APPENDIX E

COLOMBIA
HOUSE PROCESS

PART 4:
CONSTRUCTION
HANDBOOK

Center for Environmental Structure
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CONTENTS

MAJOR PURPOSE OF THIS HANDBOOK

The essence of the Santa Rosa project lies in the fact that houses are adapted individually to the needs of individual families, and to the special qualities of each unique site in the neighborhood. As a result, each house has a different plan, and the modular design, or steady repetition, common in low cost housing projects, does not occur.

The major purpose of this handbook is to demonstrate how the typical construction system for the region can be modified to take care of the non-modular and non-repetitive character of the houses, without increasing either materials cost or labor cost.

THE ESSENTIAL CHARACTERISTICS OF THE NORMAL CONSTRUCTION PROCESS:

The normal method of construction used in the Santa Rosa area has the following general characteristics:

1. Repetitive design and construction.

2. Standardized details.

3. Modular components as the basis of the construction system.

4. Congruency between component module dimensions and building dimensions.

5. Prefabrication of some components, in large standardized batches.

6. Knowledge of building and detail dimensions in advance, before construction starts.

THE ESSENTIAL CHARACTERISTICS OF THE MODIFIED CONSTRUCTION PROCESS:

The method of construction which is needed to build the Santa Rosa project has the following general characteristics:

1. Repetitive design and construction does **not** occur. Every

house is different, to fit the unique conditions of each site and the special needs of the individual families.

2. Standardized details are used, with some modification to allow flexibility.

3. Modular components as the basis of the construction system.

4. Building dimensions are often not congruent with multiples of the component modules.

5. The same prefabrication of components occurs, but not all in large standardized batches. Certain components are prefabricated to fit the unique dimensions of the individual houses, and a limited percentage of other generally standardized components are also built to fit.

6. Building and detail dimensions are not known in advance.

In making the change from the normal construction process to the modified construction process, so as to allow dimensional variations from house to house, five specific types of problems occur:

1. Problems of construction details and operations.
2. Problems of production of prefabricated components.
3. Problems of construction layout.
4. Problems of sequence and construction time.
5. Problems of building structure.

The first section of this manual addresses the first two difficulties, those of construction details and of the production of components. For every construction operation that is affected by the layout process and the individual designs of the houses, there is an outline definition of the operation or detail as it is currently used. This is followed by a discussion of the anticipated practical difficulties which may arise with its use in an irregular house plan, and a description of low cost modifications and techniques, which allow the normal operation to be adapted to these special conditions, simply and economically, without slowing down construction, and without increasing cost.

The typical variations in plan which arise because of the unusual neighborhood plan, site plans, and house plans include the following features:

1. Complications in foundation layout, which require stepped foundations, retaining walls, and changes in floor

elevations, as the house sits on the terrain.
2. Variation in ceiling heights.
3. Rooms whose dimensions do not correspond to modules of the plaquettas, or to modules of the precast beams.
4. Walls which do not correspond to integral modules of blocks.
5. Rooms which may have non rectangular plans, requiring non rectangular pieces cut in floor elements and roof elements, and requiring non-identical lengths in precast beams.
6. Complications in roofs, due to roof dimensions which do not correspond to modules of the roofing material, or to non rectangular roof plans.
7. Staircases which do not correspond to typical straight runs, but require turns, special landings, and winders instead of standard treads.
8. Window sash and window frames which may be non standard, and must be fabricated to unusual dimensions, horizontally or vertically, without increase of cost.
9. Doors which may be non standard, and which also must be fabricated to unusual dimensions, without increase of cost.

This handbook was written to insure that the houses can be built according to the individual designs of the families, but **without incurring extra construction costs**.

There is a second category of modifications, which are also introduced in the first section of this manual. In order to get good houses, it is our assumption that the houses must have certain important features, which do not normally exist in the standard low cost houses. In order to get these unusual features, without increasing cost, we have invented ultra-low cost ways of building these features, so that they come feasibly within the range of such a project.

Examples of features covered under this second category include:

Garden walls for everyone
Exterior stairs
Retaining walls for front gardens
Ornament around doors
Extra overhang of the roof
Substantial and pleasant cornice/eave detail at the roof edge
Ornamented ceilings
Floor tiles

The second section of this manual deals with the third, fourth, and fifth problems listed above, those of construction layout, sequence and time, and building structure.

In the normal, repetitive method of construction, all building, component, and detail dimensions are known in advance through the use of a repetitive design. This allows a production process relying on the manufacturing of large numbers of identical components, which can be used in the same place in any house. This in turn allows an efficient sequence of production, in which the components are prefabricated long in advance, and can thus be stockpiled, and ready to use at any moment. Additionally, engineering for the houses has only to be worked out once for the standard design.

In normal, non-repetitive methods of construction, either:
1. There is no prefabrication of components. Each piece of the building is built to fit at the time it is needed.
2. All building dimensions are known in advance through the use of elaborate working drawings. Prefabrication of components is then possible, based on dimensions derived from the drawings.

For the Santa Rosa project, in order to keep both the construction costs and the construction time down, prefabrication of components is essential, and individual sets of working drawings are impossible. It is therefore necessary to use a layout and sequencing process in which component dimensions are measured from the building directly, to avoid drawings, but are measured off far enough in advance to allow sufficient time to prefabricate the components. In addition, to help get things such as the placement of openings and the structural system right, specific guidelines, rules of thumb, and allowances are specified by category in the appendix. These rules are used at the appropriate times, in conjunction with the layout process.

In order to make final decisions about the size and placement of certain details, such as windows and doors, this handbook also describes some very quick and rudimentary methods of making these decisions on the site using "mock-ups," which allow families to see just how these details will look in a matter of minutes, and with the aid of simple rules of thumb, which help families to make these decisions intelligently and efficiently without too much fuss and confusion.

SUMMARY OF THE CONSTRUCTION SYSTEM

The Santa Rosa de Cabal project intentionally uses the normal method of construction, typical for low cost houses in the region, with only minor modifications. This is done because it is important that the process defined here should be easy to replicate. It is our hope that the general process pioneered in this project can be widely copied in the next few years. From this point of view, unnecessary innovations in construction will only get in the way.

The construction system for the houses to be built in Santa Rosa de Cabal in Colombia is the typical Construyamos building method of reinforced concrete beams and columns and concrete block infill. Trench foundations are used, with a reinforced concrete seismic ring beam poured on top. Ground floor slabs are free floating within the seismic beams, on grade and level with the top of the seismic beams. Block walls are constructed first, leaving spaces in which to pour the columns, and reinforced beams are poured on top of the blocks at the top of the first and second floor walls. In this handbook these beams are referred to as perimeter beams. The second storey floor is supported by prefabricated concrete beams which are locked into the perimeter beams by pouring the perimeter beams around them. Reinforced concrete plaquettas span between the floor beams, forming a structural floor, on which a finish floor material can be laid. Gable ends are built of block laid up on top of the second storey perimeter beam. Roofs are pitched, and are supported by long bamboo purlins, which span between masonry gables. Roof material is asbestos eternit. The exterior of the buildings are finished with cement plaster. Garden and other walls are built of concrete block and some poured concrete.

SECTION 1:
CONSTRUCTION DETAILS AND OPERATIONS

1. FOUNDATIONS, FOOTINGS, AND RETAINING WALLS

Foundations are built using trench footings filled with balastro and concrete. Footings are built under all load bearing walls around room perimeters. Steel sticks up from the footings at the locations of the columns for the walls. Reinforced seismic beams are poured on top of the footings, and are 20 cm by 20 cm. Slab surfaces are level with the top of the seismic beam. The masonry walls are built on top of these seismic beams. Typically, the footings are poured in the trench up to the level of the ground surface, and are formed by the soil itself. In cases where houses are built on hillsides, the house is primarily cut back into the hillsides, with the footings on the uphill side retaining the soil above.

The layout process produces variations in floor elevations within the individual houses, and floors at elevations in which portions of the slabs are above grade. This results in the necessity of bringing the footings up out of the ground to retain earth for the slabs.

Additionally, in order to provide a solid visual base for the houses, it is desirable to set the walls back from the footings by about 3.5 cm, so as to form an exposed plinth, which is a strong center in itself.

The layout of the streets and yards on the hillside requires that retaining walls be built.

DIFFICULTIES:

1. SEISMIC BEAMS NOT ALL AT THE SAME LEVEL, AND ARE THEREFORE NOT TIED TOGETHER WHERE THEY OVERLAP.

In situations where the seismic beams from different volumes at different levels overlap, reinforced concrete columns are poured between the two beams, tying them together. This solution is already used by Construyamos.

Also note that the changes in level in the houses must be built as multiples of the bricks or blocks, so that first floor wall and stair construction is not complicated.

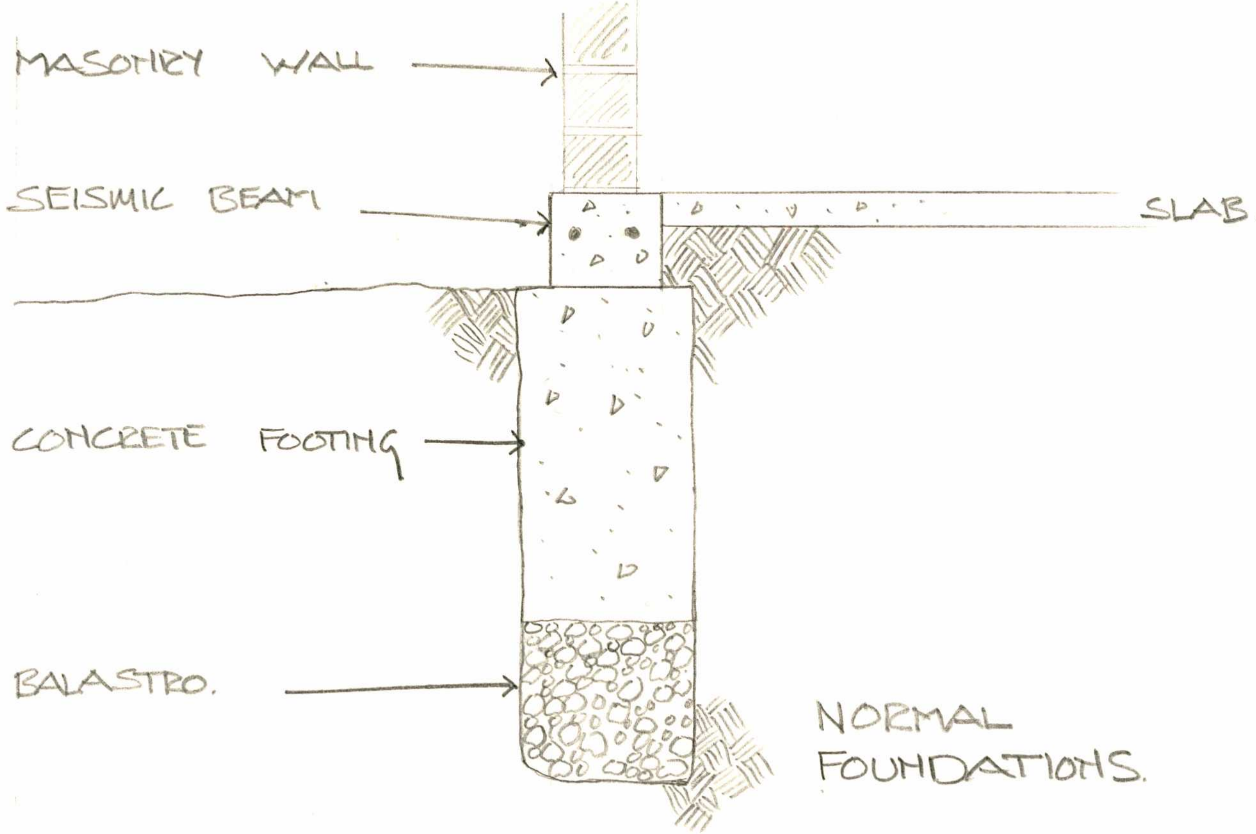
2. EXPOSED FOOTINGS AND RETAINING WALLS REQUIRE FORMWORK, ESPECIALLY ON THE DOWNSLOPE SIDE OF THE HOUSES, AND ALONG THE STREETS.

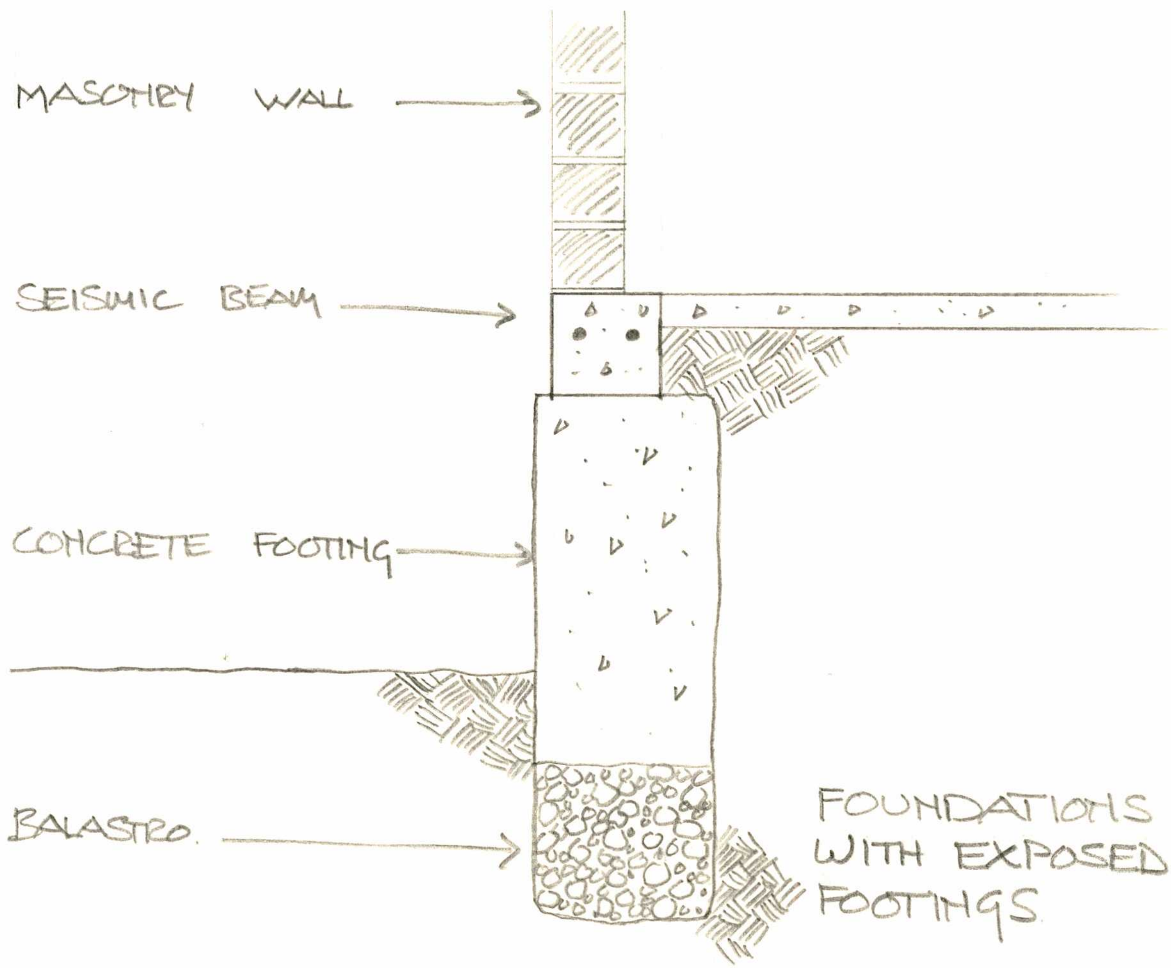
In the typical construction system, when footings have to be brought up out of the ground, they are formed and braced with wood. However, for the Santa Rosa project, footings will have to be formed up out of the ground quite frequently, and so we are proposing the following ultra-low cost method of formwork, so that there will not be a cost increase as a result of the additional forms.
Two methods of forming the concrete are used:

1. <u>On the inside of the footings, backfilling is done before the beam is poured, and the backfill itself serves as the inside formwork</u>. In order to get a stable vertical surface in the soil, cut blocks of dense soil are stacked for backfill, as described in the next section on floor slabs.

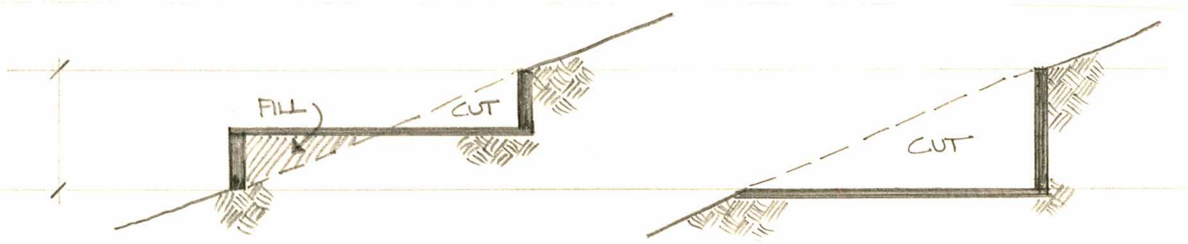
2. <u>The outside of the exposed footings are formed with concrete blocks, which will later be reused in the house, and therefore can be used as forms at no cost</u>. At the most, four courses of block will be required to form the maximum height of the exposed footings. Four courses of block can be temporarily shored to resist the hydrostatic pressure of the concrete with dead weight alone, using additional layers of blocks, sandbags, empty cement sacks filled with heavy soil, and other readily available dead weight. A mold release must be used on the inside of the blocks so they can be removed. Cost free mold releases include smearing the inside faces of the blocks with wet sand or clay, or lining the inside face of the block walls with layers of old newspapers, or even banana leaves. The best mold release will be determined during the construction of the model house. To aid the ease of dismantling the block forms, they are removed from the concrete the day after the concrete is poured, when it is barely cured. The concrete must be kept wet for a day or two after the block forms are removed.
Wood forms are not required to form exposed footings and retaining walls using this technique.

Retaining walls need to be poured concrete only when they are high. In cases where retaining walls are 50 cm or less, they can be built out of concrete block, brick, or local rock.


MASONRY WALL
SEISMIC BEAM
SLAB.
CONCRETE FOOTING
BALASTRO.
NORMAL FOUNDATIONS.


MASONRY WALL
SEISMIC BEAM
CONCRETE FOOTING
BALASTRO.
FOUNDATIONS WITH EXPOSED FOOTINGS

NOTE: For hillside houses, bringing the footings up out of the ground on the downslope side does not involve additional concrete, as the total height of retained earth is the same as if the house were cut back into the hill. Additionally, retaining the earth with two short walls rather than one tall wall at the back reduces the total pressure on the walls, and therefore less steel is needed.



Also note that this method eliminates the problem of disposing of surplus excavated soil, as the soil from the upslope cut is used for the downslope fill.

2. FLOOR SLABS

Floor slabs are free floating within the seismic beams, on grade and level with the top of the seismic beams. Typical slabs are unreinforced concrete, 7 cm. thick, and are poured after the walls are built.

The layout process requires that the slabs be poured immediately after the seismic beams are completed, before the walls are started, in order to be able to do the layout of the prefabricated components at full scale on the slab.

The variations in floor elevations on the hillsides result in slabs being poured partially below original grade on the upslope side of the slab, and partially above the original grade of the hill on the downslope side of the slab, to the tops of the seismic beams. The downslope areas within the seismic beams must be backfilled to produce a level grade 7 cm below the beam tops, on which the slab can then be poured.

DIFFICULTIES:

1. THERE ARE NO ANTICIPATED PROBLEMS POURING THE SLABS EARLIER THAN USUAL.

2. THE BACKFILLED AREAS WITHIN THE SEISMIC BEAMS WILL BE SUBJECT TO SETTLING AND COMPACTION, WHICH CAN RESULT UNEVEN SLAB SETTLING AND CRACKING.

Soil for the backfilled areas is cut directly out of the undisturbed soil on the upslope side of the slab, which must be excavated down to grade before the slab is poured. The dense soil must be cut out in peat-like blocks with spades, and restacked tightly to backfill. Broken shoveled soil must be avoided, to minimize the expanded volume of the backfill. After backfilling, the backfilled area should be further compacted if possible (using local technology, or even stamping or dropping concrete blocks).

3. WALL CONSTRUCTION

Load bearing walls are typically reinforced concrete frames with masonry infill, and are built in the following sequence:

1. The first floor masonry infill is laid up on the seismic beams first, before the columns are poured, with spaces left in the block coursing for the concrete columns. The blocks therefore serve as two sides of the forms. Reinforcing steel is set into this space between the block, and laps the steel sticking up out of the seismic beam so that the columns and seismic beams are tied together. Openings for windows and doors are formed as described in the next section. Block walls are 20 cm. thick, brick walls are 15 cm thick; columns are the thickness of the wall X 40 cm.

2. Wood forms are put in place on the open sides of the column spaces, and the first floor columns are poured within the block walls. The columns are poured up to top of block walls, with steel sticking out of top to tie into beams and columns above.

3. Precast floor beams are set on top of the block walls and the perimeter beams are poured around the ends of the beams, locking them in place.

4. The reinforced perimeter beam is formed and poured on top of the masonry walls, with the ends of the floor beams locked in place by the concrete.

5. The second storey walls are built the same way as the first, except that there are no floor beams at the top.

6. Gable ends on the walls are built of masonry up to the level of the roof peak, with the same pitch as the roof.

The walls are built to the same dimensions in each house, with all walls meeting at right angles, and wall dimensions being multiples of the integral modules of the blocks.

The individual house layouts have walls with unique dimensions, and walls that meet at angles other than 90 degrees.

Because the houses have different configurations and dimensions, column locations are different for each house.

DIFFICULTIES:

1. WALLS WHICH DO NOT CORRESPOND TO MULTIPLES OF THE INTEGRAL MODULE OF THE BLOCKS.

The small module dimensions of the masonry and the method of construction of the walls allows corrections to be made without adjusting the dimensions of the walls. All walls are built with alternating columns and masonry infill: when the masonry is laid up, off module irregularities are taken up in the flexible dimensions of the columns by making adjustments in the width of the columns spaces.

2. NON-ORTHOGONAL TURNS IN THE BUILDINGS.

Turns in the building are always reinforced with columns at the corners. The faces of the adjoining walls provide support and alignment for the formwork, so that the apex of the corner is in the column, and clumsy turns in the masonry are avoided.

3. VARIATIONS IN CEILING HEIGHTS.

Ceiling height variations are produced by changes in elevation of the first floor slabs and the second storey floors. Walls are all formed up to the level of the second storey floor before the perimeter beams are poured. So that wall construction is not difficult, variations in slab elevations and heights to perimeter beams must be in multiples of the vertical dimensions of the blocks or bricks used in the walls, as was described earlier. Note that in cases where second story floors are at different levels, there will be an increase in the lineal footage of perimeter beams which must be formed and poured, due to an additional perimeter beam in each common wall. This condition should be kept to a minimum. In cases where houses are laid out with second floors differing in elevation by 30 cm or less, the second stories should be adjusted so that the floors are at the same level.

4. VARIATIONS IN COLUMN SPACINGS AND BEAM SPANS.

Columns and wall locations (which dictate floor beam spans) must be laid out at the beginning of construction in conformance with the structural guidelines and rules in Appendix B (to be written by CES staff in Colombia through consultation with Construyamos engineers).

4. EXTERIOR OPENINGS

Location of all openings for the normal repetitive houses are known in advance, and are the same for each house. Openings are formed in the masonry infill as it is laid up. There is no reinforcement below or on the sides of the openings. The openings use the perimeter beams above as the headers. All windows therefore have the same header height. Window sills are precast concrete pieces, which are dropped in place as the walls are built.

Openings will be in different places as a result of the different plans of the houses, and are not known in advance.

Many openings will be built to different sizes, depending on how they are laid out.

DIFFICULTIES:

1. DETERMINING THE OPENING LOCATIONS FOR EACH HOUSE, AND ADJUSTING THE BUILDING STRUCTURE SO IT WORKS.

Locations for the openings are determined in three stages. Rough locations are first determined as part of the house layout, and are recorded in the first sketch of the house. These rough locations are then transferred and checked on the actual site after the slabs are poured, so that construction of the masonry walls can be started. After the masonry infill is built up to the heights of the sills (which may vary), final decisions about window placements are made, using the assistance of the CES field staff, and simple techniques for "mocking-up" the openings.

2. BUILDING WINDOWS WITH HEADERS BELOW THE PERIMETER BEAM

To avoid having to use special headers, most windows are built up to the normal height, with the perimeter beams acting as the header. For cases where the header height is slightly lower than the bottom of the perimeter beam, the formwork for the header is built slightly low, so that the concrete extends below the normal bottom line of the perimeter beam. This results in a very small increase in the amount of concrete used. Cases where the header is lowered substantially must be kept to an absolute minimum, and used only for important rooms or situations. The most straight forward way to make the headers is to prefabricate them in shallow box forms, like those used to form the floor beams (see section 5). Forms for the headers are reusable, and two or three should be enough for the whole project. (To eliminate the use of wood forms altogether, headers can be poured in trench forms, cleanly cut into the clay with straight sides, with the bottom surface up, so it can be troweled flat.) The cost of the prefabricated headers is slightly offset by the fact that forms are not required above the openings, because masonry is filled in above the headers up to the level of the top of the wall. In rooms with tall ceilings, the cost of the header will be further offset by the reduction in window area, which is paid for by the square meter.

5. FABRICATION OF FLOOR BEAMS

Floor beams are precast on the ground in shallow box forms, to standard lengths which fit in any house. Beams are then set in place on top of the masonry walls before the perimeter beam is poured. The perimeter beam is poured around the ends of the floor beams, to lock them in place.

The rooms in the houses have different dimensions, and the floor beams must then be produced to fit the unique dimensions of each house. In some cases rooms are non-orthogonal, and the floor beams meet the perimeter beams at off angles.

DIFFICULTIES:

1. PRODUCTION OF LARGE NUMBERS OF BEAMS WITH DIFFERENT DIMENSIONS.

Floor beams are cast on the ground in box forms, using the typical technology. All box forms are built long, allowing any length beam to be made in them. Shorter beams are formed by dropping precut pieces of wood into the box to form a partition. The simplest method of securing the partitioning piece to resist the pressure of the concrete is with dead weight--either a few concrete blocks or a sand bag.

2. OFF ANGLE CONNECTIONS OF FLOOR BEAMS TO PERIMETER BEAMS.

Because the floor beam ends are poured into the perimeter beams, the end condition is unimportant, and right angled ends can be used. In the few cases where the angle is acute enough so that the beam end must be modified, rather than try to form the ends of the beams with braced partitions set on an angle and cut to fit, the standard right angle partitions are used, and the angle is created inside the partition with a piece of filler--styrofoam if it is available, or wadded paper or banana leaves.

6. FABRICATION OF PLAQUETTAS

Plaquettas are prefabricated in large numbers in reusable forms on the ground. They are reinforced with pieces of laminate, a plastic piece with an array of holes in it for the concrete to pass through. A first layer of concrete is poured in the form, the laminate is set in, and the form is filled to the top. The plaquettas are built to standard dimensions of 60 cm X 60 cm X 5 cm. Forms are constructed using pieces of laminate, which are attached together to form a triangular section. These pieces are then attached together to form a ring in which to pour the concrete.

The layout process results in rooms which have unusual dimensions that do not correspond to the modules of the plaquettas. Rooms may be non-orthogonal, and therefore do not conform to the rectangular shape of the plaquettas.

DIFFICULTIES:

1. FORMING THE PLAQUETTAS TO NON-STANDARD DIMENSIONS OR NON-ORTHOGONAL SHAPES.

About seventy to eighty percent of the plaquettas can be made to the normal size and shape of 60 cm X 60 cm. Unusual plaquettas occur only at the edges of rooms, and then only on one or two sides, where they have either different dimensions, different shapes, or both. These atypical plaquettas are built in the same forms as the standard plaquettas. Irregular shapes and unusual sizes are made by dropping a piece of wood into the form to produce the required size and shape. The wood divider is braced with dead weight. The inserts can be reused frequently, and thus must be kept track of closely, as having to cut new ones often would be an unnecessary expense.

2. MEASURING THE UNUSUAL PLAQUETTAS.

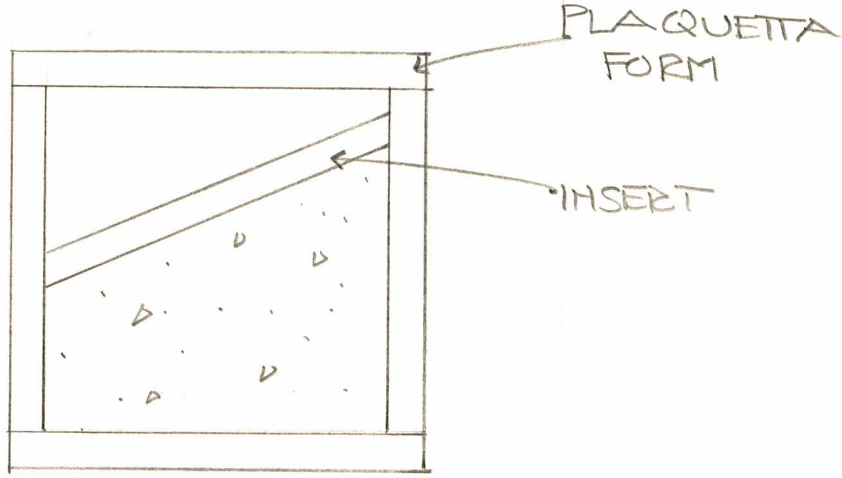
Measuring the sizes for the plaquettas in advance will only lead to mistakes and waste. The unusual plaquettas are therefore measured directly for the space in which they have to fit. Once the floor beams are in place, most of the field of plaquettas can be set down on the beams in their final locations. Along the edges of the rooms where unusual plaquettas will be required, spaces are left, which can then be measured directly. This suggests a two stage production process, in which the bulk of the plaquettas are prefabricated at a centralized location, and then the unusual plaquettas are made at each house, after the standard plaquettas are in place.

3. KEEPING TRACK OF ALL OF THE UNUSUAL PLAQUETTAS, EACH OF WHICH IS BUILT TO FIT IN ONE SPECIFIC LOCATION.

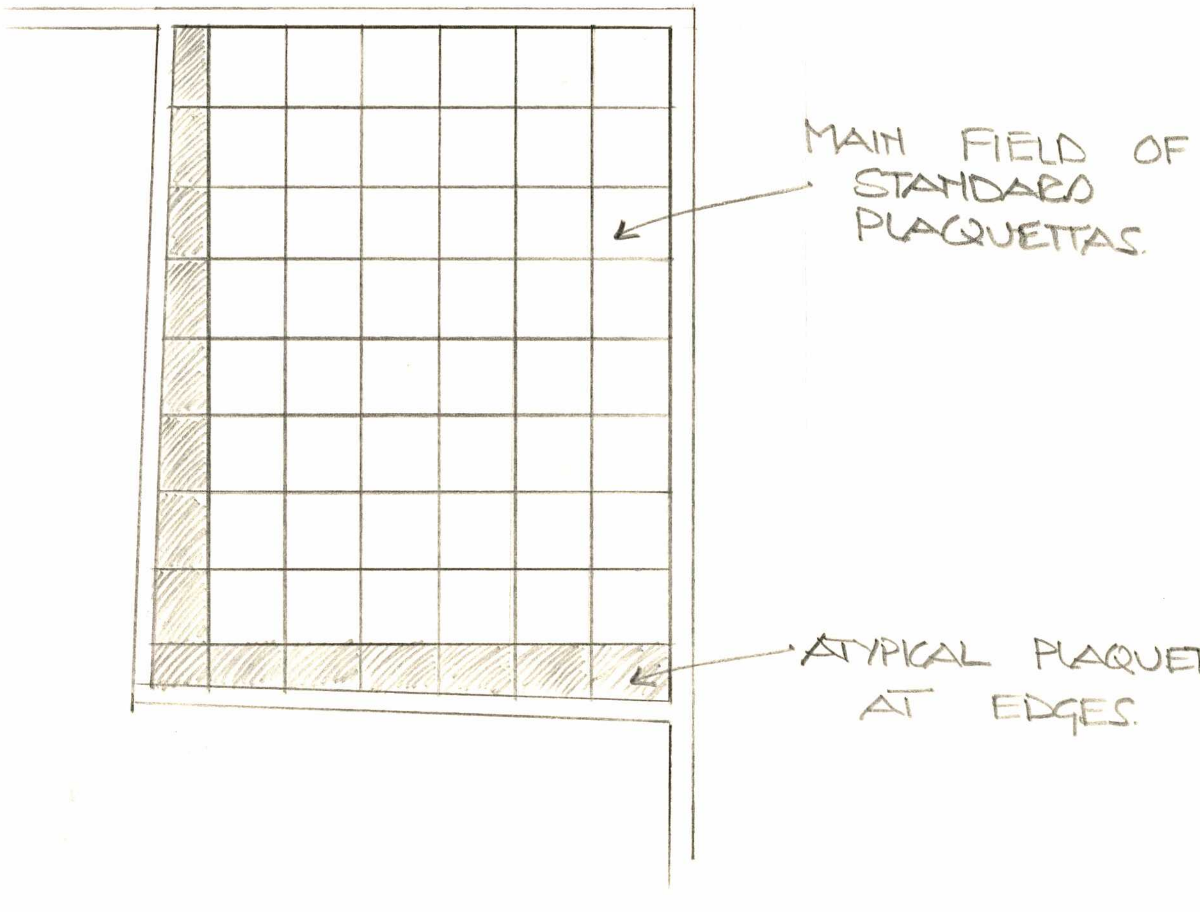
Making the unusual plaquettas at the house they will be used in reduces possible confusion a great deal. Since the plaquettas are formed with the exposed ceiling side down, information for each plaquetta's location can be scratched directly in the wet concrete. Further confusion can be avoided by making the unusual plaquettas on the ground right below the place where they will be used.

See Item 17 (ornamented ceilings) for ornamentation in the plaquettas.

PLAQUETTA FORM.



PLAN OF IRREGULAR ROOM.



7. MIRADOR

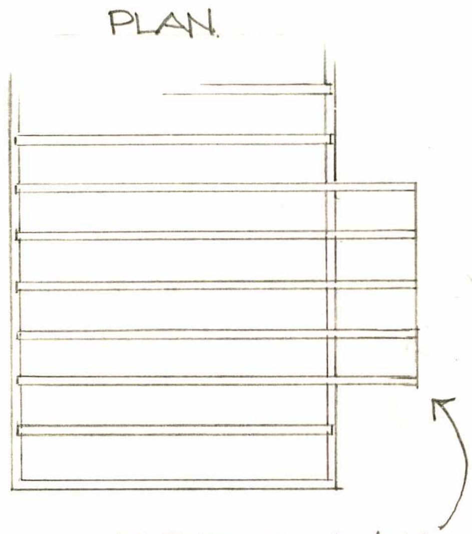
Miradors are cantilevered off the second floors of buildings, by extending the floor beams through the perimeter beams and beyond the plane of the first floor facade. Superstructure construction is the same as the rest of the building, with a reinforced concrete frame and masonry infill, and plaquettas spanning between the floor beams.

If miradors are built, especially on the street sides, the exposed ends of the beams should have ornamental or corbeled shapes.

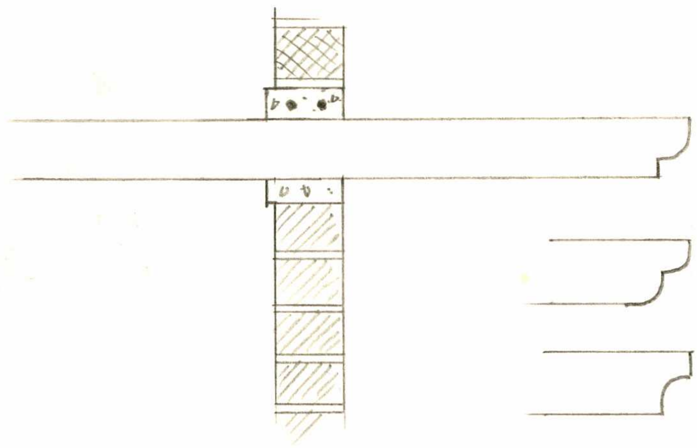
DIFFICULTIES:

1. FORMING THE ORNAMENTAL ENDS OF THE BEAMS.

Corbeled or ornamental ends on the beams can be simply formed be placing a negative insert in the end of the box form for the beam. These inserts can be made of styrofoam if it is available, wood, or for no cost at all, can be shaped out of wet clay inside the form. Every family chooses their own ornamental shapes for the beam ends, so that they are different on all the houses.



MIRADOR WITH EXTENDED FLOOR BEAMS



SECTION THROUGH WALL SHOWING EXTENDED FLOOR BEAMS

8. ROOF STRUCTURE

The roof structure is long bamboo purlins, which span between masonry gables. The roofing material is nailed directly onto the bamboo from above. The bamboo purlins sit in notches built into the top of the gables. At the ridges there are two purlins, one on either side. Roofs are typically rectangular, and are all the same sizes.

Variation in building plan dimensions means that the roofs will be different sizes, both in length and width. In some cases, roofs will be non rectangular. Some buildings with turns in the volumes will therefore have hips and valleys in the roofs.

DIFFICULTIES:

1. IN LONG BUILDINGS, SPANS BETWEEN GABLES WILL BE EXCESSIVE

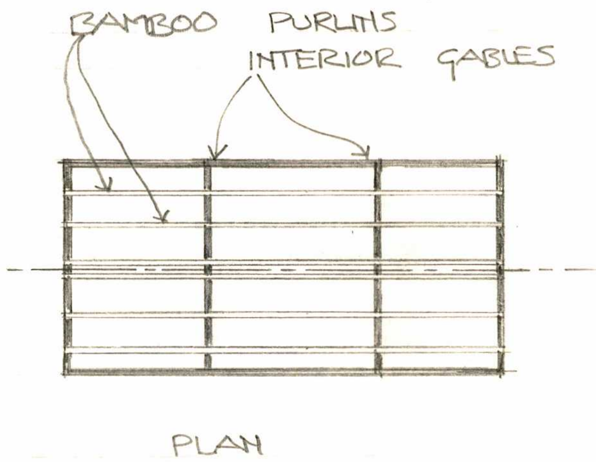
In the cases of long narrow building volumes, interior masonry gables are built. Houses are laid out to insure that walls will be in the correct places to build the interior gables. Notches are built in the tops as for the end gables, to receive the purlins.

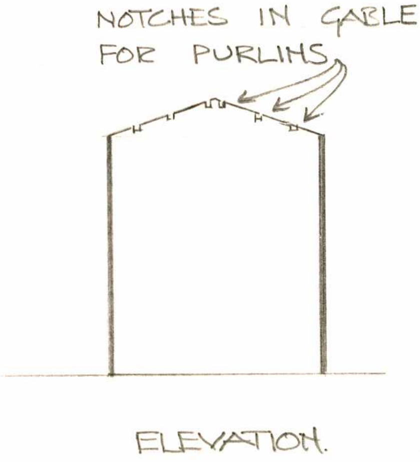
2. HIPS AND VALLEYS AT TURNS IN THE BUILDINGS

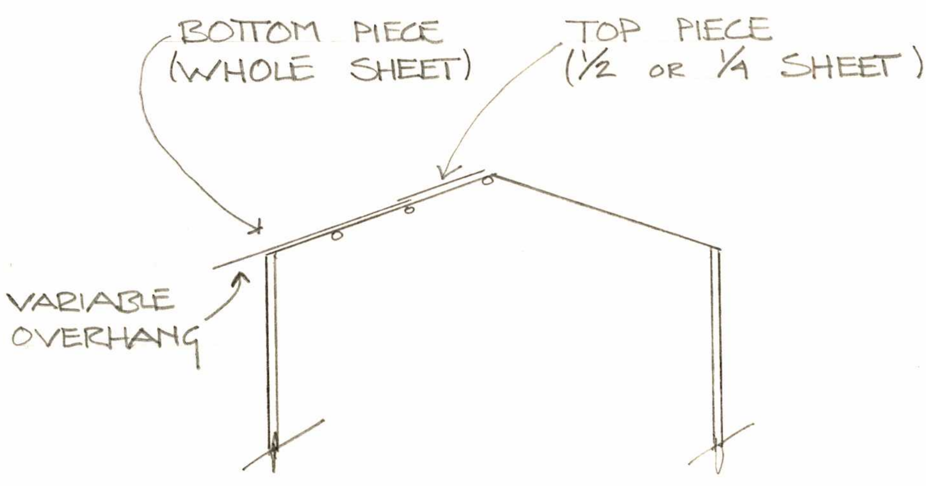
Hips and valleys are resolved by building interior gables at all turns in the buildings. Purlins are notched into them as in other cases

NOTE 1: Notches for the roof purlins in the masonry gables must be located to fit the modules, half modules, and quarter modules of the eternit, and should be measured from the ridge down, not from the eave up, so that the off-module spacing occurs at the bottom edge of the roof.

NOTE 2: The pitch of the roofs is 1 vertical to 3 horizontal. All gables must be built to this slope, except in the rare cases where there is a turn in the building without a break in the roof, and the smaller volume therefore has a steeper pitched roof. If this condition occurs, the steeper pitch is established on the site, as an automatic product of the volume width and the fixed ridge height of the larger volume.


BAMBOO PURLINS
INTERIOR GABLES
PLAN


NOTCHES IN GABLE
FOR PURLINS
ELEVATION.


BOTTOM PIECE
(WHOLE SHEET)
TOP PIECE
(1/2 OR 1/4 SHEET)
VARIABLE
OVERHANG

9. ROOF SURFACE

Roof surfaces are asbestos eternit, which is purchased in 220 cm X 90 cm sheets. The sheets have interior and exterior sides, which are not reversible. The sheets are set directly on the roof structure, and nailed straight through into the purlins. The sheets lap at both horizontal and vertical joints in the normal way. Sheets are cut with a nail tapping and breaking technique, which works in all directions (with the corrugations, across the corrugations, or at a bias to them.) The ridge cap is a purchased piece with corrugations down its length to match the roofing sheets, and is available in 180 cm, 240 cm, and 3 m lengths. Ridge caps are set directly on top of the eternit sheets, and are nailed through to the trusses. Roofs are generally rectangular.

The houses are laid out so that roofs are sometimes non-rectangular. At turns in the buildings the roofs have hips and valleys, which do not occur in the normal houses. Also, the roofs have different widths, which do not conform to the modules of the eternit.

DIFFICULTIES:

1. POSSIBLE WASTAGE FROM OFF MODULE CUTS TO FIT DIFFERENT ROOF DIMENSIONS, AND FROM MAKING BIAS CUTS AT HIPS AND VALLEYS OR AT THE GABLE ENDS OF NON-ORTHOGONAL ROOFS.

Waste from different roof widths can be eliminated, in all cases, by making adjustments in the eave overhang, so that the length of the roof surface is always a multiple of whole, half, or quarter sheets of eternit. Eave overhangs have a minimum overhang of 40 cm, and a maximum overhang of 85 cm. Minor adjustments can be made by changing the overlap of the eternit sheets.

The use of the eternit modules is as follows:
Volumes 3 m wide: one full (220 cm) sheet, with a 60 cm overhang at the eave.
Volumes 3-4 m wide: one full 220 cm sheet and one quarter (55 cm) sheet, with an overhang at the eave varying between 42 and 85 cm.
Volumes 4-5 m wide: one full (220 cm) sheet and one half sheet (110 cm), with an overhang at the eave varying between

45 and 85 cm.

Waste from bias cuts can be reduced through careful control of this operation, so that cut pieces are always used up. Note that the symmetrical nature of the angles means that the leftover pieces can be turned around and used along the same angled end. To make sure that the pieces are used as efficiently as possible, roofing always starts at the angled ends (or hips and valleys) and works towards square ends, to provide as much flexibility as possible.

2. DETAIL AT THE HIPS AND VALLEYS

At all hips and valleys, there is a gable running up the hip or valley. For valleys, narrow, concave (up) lengths of eternit are nailed into the gable top surface, before the eternit sheets are places. For hips, after the eternit roofing is in place, narrow, convex lengths of eternit are nailed through to the gable. If this does not prove to be secure, this piece can be wired down to anchors in the gable, or to the eternit sheets themselves.

10. EAVES AND OVERHANG

There are not overhanging roofs on the normal houses. Eaves at gable ends are just eternit overhanging the walls by 5-10 cm. Eaves at the low edges of the roofs are treated in several ways. In some cases the eternit is overhanging slightly, with gutters suspended from the walls on metal hangers. This is typical for that backs of buildings. In other cases a small parapet is built up in front of the roof edge, with the gutter in between the roof edge and the parapet. This is common for front eaves. Gutters are purchased as plastic pieces, and are attached to the walls by hangers.

LOW COST CONSTRUCTION OF THE EAVE:

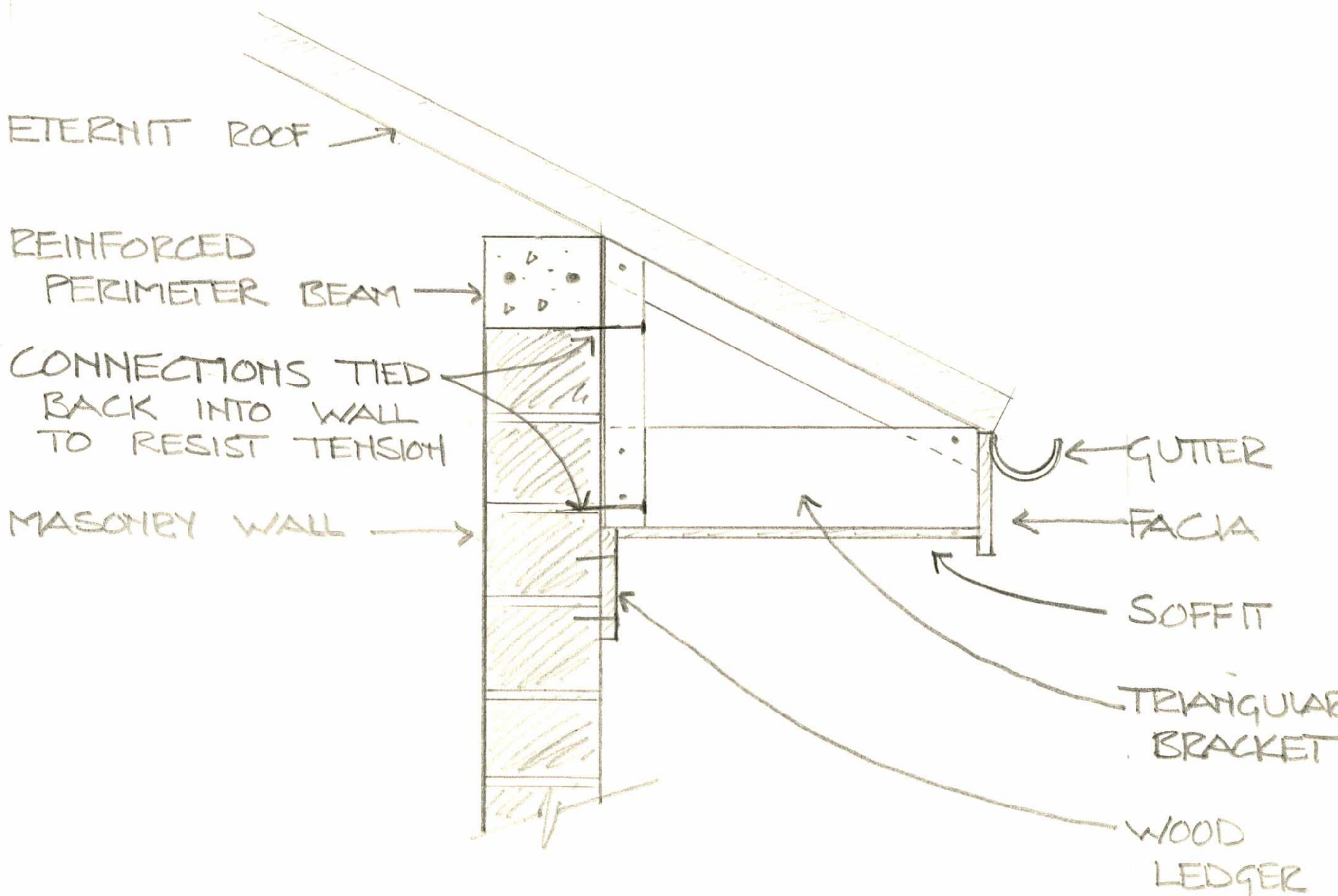
The eaves overhang the main volumes of each house by up to 85 cm, depending on how the modules of the eternit work out. Small, one storey volumes at the back of houses do not have an overhanging roof. Support for the eave is provided by triangular wood brackets, which are attached to the side of the building just under the roof edge. These brackets provide the structure on to which the eave soffit and facia can be attached, at minimum cost. Most of the extra cost for the overhang will go to the soffit and facia themselves.

The triangular brackets are fitted on the building itself, so complicated measurement is avoided. The sloping cord of the bracket must match the slope of the roof, and this slope can easily be determined by projecting the slope off from the gables with a length of wood. The brackets sit on an exposed wood ledger, about 3 cm by 23 cm, which is bolted back into the wall. The brackets are also attached back to the masonry wall. The method of attaching the ledger and brackets depends on what is available, but are laid up in the wall as it is built, and must be able to resist tension, so the brackets cannot be pulled off the wall. A simple method would be to embed wire in the mortar as the wall is built, and then tie the bracket back with the wire.

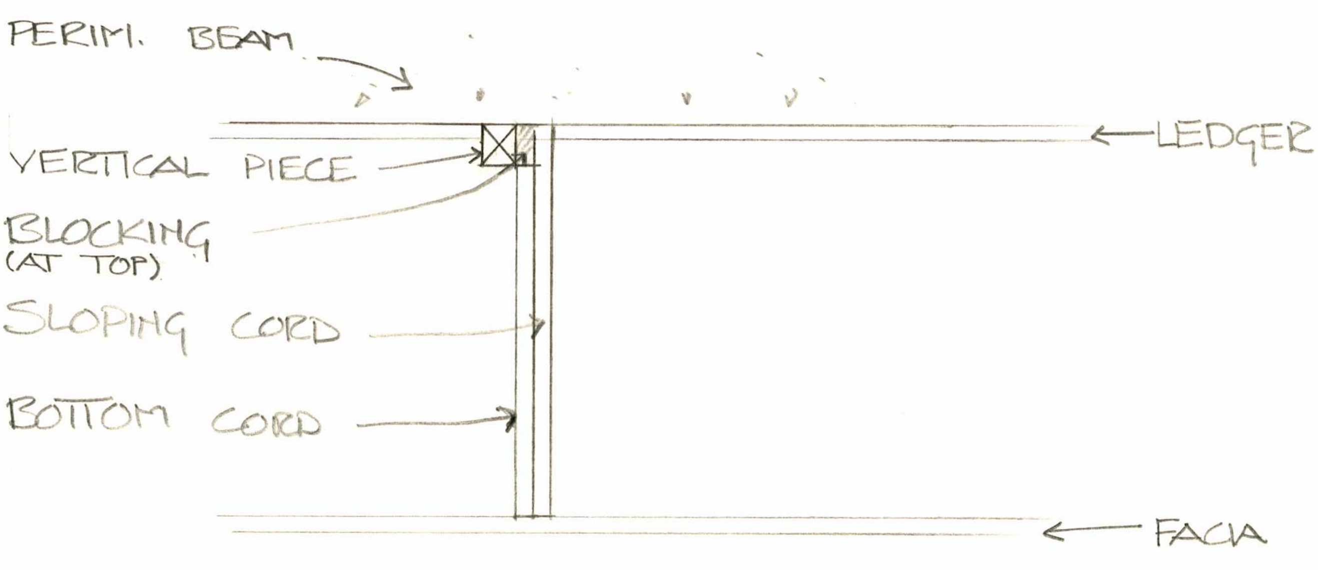
The facia is a 2 cm by 30 cm piece of wood, nailed directly to the bracket ends. Soffits can be very thin pieces of wood nailed directly up to the bottom cord of the brackets To save money, the soffit can be left off at inconspicuous places (back sides etc.) The facia overhangs below soffit slightly (2 cm).

On gable ends of buildings, a 30 cm deep facia board is attached just under the roof line

EAVE CONSTRUCTION.



EAVE STRUCTURE (PLAN).



11. VERANDA COLUMNS AND COLUMN CAPITALS

When columns are used in the normal construction, they are either wood or metal, and about 10 cm by 10 cm in section.

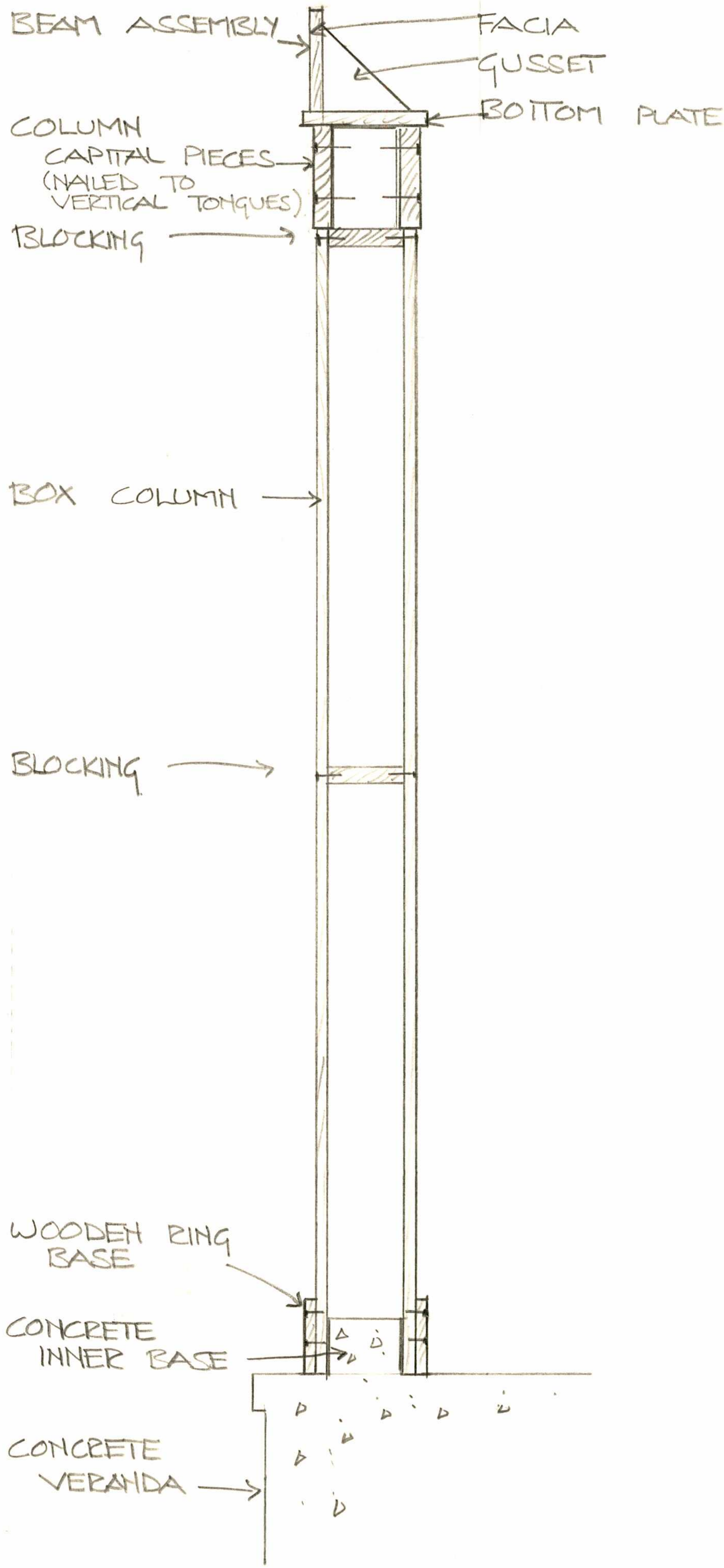
Crucial issue in getting the veranda nice is to use large members for the columns, on the order of 20 cm by 20 cm, with substantial capitals at the top.

DIFFICULTIES:

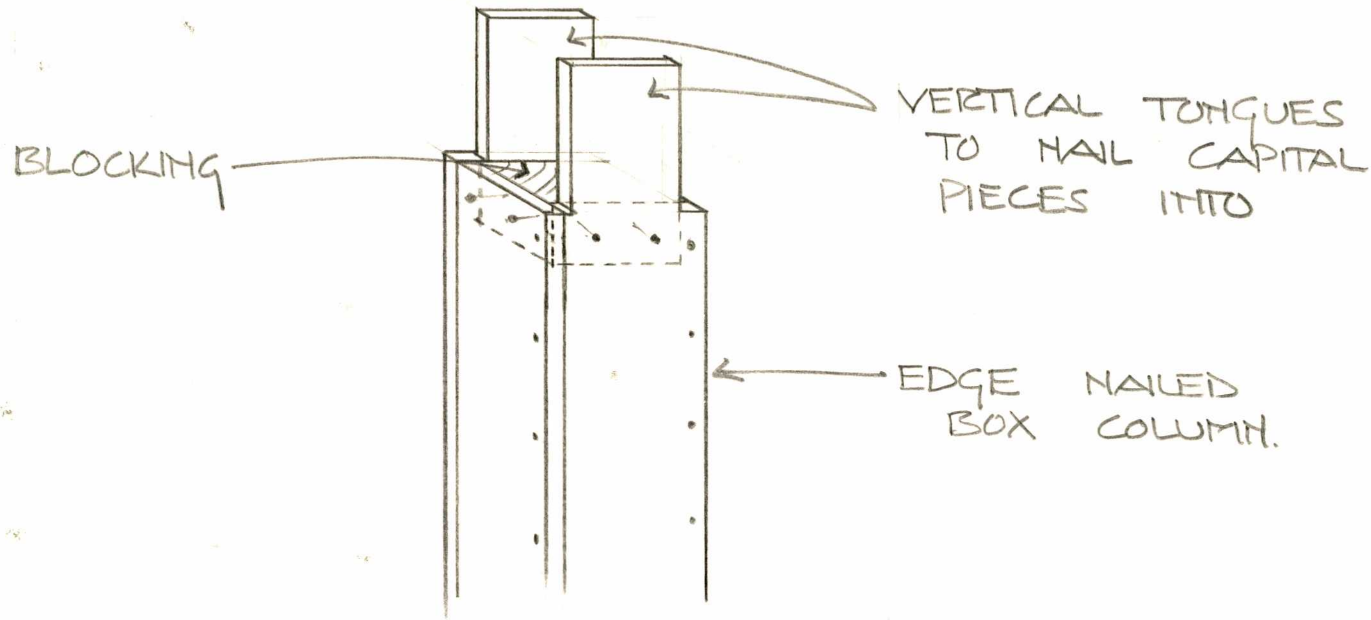
1. COST OF LARGE COLUMNS AND CAPITALS

10 cm by 10 cm columns have a cross section of 100 sq. cm. Solid columns, 20 cm by 20 cm, have a cross section of 400 sq. cm. and are therefore out of the question. In order to get large columns, box columns must be used. If 2 cm by 18 cm pieces are used, total cross section of wood is 144 sq. cm. If 1.5 cm by 18 cm pieces are used, total cross section of wood is 108 sq. cm.
Box columns are built as shown in the sketch, with interior blocking at the middle and top, and edge nailing.
The connection to the slab is gained by first pouring a small concrete base, (after the slab, and tied in with rebar) about 10 cm high, and having the dimensions of the inside of the box column. The column is fitted over this, and a wood ring is nailed on around the outside to hold the bottom together, and to form a visible base.
Column capitals are built out of wood about 3.5 cm thick. Two pieces are used, one for the front and one for the back, as shown in the sketch.
The beam across the column tops is also made of thin wood stock, as shown in the sketch, and forms a shelf for the veranda roof structure to sit on.

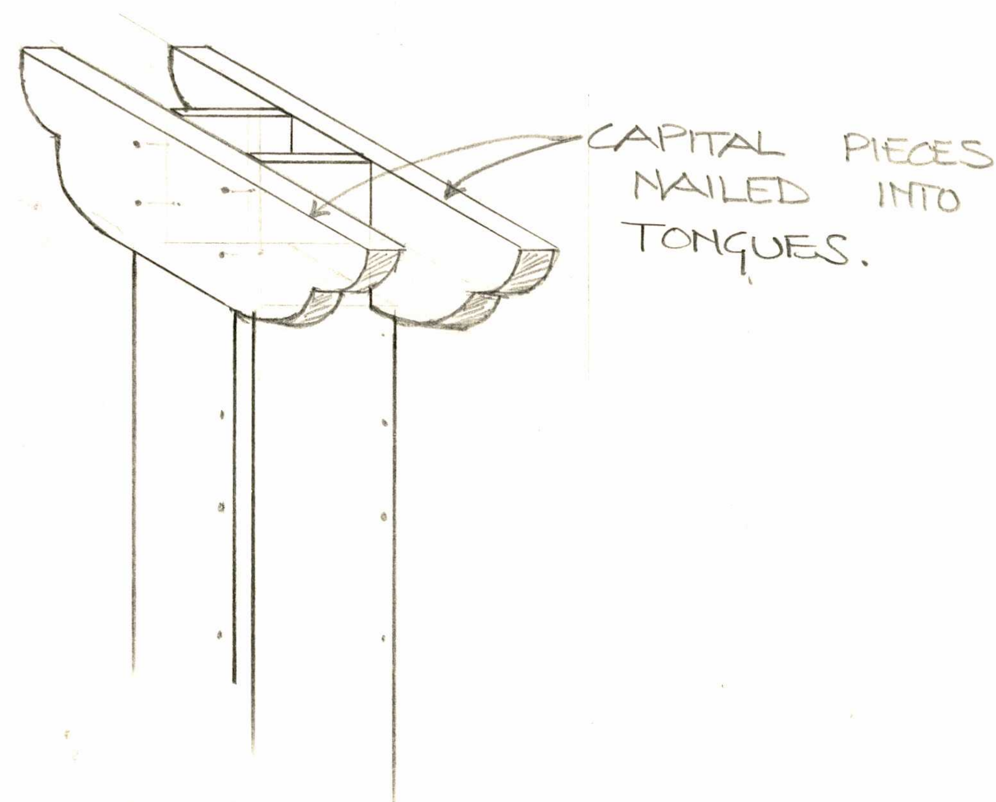
COLUMN
SECTION



COLUMN TOP
WITHOUT CAPITAL.



COLUMN CAPITALS



12. VERANDA ROOF

The veranda roof is built with a bamboo supporting structure, and ceramic tiles above. This is a common system for the region.

Verandas will frequently have non rectangular plans, due to the unusual shapes of the lots

DIFFICULTIES:

1. CUTTING THE TILES TO FIT NON RECTANGULAR ROOFS

If the tiles cannot be cut on an angle, which is likely, two techniques can be used. On open, non rectangular ends, the tiles are laid up overhanging the end, and are left ragged. On non rectangular inner ends (against a wall) or situations where the roof top meets the building on an angle, the tiles are laid up as close to the wall as possible, and then flashed over with eternit or metal flashing.

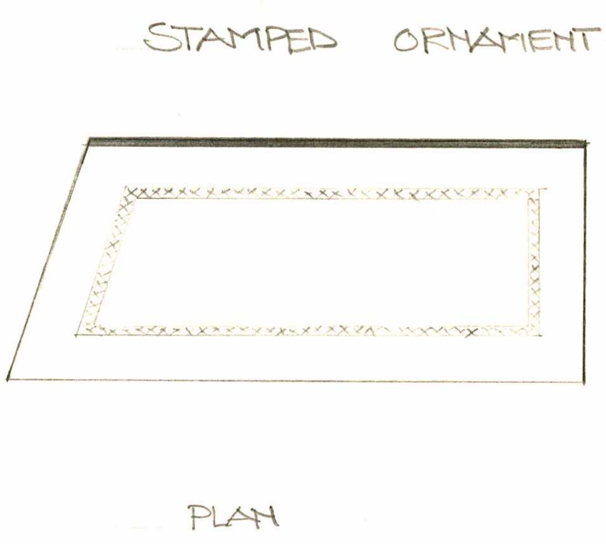
13. VERANDA FLOOR FINISH AND EDGE TREATMENT

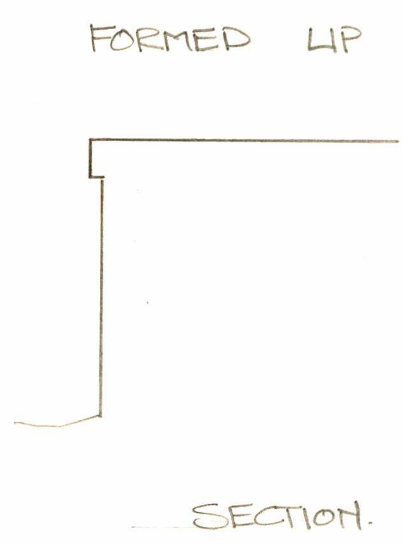
The veranda floors are concrete slabs, poured with the other slabs. In some cases the verandas slabs will be above grade, and will therefore have a small wall at their edges, down to the existing grade. The edge of this wall should be built with a small lip at the top. Ornamental patterns can be stamped into the wet concrete slabs of the verandas, using carved wood stamps.

DIFFICULTIES:

1. FORMING THE VERTICAL WALL AT THE VERANDA EDGE.

This wall can be formed using the same technique as for the exposed footings, with concrete blocks as formwork. To get the lip at the edge, a top course of brick need only be set back (away from the wall) 1.5 cm or so. See section 1. on foundations and footings.

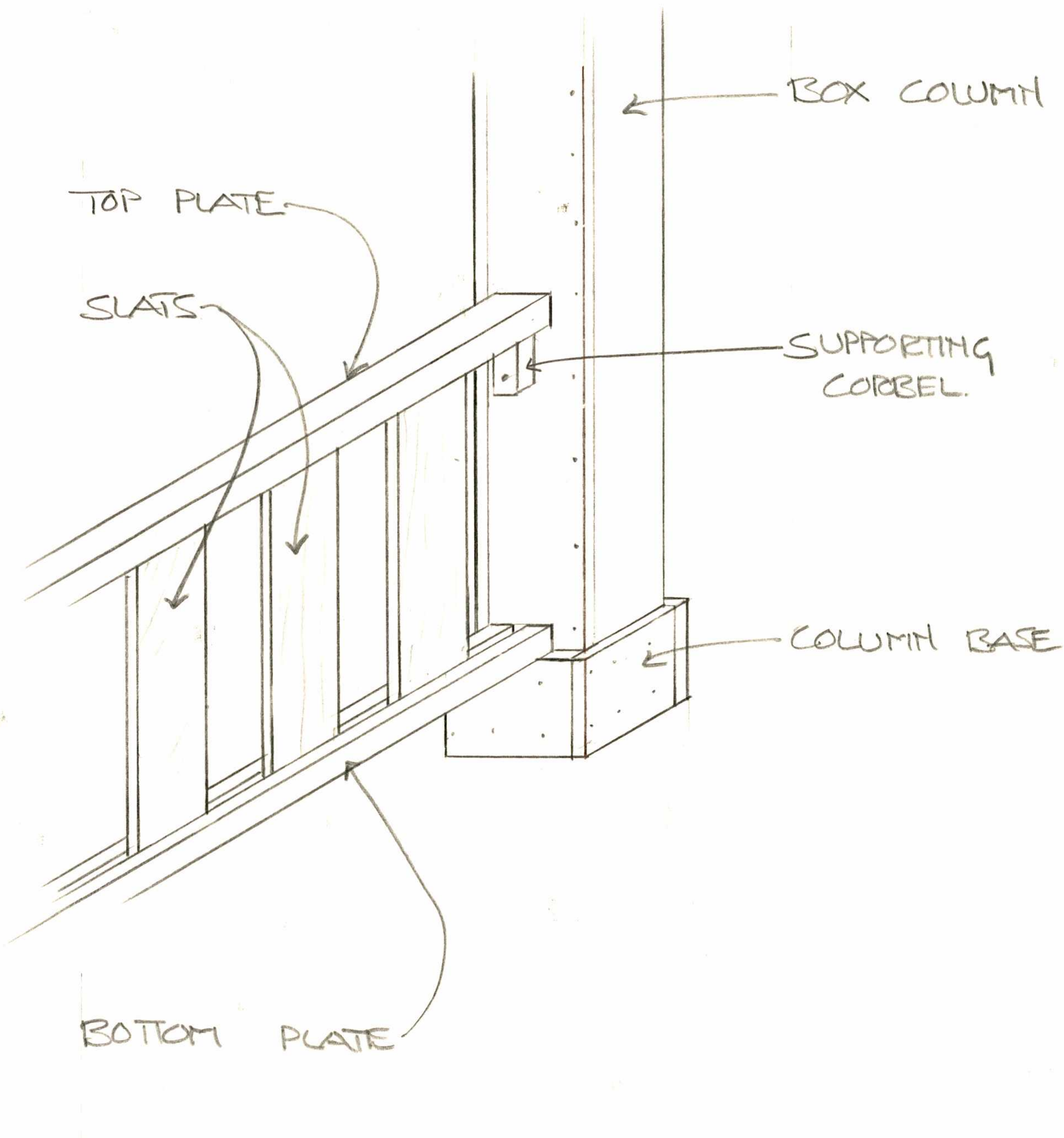




14. VERANDA RAILING

Veranda railings are wood, as was previously agreed by Hernan. Railings consist of two plates, top and bottom, which are dadoed down the middle to accept vertical slats. Alternately, the bottom plate is not dadoed, and small trim strips are nailed to either side of the slats. This is a better detail for weather. Sections of rail span between the veranda columns, and sit on small blocks of wood nailed into the column, which serve as small corbels.

VERANDA RAILING.



15. INTERIOR STAIRS

Interior stairs are masonry, with supporting sides of block or brick and reinforcing concrete columns, and long plaquettas spanning between the two supporting walls for treads. Stair treads are concrete, and are built like the plaquettas, with a reinforcing laminate in the middle.

Staircases will not always have straight runs, but instead may have turns and landings.

DIFFICULTIES:

1. STAIR TREADS WILL NOT ALL BE OF THE SAME DIMENSION AND SHAPE.

Unusual stair treads can be produced using the same method as for unusual plaquettas, with inserts in the form, to produce the required size and shape. See the layout section of this manual for directions on laying out the treads for construction.

2. CONSTRUCTION OF LANDINGS

Landings can easily be constructed using long plaquettas, set side by side, and supported in the usual way.

16. EXTERIOR STAIRS

Short runs of exterior stairs are as simple as possible--just a straight concrete pour filled with rubble for one or two steps. In cases where the exterior steps are high, because of hills, they can be built the same way as the inside stairs. It is possible that locally manufactured metal stairs, for long exterior runs, will prove to be less expensive than masonry.

Garden steps must be extremely simple. Simply bedding a paving slab down will suffice in most cases. For situations where this is not stable enough, treads can be poured in place with the most rudimentary forms possible, and anchored by first driving a 2 X 4 into the ground at either end if each step, pulling it out and dropping a scrap of laminate or steel (whichever is cheapest) into the hole, then filling the hole with concrete as the step is poured, so that there are small anchoring piers underneath the step.

17. ORNAMENTED CEILINGS

The first floor ceilings are the exposed concrete floor beams and the underside of the plaquettas. Ornaments can be cast directly into the components of the ceiling as they are poured.

For the floor beams, the beam section can be changed so that they have rabbetted lower corners, simply by placing small wood strips in the bottom of the form.

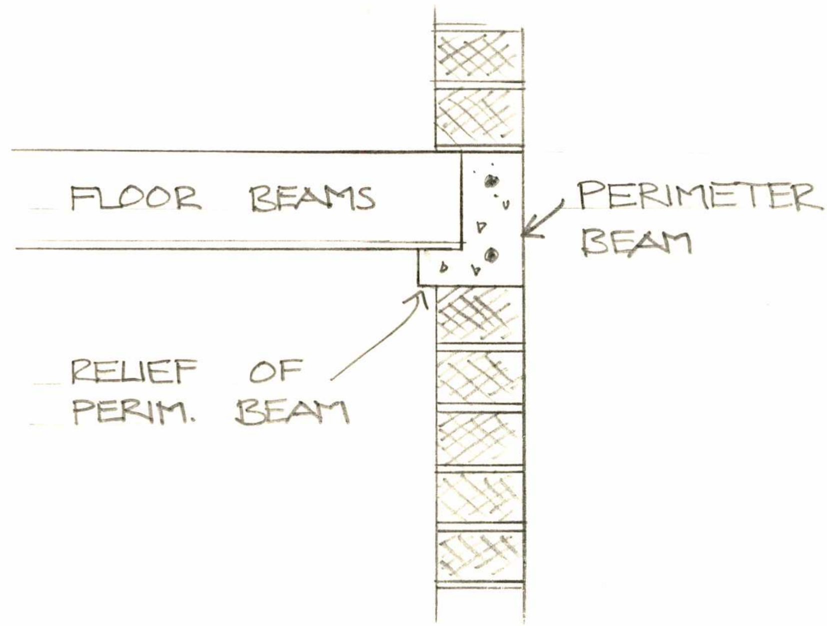
It is quite simple to cast ornaments into the underside of the plaquettas. Every other plaquetta can have an ornament cast into the bottom. CES people can help families with designing ornaments, and each family's can be different.

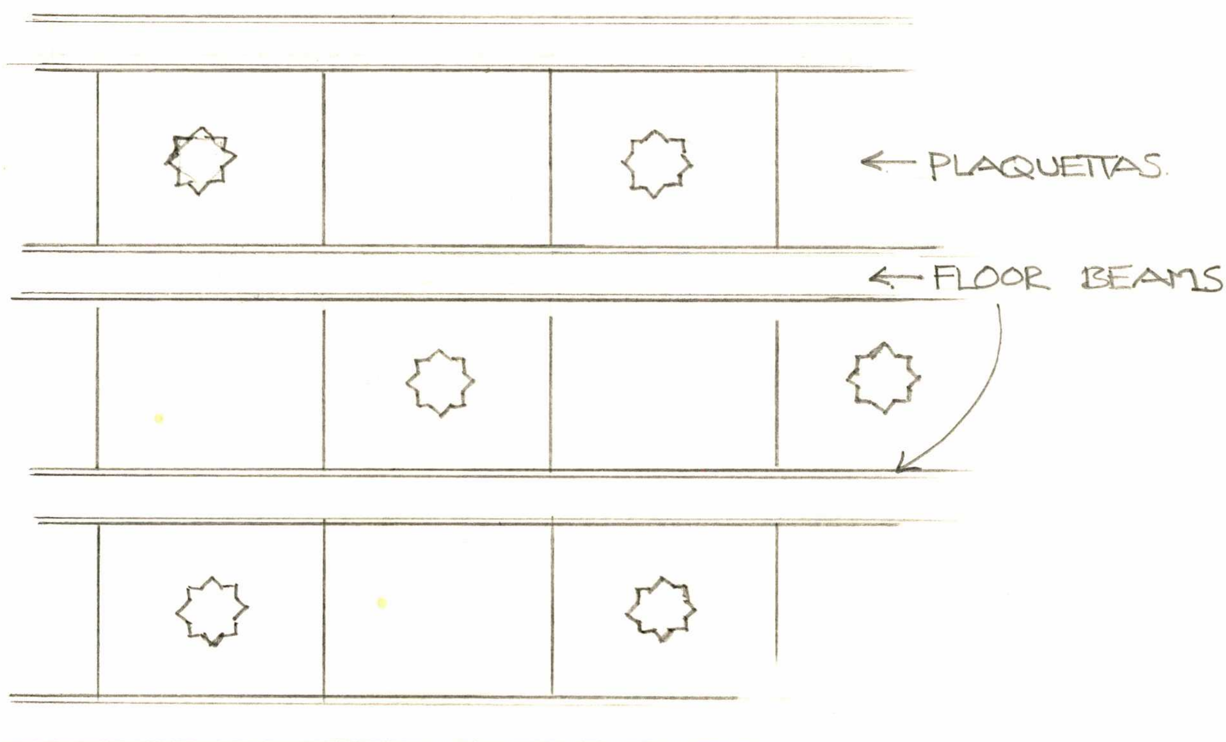
The simplest way to cast ornaments is to make them concave in the bottom of the plaquettas. A concave mould can be carved in wood or even cast with cement and sand over a clay negative. From the mould multiple clay negatives can me made, using the clay off of the site, which is pressed into the mold. These clay negatives can be set into the bottom of the plaquetta forms, and the concrete poured over them before they dry out. An alternate method would be to stamp ornaments into the top surface of the plaquettas as they are poured, and then turn them over so the stamped side faces down in the ceiling.

The floor beam/perimeter beam connection is quite important for making a good ceiling. The perimeter beam should be in relief 2-3 cm towards the inside, and about 5 cm lower than the bottom of the floor beams, to form a strong center. This can be done using the same forms as are normally used, and just building them out from the wall with a wood insert, to get the relief. If this cannot be done with the concrete perimeter beam itself, it could be done with plaster, using the screeding technique.

There are no second floor ceilings--the underside of the eternit and the purlins are left exposed, but possibly painted.

POSSIBLE SECTION OF FLOOR BEAM.





REFLECTED CEILING PLAN SHOWING ORNAMENT LAYOUT.

18. INTERIOR FINISH

The interior of the buildings are finished with a coating of cement plaster.

In addition to a plaster rendering, baseboards can be improvised to form a border at the bottom of the wall.

There are two possible ways to get this extra item:

The easiest technique is simply to use a slightly wider coarse of block or brick at the base of the wall, which is plastered over with the rest of the wall, and thus produces a thickening at the bottom of the wall.

The second technique is to use the plaster screeding technique, which is used for the door and window surrounds, and is described in the section for that item.

19. FLOOR FINISHES

Floors are finished by covering the slabs and the plaquettas on the second floor with tiles set in and grouted with mortar. Tiles are purchased, and are available with patterns on them. In some cases the second floors are wood.

The irregular shapes and dimensions of the rooms means that tiles around the edges of the rooms will not fit in some cases.

DIFFICULTIES:

1. TILES WILL HAVE TO BE CUT.

It is unlikely that tiles can be cut. Scoring and snapping can be tried. To solve the problem, if the tiles cannot be cut, simply do not place tiles at the edges of the rooms, and fill the odd spaces with mortar

2. POSSIBLE WASTAGE OF CUT TILES.

If tiles are cut, waste can be controlled by ruling that all houses must use up their own off-cuts. This would mean that in some places several small pieces of tile would be used instead of one whole piece.

20. WINDOW AND DOOR FRAMES

Window frames are wood, and are nailed directly into the edges of the masonry walls on the interiors of the openings.

No anticipated difficulties, as the frames are not prefabricated, and are cut to fit.

21. WINDOW SILLS

Window sills are precast concrete pieces, which are set in place as the wall is built.

Window sills should be built so they overhang on the inside and outside. This can be done by simply enlarging the normal forms for the sills.

DIFFICULTIES:

1. OVERHANGING SILLS REQUIRE MORE CONCRETE, BECAUSE OF THEIR BIGGER SECTION.

The cost increase is negligible in terms of the total budget. The total volume of concrete could be recovered, for instance, by reducing the thickness of the slabs by about 3 mm.

22. WINDOW SASH

Window sash are wood or metal. The sash are made by local shops to order, and are paid for by the square meter. In the normal houses, a few typical window dimensions are used repetitively.

In the new houses, window sizes will be determined to fit each individual room in each house. Sash will be wood.

DIFFICULTIES:

1. POSSIBLE INCREASE IN EXPENSE FOR WINDOWS OF MANY DIFFERENT SIZES, AND POSSIBLE EXTRA EXPENSE FOR WOOD SASH.

Different sizes of windows should not cost extra, because they are produced by local manufacturers and are paid for by total area only. It is unclear if wood sash is actually more expensive than metal. If it is, wood sash will be used only in important rooms and on building fronts.

23. DOOR CONSTRUCTION

The method for door construction is the same as for the window sash. Local shops build the doors, and no problems in making different sizes should be encountered.

Front doors should be built tall, using transom windows above the doors. A wood cross piece is framed into opening, and a piece of sash is set in place above the door.

24. WINDOW AND DOOR SURROUNDS

Windows and doors are to have surrounds about 2-2.5 thick, 11 cm wide on the sides, 12 cm on top, and 15 cm below the sills.

Window surrounds are built up out of cement plaster, using the screeding technique described below.
Metal hangers must be built into the wall around all openings, to solidly tie the surrounds back to the walls. A piece of board with the desired thickness is held up against the wall adjacent to where the surround will be, and the plaster is screeded against the wood, for a consistent thickness, flat surface, and straight edge. Adding lime to the plaster will help make it adhere to the wall.

25. ORNAMENT AROUND DOORS

Ornaments around the doors are built into the plaster door surround, either by stamping the wet plaster as it is screeded, or by carving into the plaster when it is only slightly set.

26. GARDEN WALLS

Garden walls are normally built using the same method as for the house walls, with brick or block and concrete columns. The columns are built flush with wall, and the walls are 180 cm high.

The garden walls must be built early on, to assure that they are completed and to help establish the larger centers as soon as possible. The construction of the walls is the same as described above, with the possibility of the following modifications.

1st MODIFICATION: LARGE COLUMNS

Building the columns so that they form significant centers themselves is the first priority. Large columns, 35 cm by 35 cm and about 10 cm taller than wall, are built at 3.6 m centers. These columns can be either solid concrete, poured after the block is laid up, or perhaps better, they can be built with single cell concrete blocks, made on the site, and then grouted solid. The columns are vertical, but the block or brick follows the slope of the hills. Triangular voids in between vertical columns and angled brick are filled with mortar. If block columns are built, the wall should be built in the reverse order, with the columns first, and then the masonry infill.

2nd MODIFICATION: CAPS ON THE COLUMNS AND WALL

Caps are built on the columns using prefabricated plaquetta-type pieces, grouted in place. To secure them to the column, steel can be left sticking up from the top of the columns, holes can be cast in the caps when they are built, and the caps placed over the steel and grouted firmly in place. Caps on the wall are long precast pieces, set in place after the masonry is laid up, and steel left sticking out of the ends of these caps are locked into the column when it is poured.

3rd MODIFICATION: ELABORATE VERSION WITH VERTICAL PLAQUETTAS

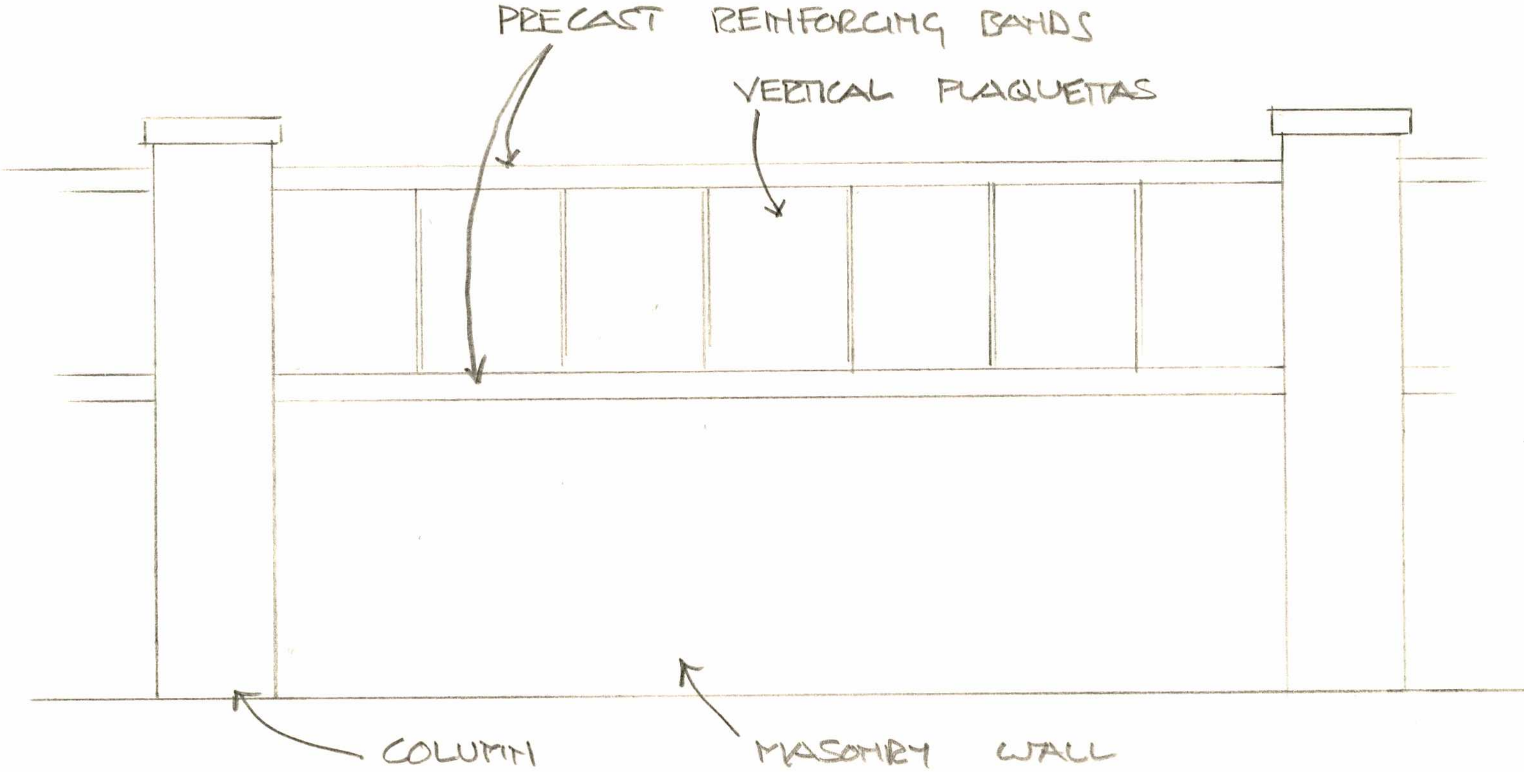
In this elaborate version, the walls and columns are built in two stages. A first lift of wall and columns is built up to about 1 meter, using the single cell blocks for columns. Precast horizontal bands, which have a slot cast in the top to accept vertical plaquettas (see section in the sketches) are set on top of the wall. These bands have steel sticking out of the ends, which go through holes in the block, so that they are locked into the column when it is grouted.

The second stage begins with building the columns up to their full height, and then setting special vertical plaquettas in mortar in the slot in the horizontal band. A precast reinforced concrete cap is then set on top of the vertical plaquettas. This cap has a slot in its bottom side to accept the plaquettas (see section in sketches), and steel sticking out of the ends to lock it into the column. The columns are grouted solid, and column caps are set in place.

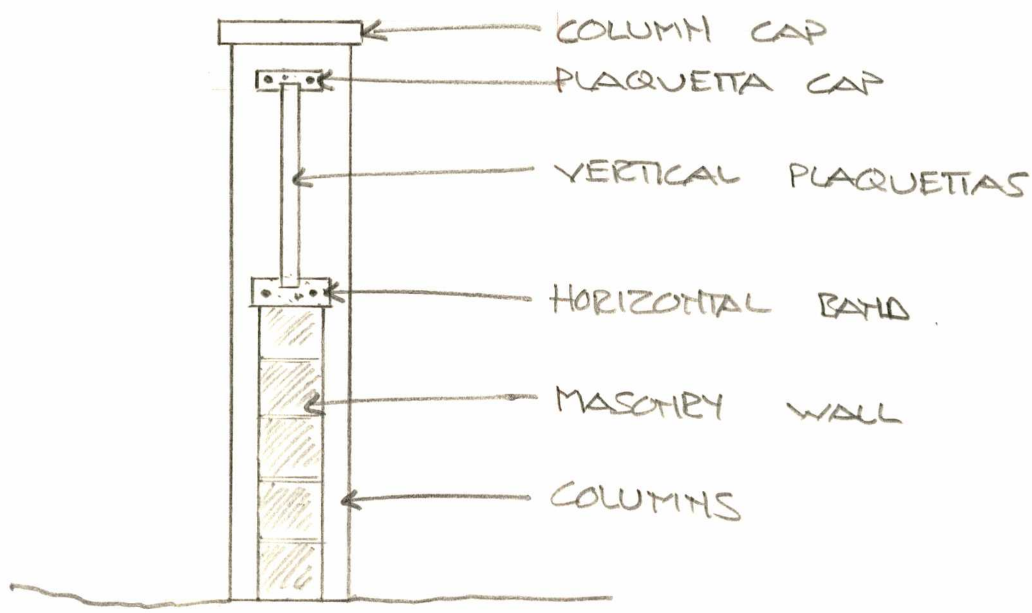
The vertical plaquettas are precast, and for hillside cases have angled tops and bottoms, to match the slope of the hill. These vertical plaquettas are 45 cm by 65 cm, and do not need to be reinforced with laminate.

20% of the single cell blocks must be made with holes in their sides, to allow the steel of the horizontal bands to pass through. Knocking holes in the blocks after they have hardened is very difficult.

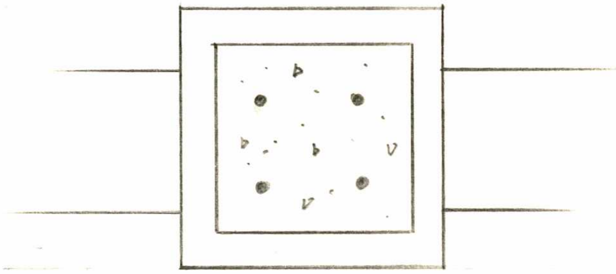
ELABORATE VERSION OF WALL.



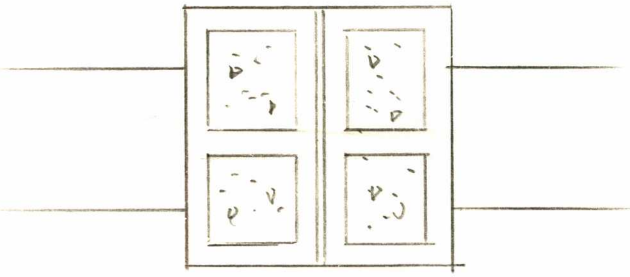
SECTION.



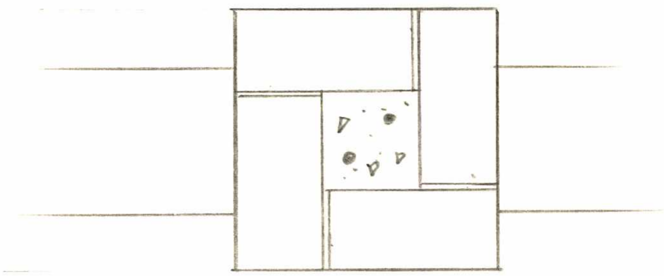
POSSIBLE METHODS OF COLUMN CONSTRUCTION.



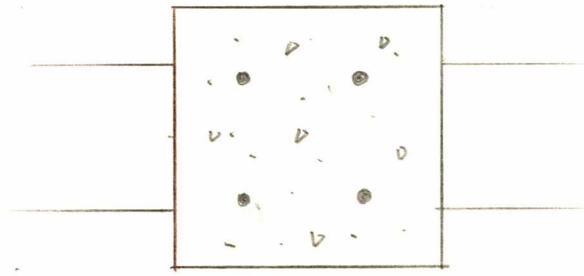
SINGLE CELL CONCRETE BLOCKS



STANDARD CONCRETE BLOCKS.



BRICKS WITH CONCRETE CORE.



SOLID POURED CONCRETE

27. ANTEJARDIN SURFACE

The surface of antejardins is very simple and cheap. Grass with a few concrete pavers is all that is needed.

28. ANTEJARDIN WALLS

Antejardin walls are low, so that people can sit on them, and so that antejardin is well connected to the street. The walls are 60 to 100 cm tall, and 40 cm wide. The walls are built as empty cavities, with a single course of bricks on either side, and precast concrete plaquettas on top. The plaquettas should be slightly wider than the wall, so they overhang 2 or 3 cm.
Production of the top plaquettas is the same as for the floor plaquettas, including the methods used for the production of odd sizes.

29. BENCHES

Benches are built using the same construction system as for the stairs and antejardin wall, with low brick supporting walls and a reinforced concrete plaquetta on top for the seats.

30. EXTERIOR FINISH

The exterior of the buildings are plastered with a cement/lime/sand plaster. Oxide pigments are available to color the plaster. This would be much more permanent than paint, and cheaper.

SECTION 2:

CONSTRUCTION LAYOUT PROCESS:

Before footings are poured:

1. Stake out column locations.
Before the seismic beams are poured, concrete column locations must be determined so that vertical steel for the columns can be placed in the trenches.

After the footings and the floor slabs are poured, important features of the building are painted on the slab for direct measurement:

2. Establish rough window and door locations.
Mark the approximate locations of first and second storey openings, directly on the slab while referring to the original layout sketch in the house record book, and with the aid of CES staff.

3. Mark wall location and thickness.
Mark the location and thickness of the first and second storey walls directly on the slab. Adjust the interior walls to insure that the major transverse second storey walls, which will have gable tops to support the roof purlins, are not spaced further apart than allowable purlin spans, and are supported by interior load bearing walls directly below.

4. Mark out all interior stairs.
Locate all interior stairs, and mark the projected position and size of the individual treads directly on the slab. The dimension and shape of the plaquettas for the treads can then be measured directly off the slab at any time, and the location of tread supports can be plumbed directly up from the slab during wall construction.

5. Mark out all second storey floor beams.
Establish the location and length of the floor beams (while referring to the GUIDELINES FOR BUILDING STRUCTURE). Measure the length of the floor beams from the marked inside faces of the walls, and add __ cm to account for interlock with the perimeter beams. Record this length, along with the position, orientation, and room and house number of the beam. If biased ends are required on the beams, record the angles, which ends they apply to, and check the length of the beams again, taking into account the biased end. Production can then begin at any time.

BOOKKEEPING AND ORGANIZATION

In the normal construction method it is not necessary to keep track of individual components as they will all fit in any house. For the Santa Rosa project, large numbers of individually fit components will be produced. This calls for a reliable and efficient system of production accounting to keep track of all the individual components for each house

Record book for each house, in which small sketches are done, and all dimension of components are recorded. Books have the same numbers as the houses, and are kept by the CES project manager, but are available to the families during working hours.

Numbering the houses
Labeling of rooms
Labeling room sides
Labeling of components and orientation within the rooms

All prefabricated components must be kept track of very carefully. Each house must have a number, and a clear and unambiguous system of labeling components must be initiated, otherwise it could lead to great confusion.

CONSTRUCTION MANAGER TASKS IMMEDIATELY UPON ARRIVAL

Engineering questions must be resolved by CES construction manager immediately upon arrival in Colombia, through discussion with Construyamos engineer, as this information might change construction details and house layout considerably.

concrete column size and spacing
allowable spans
reinforcing openings
size of perimeter beams
size of floor beams
amount that floor beams interlock with perimeter beams
seismic concerns
size of headers
allowable purlin spans
stair issues
mirador structure, modifications to perimeter beam at intersection

GUIDELINES FOR BUILDING STRUCTURE

To be written by CES construction manager in Colombia
concrete column min. size and max. spacing
reinforce openings?
allowable spans of perimeter beams
size of perimeter beams and steel distribution
sizes and allowable spans of floor beams
seismic concerns
stair supports

STUB-REBAR TECHNIQUE OF FORM SUPPORT

For forming beams and columns up in the air on the walls, a major part of the expense is in the supports for the forms. It is possible to use the wall itself as the support for the forms.

One course of block below the top, rebar stubs are set in the mortar bed so that they stick out on either side by about 10 cm. Spacing every 1 or 1.5 meters. When they are set into the wall, they should be wrapped in a banana leaf or paper or plastic, so that they can easily be pounded out of the wall later.

These stubs then from the support for the sides of the forms, and with a bit of ingenuity, the forms could also be tied back to these stubs to resist the pressure of the concrete.