5%. Under good soil condition wall density must be at least 3.5 %.

10. How to set the confining columns to the wall?

Be sure the reinforcement bars of the columns and stirrups were placed and fixed properly at the stage of the foundation.
Maximum distance between confining columns in a 14cm thick wall is 3.50m and for a 24cm thick wall is 5.00m. In both sides of a wall an empty place for column place when layering bricks edges of wall are "teething" (castled vertical edge) making layers not aligned vertically at the edges of wall -as shown in photo -, and obtaining a better tying or anchorage between column and wall.

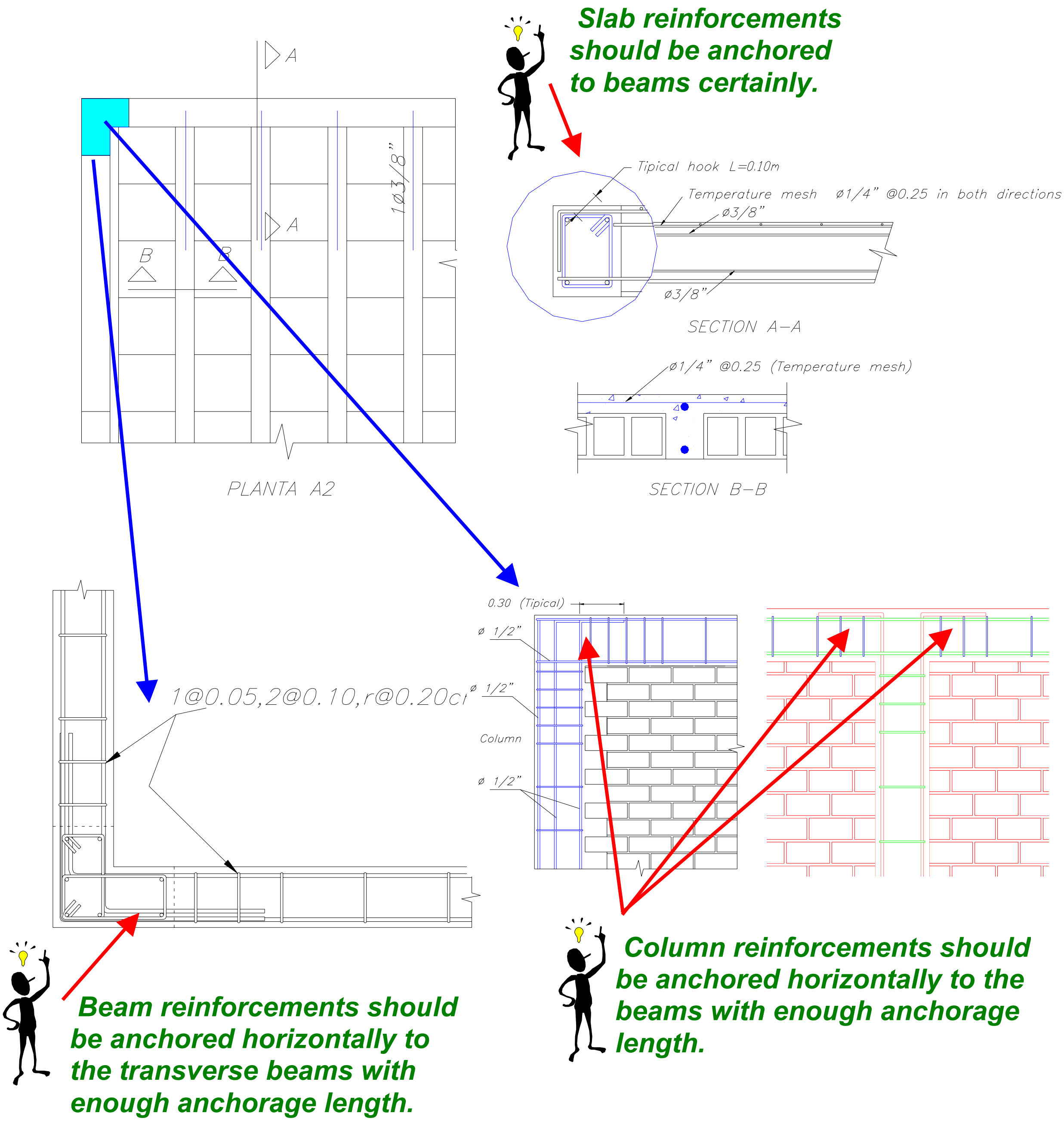
- **Placing the forms**
  The forms are made from wood panels or steel plates. Bracing of the panels is needed to assure stability of the form.

- **Placing of concrete**
  The concrete must be transport by the operator in clean cans and drop from the top of the column. The process must continue in order to assure uniformity of the mix and avoid dry joints among it. Vibration of the poured mix is required.

When placing concrete a good vibration should be perform (through the use of vibrator devices if possible) in order to get a continuous element without air pockets (vacuum bags), which weakens wall resistance. For concrete with strength resistance of 210kgf/cm^2, the volume proportioning of materials is 1 of cement, 2 of stone and 2 of sand. The water cement ratio is around 0.45. Amount of water can be varied based on the test mixing because weather conditions, temperature and other external factors.

11. How to tie the walls and Columns?

At the upper part of walls and between columns are made the collar beam, which distribute load from slab, supply confinement and anchorage to the wall.
Collar beam is as wider as the wall thick and its height are the same that slab thickness –but 17cm as a minimum-. Minimum reinforcement bars are 4#3 bars with stirrups spacing each 25 cm. Concrete for beams and slab are placed together.



12. How to build the slab and beams?

- **Preparation of Forms and Steel Reinforcement for beams and slab**

For concrete element (columns, beams, stairway and slab) reinforcement are corrugated bars of steel, cut in appropriate length. After finishing wall construction and with arrangement of beam reinforcement, forms for slab are placed. The anchorage and developing length of bars must be considered and also the minimum covering for the bars (see Table bellow).

Minimum covering for concrete elements placed at site construction	
Description	**e (cm)**
Elements in contact with ground or exposed to weather	
For diameters equal or smaller than 5/8▯h	4
For diameters more than 5/8▯h	5
Elements placed above ground or in contact with sea water	7
Elements neither in contact with ground nor exposed to weather	
Light slabs	2
Walls or shear walls	2
Beams and columns (measured to the stirrup or hoop)	4
Shells or folded thin slabs	2

If wood forms are used, wetting the plates prior the concrete placing is recommended, which is a similar procedure to wet bricks. It demands extremely care for keeping the level of the forms. Only small deformation of the plates due to concrete mix pressure is allowed.

Splice length of steel bars should be checked according with its diameter. Splice length should be at least 20 times the diameter of bar

Levels of bottom boards of the form for slab and beams must be checked, to assure the height of the story.

Before place the concrete on the slab verify the position of tubes for electrical wires and devices. Also verify the position of the water and sewage sanitary pipes.

If you are working in a high floor use a electrical lift for transport the concrete or use a ramp for transportation using bogies.

Put wood panels over the slab to route the flow of transit during the concrete place process

- **Preparing the concrete for beams and slab**

For concrete with strength resistance of 210kgf/cm^2, the volume proportioning of materials is 1 of cement, 2 of stone and 2 of sand. The water cement ratio is around 0.45. Amount of water can be varied based on the test mixing because of weather conditions, temperature and other external factors. A mixer machine is recommended to use for the mix of the concrete. Ingredients of the mix are input on the machine in the following order: first introduce ¼ of the water amount, then the stone and the sand, mixing as well as possible, to finish with the cement, to complete the ¾ of water at the end of the mix.

- **Placing the concrete on beams and slab**

Prior to the placing of the concrete the surface of the hollow bricks must be wet with clean water to avoid the absorption of the concrete's water by the blocks.

The placing of concrete starts with the slab beams followed by 5cm depth of concrete over the slab. During the placement of concrete for slab, thickness of concrete should be checked, using properly a wood plug or wood rules (furring strip) to screed up to required level by sectors.

A way to do this leveling is making separated stripes of concrete with specified level and then filling the space between them–as shown in the photos. This procedure is repeated side by side successively finishing the entire slab.

A wood stick is used to leveling the surface of the concrete according with the stripes that are used as guidance for the worker.

A good vibration process must be produced to avoid voids in the concrete. Vibrators or steel bars could be used for vibration. If voids or irregularities are appeared in the concrete the resistance in the concrete will decrease.

After placement of concrete, a wood plate or brick layer's trowel (plate) is used to level the surface giving it a better finishing.

Slab should be cured immediately after concrete start to harden (at initial setting) during 7 days at least. The first day or first night of curing is the most important. Special attention should be paid to thin slabs or any structural element exposed to the weather. Forms of slab can be retired after 7 days after its placement. A covering of flat bricks or a mud covering can be placed above slab, in order to prevent the slab getting wet from rain.

The forms must be left during at least a minimum time to get the initial hardening of the placed concrete. The table shows the minimum time in days for each kind of element.

Minimum number of days to put out the forms afer get initial hardening	
Element	**Day**
Walls	1.0
Columns	1.0
Beam sides	1.0
Beam bottom:	
Lenght less than 3 meters	7.0
Lenght betwen 3 to 6 meters	14.0
Lenght bigger than 6 meters	21.0
Slab bottom in one direction	
Lenght less than 3 meters	4.0
Lenght between 3 to 6 meters	7.0
Lenght bigger than 6 meters	10.0

13. How to finish the surface of the elements?



For finishing of wall and ceiling surface it is necessary the use of scaffolds, so covering works with mortar can be made at the entire height of elements. It starts from the upper part and then run down to the lower part. The mix in volume has a proportion of 1 of cement to 3 of fine sand.

It is very important to keep the mortar workable, so the proportion of mixture must remain identically during the whole process.

In columns or concrete elements should be made small picking in order to obtain a better adherence of the mortar to the element. To check the level of surface are used metallic and/or wood squares (angles).
After the surface finishing, metallic or wooden frames for windows and doors could be installed.

Finished all the structural work, door and windows installing, walls and ceiling can be painted. At first sanding process over the elements is performed in order to discover irregularities. Then putty process to cover the imperfections must be done prior to the application of the base paint. Finally paint finishing is put over the walls.



14. How to control the quality of materials?

- **Obtain samples of fresh concrete**

It is important to take samples of fresh concrete from the mixed concrete that is being used in the building. After hardening, those samples should be tested (called compression test) to check the quality and resistance of concrete.

In the following it is described the procedure to take a sample of fresh concrete.

- Take a part of fresh concrete that is being placed.

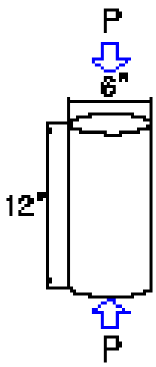
- In a metallic cylinder –should be with standard size- previously greased, put the sample in three steps or layers. Each layer should be compacted with a 60cm length and 5/8" diameter bar, giving 25 strokes as showed in the first photo below.

- Remove excess of concrete, to level with cylinder upper part, obtaining a even surface

- Mark the cylinders to identify the sample with project place, element placed (column, beam, slab, etc.) and date of placing.

- Next day remove hardened concrete from its cylinder form and place it in water for curing. Leave cylinder in water 7 days.

Compression resistance (strength) is given by the following expression:



$$f'c = \frac{P}{A} \ \text{kgf/cm}^2$$

Where P is the maximum force applied to the cylinder at the moment of failure, and A is the section (area) of the cylinder

Compression test are carried out usually at 7 and 28 days from sampling.
Concrete strength depends on water-cement relation and of the level of compacting of the mixed concrete.

Slump

This test is also named cone Abrams test, prove the concrete mix workability used in the project. For this purpose metallic cone with 30cm height, 20-cm.-bottom diameter and 10cm top diameter is used. The way to put the mix in the cone is similar to the cylindrical sample. After concrete is put on the cone, it must be removed to measure the relative settlement respect to the height of the cone.
For a workable mix the relative settlement must be between 3 to 4 inches.

Quality control of masonry

a) Compression test on piles

Piles of 4 bricks are prepared when walls are under construction. Through this test compression resistance of masonry piles is found, where maximum stress is named f´m.
Each block is placed with a mortar joint of a thickness less than 1.5 cm.
The cement -sand ratio of the mortar is the one used on the construction site.

b) Diagonal tension test

The test determines the diagonal tension resistance of the masonry. The test simulates the behavior of the masonry under extreme shear actions where tension appears in the diagonal direction of the element.
A square element with 1.20 m. of length is build with the brick unit to be use in the construction.
The load is applied on the testing in diagonal direction and load is increase under constant rate till collapse occurs.

c) Compression test of Mortar

This test determines the compression resistance of the place mortar for used to form masonry. Cubic samples of 5cm side or cylindrical samples of 5cm diameter with 10cm. height are used as testing. The test is performed in a compression test machine after 28 days of preparation of the sample.

GLOSSARY

Basic Concepts

Beam = Structural element that supports loads in transversal direction to its axis and behaves mainly by flexion. A confining beam transmit loads to the wall
Bearing wall = Wall designed and constructed in a way that can transmit horizontal and vertical loads from an upper to a lower level up to the foundation.
Column = Element of reinforced concrete designed and built to bear and transmit horizontal and vertical loads to the foundation.
Confined Masonry = Masonry method consisting in walls reinforced with confining concrete elements.
Confined Wall = Wall with reinforcement elements (beams, columns) on its four sides.
Confinement = Group of element of reinforcement of concrete (beams and columns) with the function of prove resistance and deforming capacity (called "ductility") to the bearing walls.
Foundation = Part of the building that transmit to the ground the loads and forces of the entire structure
Joint = Gap between elements of a structure in order to control contraction, expansion and vibration and avoiding cracking in the building.
Laying out = When marking on the surface of the ground the position of walls and trench alignment, using stakes and cords.
Slab = Structural element used as a floor or roof, usually horizontal and reinforced in one direction
Wall density = The ratio between the product of wall length by its thickness in reinforced walls and the area of he floor

Materials

Ciclopeous Concrete = Plain concrete, without steel reinforcement, made by "hormigon" and placing on it up to 30% in volume of stones of 10" size as maximum
Concrete = A mixing of cement paste, water, sand and crushed stone or gravel.
Masonry (Albañileria) = Material composed by brick or block units and joined by a mortar to make a wall.
Mortar = A mix of agglomerate (cement), aggregates (sand and stone) and water in a specific proportion. It is used to glue units of bricks
Sand + gravel (Hormigon) = A natural mix of aggregates: sand and stone of river deposits.

Tools and Equipment

Air or bubble level
Used to determine the level difference between two or more near points

Brick layer's trowel
(Badilejo)
A metallic or wood plate or palette used to spread mortar for brick layering or covering (finishing)

Cord
Thick thread used to level bricks between layers.

Lead Weight
Used to determining a vertical alignment. It is composed by a cylindrical form weight made of lead, which is suspended by a thread crossing its center.

Pick
A kind of hammer with one pointed edge and another cutting plane edge

Scaffold
Metallic or wood structure that permit to work in a height place

Screed Board (“Escantillon”)
A metallic or wood ruler with spaces marked to indicate and guide each layer of brick-mortar joint.

Square or Angle
Can be metallic or wooden assembled in a cross of 90° and maintain its position by another diagonally strip

Strut Column
Reinforcement element, horizontal or vertical, its function to proven stability and resistance to the wall against load perpendicular to the wall surface.

Theodolite
Survey equipment, it is used to check levels or angles (vertical or horizontal) from a point of reference.

Tray (“Batea”)
Container where mix of aggregates are placed to make the mortar.