GABION CORE HOUSE

Concept paper

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PARTNERS

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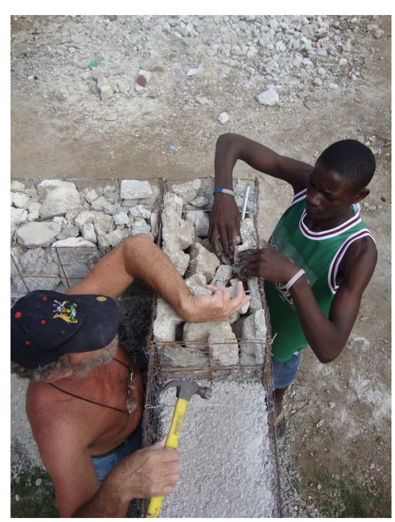
THE PRINCIPLES

A gabion is a wire cage that can be stacked vertically in a wall and then packed with various materials. Normally they are used as retaining walls, but in the case of the Gabion House their design has been modified to allow them to be stacked to form a load-bearing, masonry wall.

To enable the gabions to effectively perform as a load bearing wall they must:

- Be laid in stretcher bond.
- Be wired together, both vertically and horizontally.
- The lids removed so that the courses 'mesh' and transfer load.
- The masonry material packed tightly to avoid subsidence.
- Be protected from the weather…in this case by plaster, made with sand from crushed rubble.
- Be restrained at the top. This is achieved by spacing 12mm threaded rod at intervals of approximately 2 metres around the perimeter wall.

In the case of Haiti post Jan.12, 2010, the Gabion House was developed to 'consume' as much rubble as possible from the vicinity of the construction site. The impetus to develop such a project came from the cost of mechanically clearing and dumping the material…US$32.50 to $58 per cubic yard. (NY times, Oct 17th,2010. "Weary of Debris, Haiti Finally Sees Some Vanish") To achieve this, we also use rubble compacted into trenches for footings and sub floor build-up; as well as crushing the material in a small jaw crusher to produce sand and aggregate.



THE BENEFITS OF GABION CONSTRUCTION

The gabion cages provide a matrix of wire mesh throughout the body of the wall. It is this confinement of the masonry, both horizontally and vertically, plus the tension provided by the tie down rods, that provides the restrained flexibility responsible for **earthquake resistance.**

It is the mass of the walls, plus the foundation to top plate tie down provided by threaded rod, that gives these buildings good **hurricane resistance.**

It is also the mass of the walls and the concrete floor that provide a **thermal buffer** to external temperature variations, by providing a tempering heat/cool bank. The internal temperature is also controlled by venting the gable ends.

Many of the construction processes are semi-skilled so this will enable the **employment** of the most vulnerable in the community. There is also the possibility of setting up small enterprises to produce the gabions and crush the rubble.

The costs of construction are low. They do, however, depend on a number of factors, such as labour costs, proximity of rubble, size and amenities included in the house. In the context of Haiti 2010, we are looking to produce a 24 squ.m house for between US$4-5,000. If the saved cost of rubble trucking and dumping is deducted, the cost would be between US$3-4,000.

THE DESIGN CRITERIA

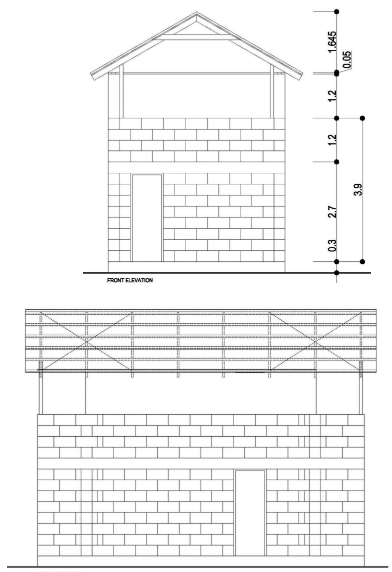
We have developed the original pilot design to include elements that are **appropriate** to Haitian architecture. The new building typology allow a shaded verandah for the entrance at the front and a second shaded verandah at the back. These areas of transition between exterior and interior, typical in tropical climate architecture, ensure cooler spaces; these becomes the areas where inhabitants usually spend most of their time at home. The Gabion structure is conceived as a **Core** house; two side windows will enable demolition to allow new doors and passages.

Housing elements such us louvre windows, railings, gables and others (see pictures right) built and personalize by each family will enhance the sense of ownership and also will provide character to the neighbourhood.

A two story building has been considered to provide "apartments" solution for areas where land is limited.

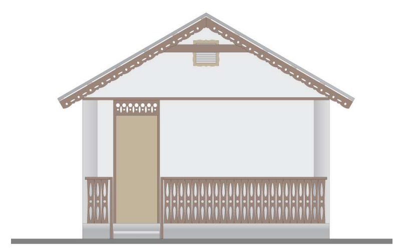
Five more gabion rows up to railing height will be needed on the second floor. Low tech panels will be used as walls.

The second floor will also benefit from an entrance front veranda and a back veranda.

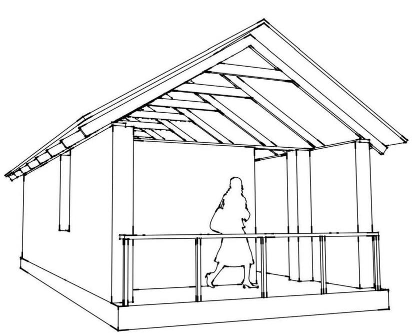


TWO STORY.
FRONT AND REAR ELEVATION

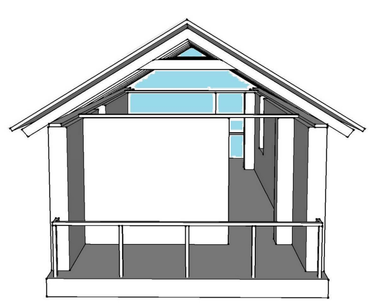
HAITIAN ARCHITECTURE



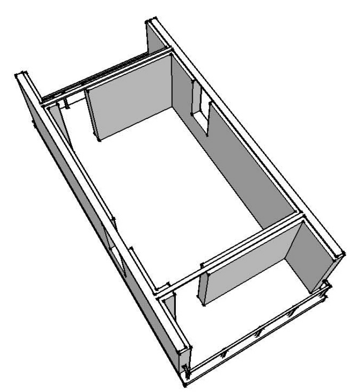
FRONT ELEVATION



SIDE VIEW VERANDAH



FRONT VIEW VERANDAH



TOP VIEW

THE STRUCTURE

Gabions are by their nature monolithic blocks. The wire cages provide a tensile capacity that holds the rock material as one block and when these blocks are stacked to form walls they achieve stability essentially by their relatively large mass compared to the remainder of the building. Hence to be effective, gabions should be used in relatively squat structural systems. However, to ease these issues threaded rods are inserted into the gabions and tensioned against the wall's top plate to achieve the following:

- To increase the load bearing on the top gabion block and hence the friction capacity of the blocks.
- Provide a tensile uplift capacity within the wall and thus mitigate the squat requirement.
- Provide a level of ductility for the structural system and hence minimize the design seismic load.

This has been the basis for the attached seismic design calculations.

Lateral loads (hurricane and seismic) produce in plane and out of plane forces and buildings require systems that resist the first and transfer the second. This house uses gabion walls to resist in plane forces and diagonal ties (timber or steel to be confirmed based on costs) at ceiling level to transfer out of plane forces to these walls. Consequently, the plaster finishing is not used structurally but instead relies on good packing of gabions.

THE CONSTRUCTION PROCESS

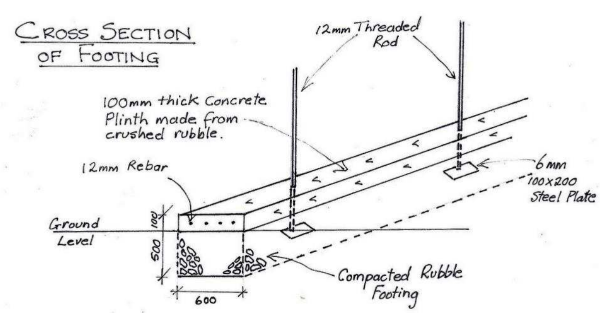
FOOTINGS

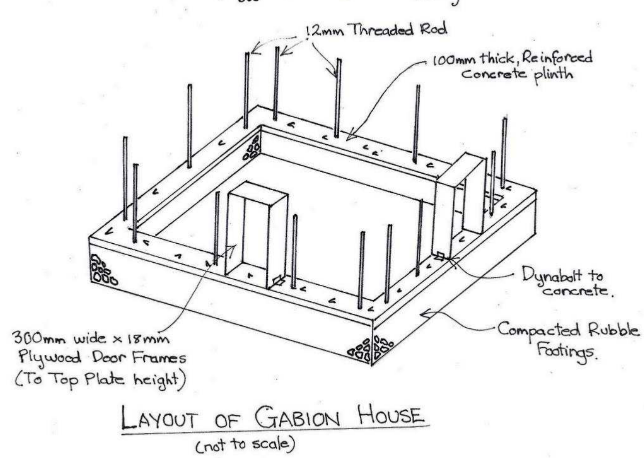
The foundations are designed as a continuous strip. In stable soil conditions the trench is dug twice the width(w) of the wall (2w) and (2w – 150mm) deep.

In this instance the gabion wall is 300mm wide so the foundation trench is 600wide and 450 deep.

The trench is filled with rubble which has been broken down using a sledge hammer to a maximum size of 100mm pieces of block or concrete.

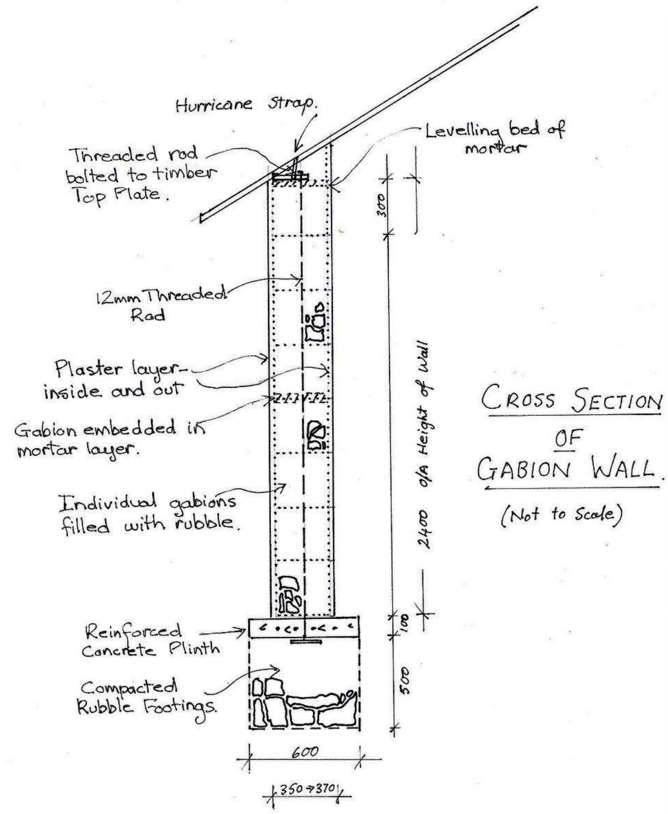
The rubble is then compacted by hand using a tamping rod and levelled using 20mm aggregate from crushed rubble.





BOND BEAM

Once the foundation has been compacted and levelled a 150mm thick reinforced bond beam is poured in situ on top of the rubble foundation. The concrete is mixed using one part ordinary Portland cement, 2 parts sand crushed from concrete block rubble and 4 parts aggregate using 20 mm crushed concrete rubble. (1:2:4)



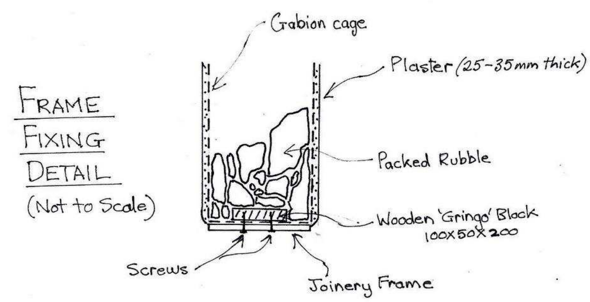
THREADED STEEL BARS

In order to ensure that the top of the wall can resist the shear force generated by an earthquake, threaded steel rods are fixed in place using 100 x 200mmsquare steel plates, 6mm thick, under the bond beam. The steel bars are spaced at two metre intervals and are 900mm long. As the wall is constructed the steel rods are extended in three lengths using steel couplers.

GABIONS

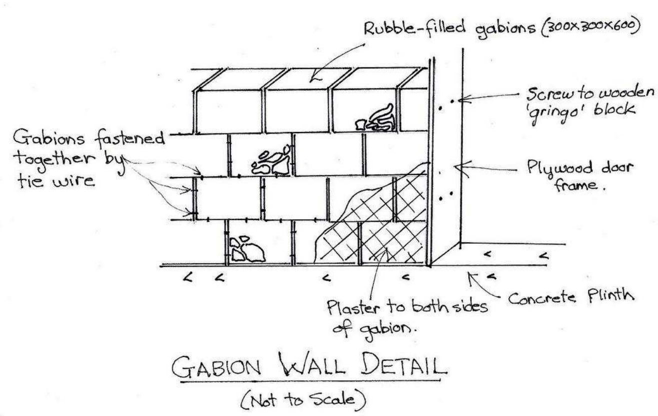
The gabion baskets are made using (A52) steel reinforcing mesh lined with chicken wire.

The gabions are 600mm long x 300mm wide x 300mm high. They are cut into the appropriate shape using bolt cutters.



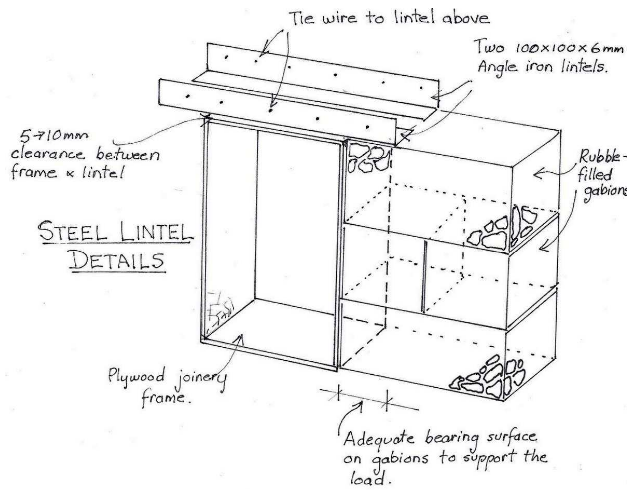
The mesh is then lined with chicken wire and the sides and ends are bent into shape and fastened together with tie wire.

The first course of gabion baskets are placed on the bond beam and fastened together using tie wire. They are then filled by hand ensuring the voids are kept to a minimum and that only rubble with one flat side is used on the two exposed faces of the gabion basket; this is important as it minimises the amount of sand/cement render used and ensures that there are a minimum of voids next to the sides of the baskets.



The second course is then laid in 'Stretcher' bond. The second course is tied to the first with tie wire, both vertically and horizontally. Half gabions are placed wherever necessary to maintain the stretcher bond. A fixing block is placed in every 2nd course adjacent to the joinery frames and secured in place by 2 screws. Work continues in this manner until 4 courses have been laid.

After the 4th course, a bed of levelling mortar is placed and the next course of gabions is embedded in this while still moist. The next three courses are placed as before until the seventh course has been laid.



We are now at the top of the windows and need to place 2 x 1.5m lengths of 100x100x6mm angle iron on top of the window surround and spanning 300mm on to the adjoining gabions.

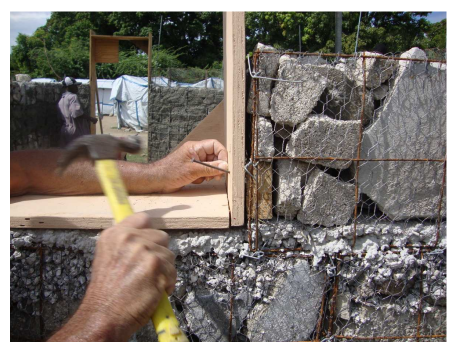
The supporting gabions and the supported gabions are tied to the angle iron with tie wire.

When the eighth and final course is in place the top of the gabions are covered with a lid made from the gabion mesh and a levelling bed of mortar is placed on top of the final course.

A 200mm x 50mm timber wall-plate is then bedded in the mortar so that the threaded steel rods protrude through the wall-plate and through a 100mm x100mm steel plate which is secured on top of the wall-plate and the entire fixed in place with a 12mm hex nut & washer – tightened to the engineer's specification.

JOINERY

The door and window openings are framed with 18mm plywood and 100mm x 50mm timber is fixed to the plywood as window & door frames.



The doors are traditional sheeted timber and bracing fixed with heavy T hinges to the frames, to resist strong winds.

The windows are traditional shutters made from planks with bracing and also fixed with strong hinges to the frame.

PLASTERING

A minimum of two coats of sand/cement render are applied to the exposed wall surfaces both inside and outside, the final coat being floated to give a nap finish.

The plaster is a 4:1 sand/cement mix; the sand is produced on site from crushed concrete block rubble using a hand operated crusher.

RISING FROM THE RUBBLE; THE PRODUCTION OF BUILDING MATERIALS

The composition of the rubble varies from site to site, and as such, a selection process must be in place to ensure that the raw materials are the appropriate ones to produce the desired finished products. The rubble can be reduced to aggregate and sand by the processes of crushing, hammer-milling and screening. Other uses, such as for footings and build up, can be achieved by fragmentation, placement and compaction.

It is envisaged that plastering sand (-2mm), fine aggregate (-10mm) and coarse aggregate (-20mm) can be produced from selected rubble for use in the gabion houses. Currently concrete slabs produce the best aggregate, while concrete blocks can be used to produce plastering sand.

Once consistent quality products are being crushed and screened from the rubble, it may be possible to value add by producing products such as concrete roofing tiles. Feasability tests will be carried out shortly, using a tile machine and style developed in Cuba.

Because selection and quality control are paramount to the success of both the buildings and the businesses supplying the products, training programs are being developed.

ENTERPRISES

The following small scale enterprises could be developed to supply an active Gabion House construction sector. While many of these operations could be relocatable, there are considerable economies to be achieved by a well established permanent site if transport costs are not too expensive.

Operation of hand or mechanically powered jaw crushers. This would be combined with the operation of a screening process. It could also be combined with a hammermill to more efficiently produce graded sand products. One owner/operator would need to employ at least 5 persons for a continuous production operation.

The production of gabions. This could be a mobile operation, and is ideally suited to women.

The production of concrete roof tiles. This would require permanent sites.

Transport services. If products are standardised and quantified, excess from local sites could be sold to other construction sites.

TRAINING

Currently training programs for the operation of the crushers and the selection of rubble are being developed by a private consortium. (HayTrac, Cemex, Unibank)

The training for the construction of the gabion houses will be provided for in the budget for the next, expanded building program. Training manuals, combined with a video, will outline the process of construction. These will be adapted to suit the local labour force.

COST BREAKDOWN

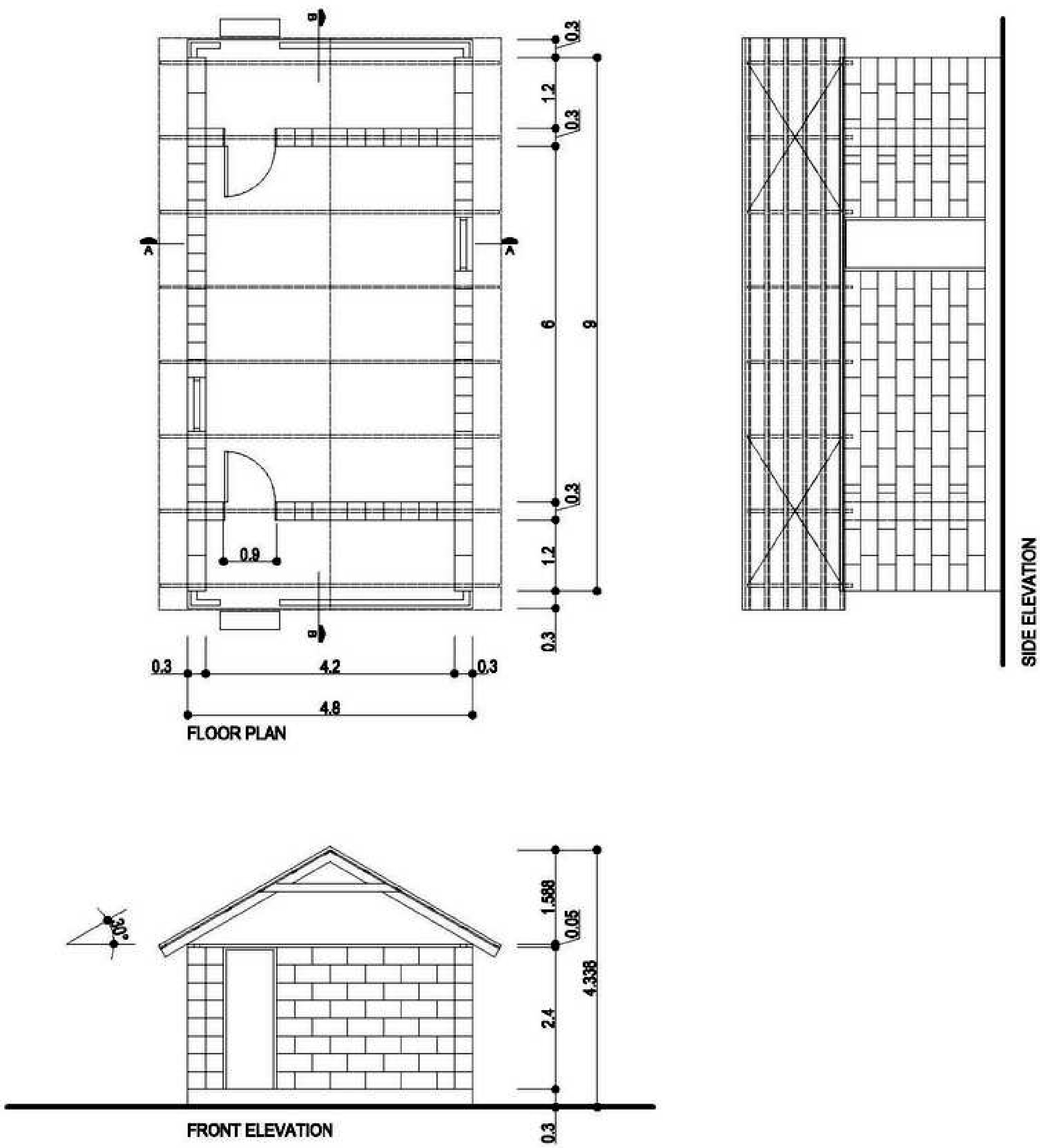
This projected cost are based on a 24 sq. m internal dimensions of the Gaibion Core House.

The cost will be subject to design, size, site and labour considerations.

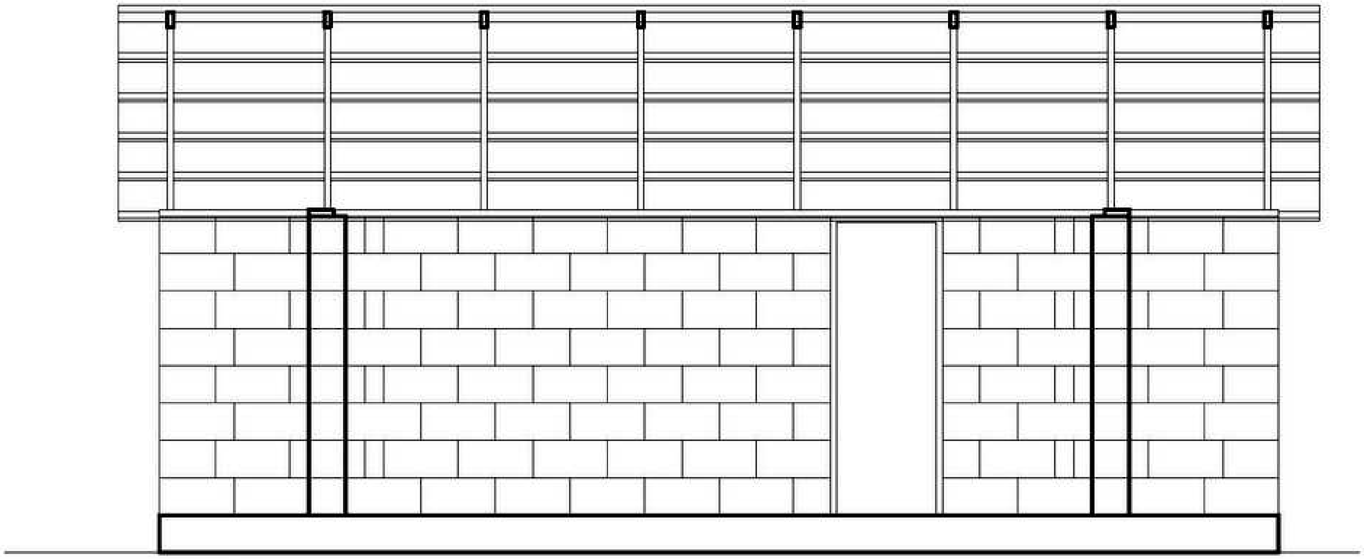
ITEM	PROJECTED COST
GABIONS 5 Rolls of square mesh 6 Rolls of chicken wire	 $900.00 $500.00
CEMENT 35 bags @ $7.50	$262.50
JOINERY 3 sheets of 18mm ply @34 ea.	$102.00
Doors & Windows	$250.00
RUBBLE Cost of collection & transport.	$200.00
LABOUR Making of gabions Filling gabions Crushing rubble	 $130.00 $130.00 $480.00
THREADED ROD	$160.00
PLASTERING	$250.00
ROOF	$600.00
TOTAL	**$3,964.50**

APPENDIX

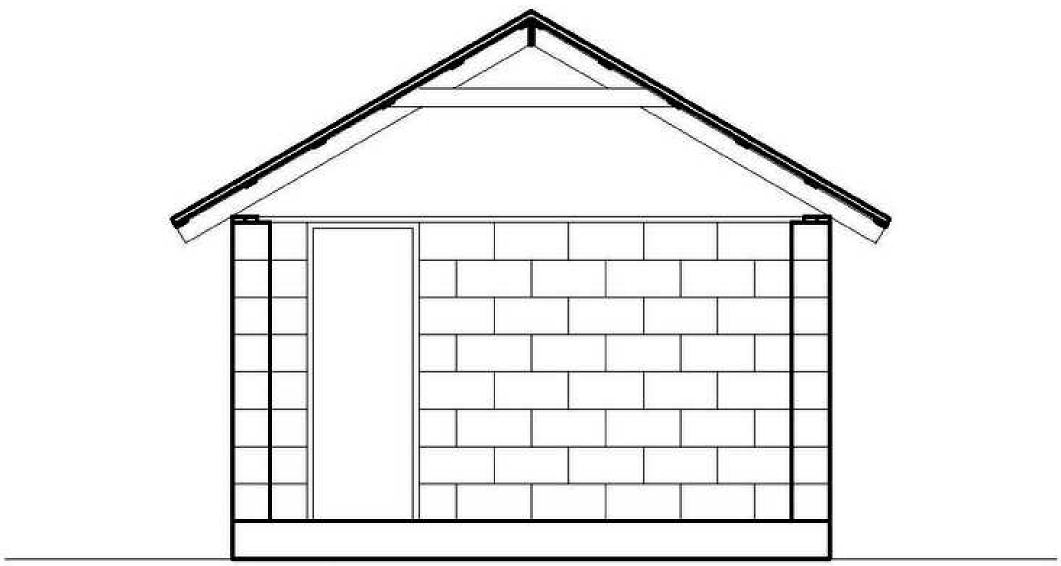
Architectural and construction drawings:



GABION CORE HOUSE		TABLE
FLOOR PLAN AND ELEVATIONS		S-01
DATE: OCTOBER 2010		
SCALE: 1:100	TABLE Nº 01 OF 06	

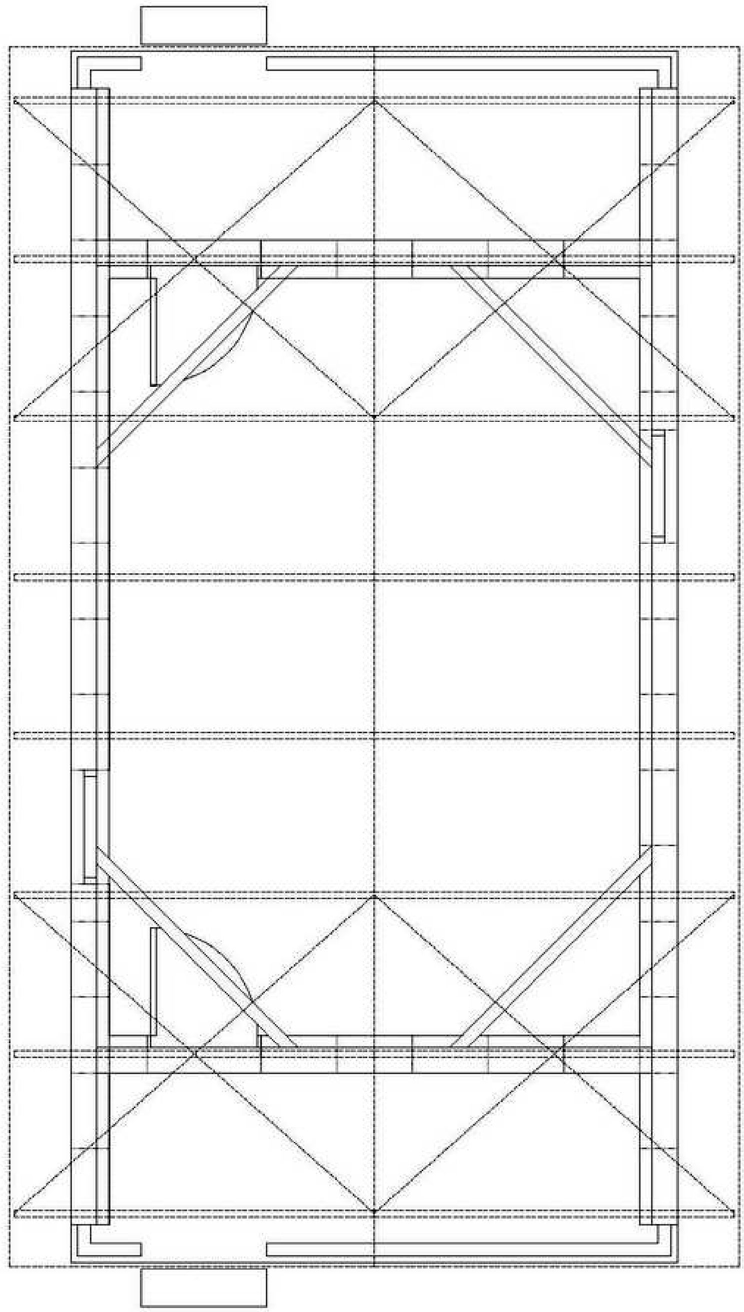


SECTION AA



SECTION BB

GABION CORE HOUSE		TABLE
ELEVATIONS		S-03
DATE: OCTOBER 2010		
SCALE: 1:50	TABLE Nº 03 OF 06	



FLOOR PLAN

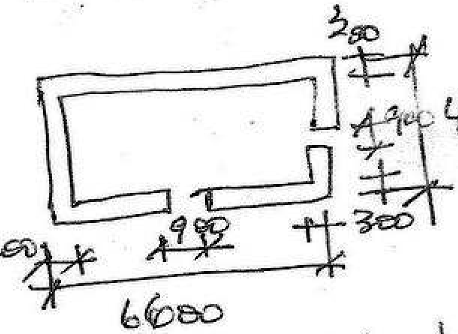
GABION CORE HOUSE		TABLE
FLOOR PLAN		S-02
DATE: OCTOBER 2010		
SCALE: 1:50	TABLE Nº 02 OF 06	

STRUCTURAL CALCULATIONS

(1) SEISMIC DESIGN CHECK.
of 2 REDCROSS HAVEN GABION HOUSE
Sept 2010
Dr REGAN POTANGAROA.

These calcs are a preliminary (first cut) for the seismic design of these Gabion houses.
The seismic resisting system consists of gabion baskets (wire) constructed into walls with 12mm threaded bars through the gabion @ approx 1.5m crs. These are anchored into the a concrete foundation and provide a limited ductile response. Loads are transferred to lateral resisting walls by diagonal corner braces located at the top of the gabion walls.
The basic house is 6.6x4.3 rectangular and is metres with a door in end wall.

House plan

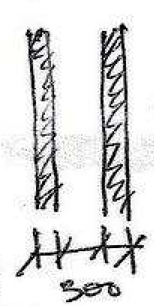


Peak ground acceleration figures (PGA) are taken from Analysis of Multiple Hazards in Haiti fig 4.

Building use: residential type
lightweight cgi roof R = 1.0
Gabion 16 kN/m³

Seismic coefficient for limited ductility = 0.5.

wall

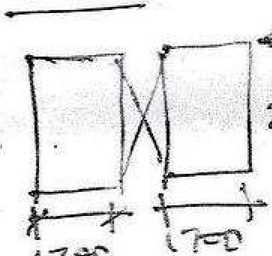


wall load
0.3 x 16 = 4.80
2 x 0.025 x 24 = 1.20
6.00 kN/m³

Seismic load
wall length
= 2 x (6.6 + 4.3 − 0.6) − 2 x 0.9
= 18.8 m.

seismic load
= 18.8 x 2.4/2 x 0.5 x 6.0
= 68 kN.
ie 68/2 = 34 kN/wall.

Review short end wall.



end wall load
2 walls
= 34/2 = 17 kN.

shear = 17 x 10³ / (1700 x 300 x 0.85) = 0.04 MPa, v low

Ignore plaster shear @ widths of top gabion; weight of blocks → 0.3 x 0.3 x 1.7 x 16
= 2.45 kN.
stress = 0.005 MPa.

ie pressure load

0.04 − 0.005 = 0.035 MPa

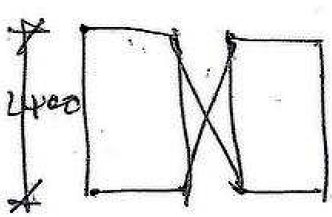
hence load-pressure of threaded bar

$= \frac{0.035 \times 1700 \times 300 \times 10^{-3}}{0.85}$ kN.

= 21 kN.

Hence snug tight threaded rod and do full turn after. Ensure gabions are compacted/packed in as much as possible.

Flexure



OT moment

$= \frac{34}{2} \times 2.4$ / wall

= 41 kNm.

Using 1MPa bearing block.

113 × 250 = 28 kN

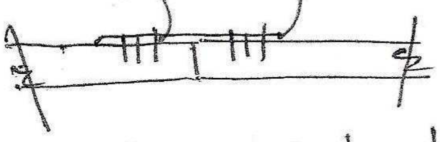
bearing block $= \frac{28000}{300 \times 0.85} = 110$mm

hence BM capacity

$BM = 28 \times (1.7 - 0.15 - \frac{0.11}{2})$

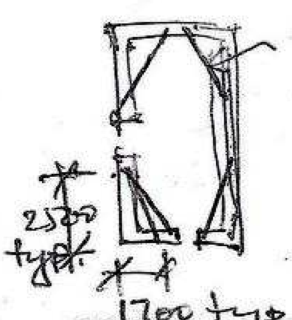
= 42 kNm. OK.

Bld OK. for seismic of 2.

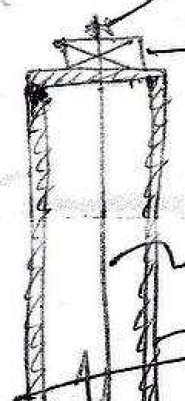


top plate tie

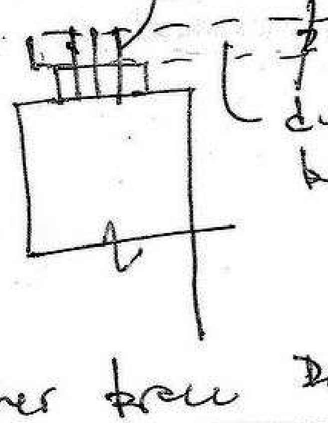
Load Transfer.



plan.



top of wall detail



Corner brace Detail.