PROJECT CONCEPT

Phase 1 Orphanage

This project intends to help VPWA (Volunteer Partnerships for West Africa) reach its goals of expanding its sustainable, socially beneficial projects in the Greater Accra Region of Ghana.

The Eastern Region has been chosen for this project site because it records the highest prevalence of HIV/AIDS in Ghana and the highest number of children orphaned as a result.

The goal for this project is to build an orphanage in order to address the immediate needs of the village of Damang, but also to begin the more long-term project of creating sustainable, development projects in the region.

With the modest volunteer fees that VPWA charges, it will be able to both sustain this current project and also start putting aside funds for the future expansion of VPWA’s infrastructure. Essentially, VPWA will use the profits generated by this orphanage (through volunteer placement fees) to fund other projects like a school that these children can attend and community sports programs in which they may partake. As each new project will draw an increased number of volunteers who provide valuable service as well as resources and funding, the more projects that are up and running, the greater VPWA’s potential to expand and create more important projects in its community.

This orphanage is the first step of many for VPWA’s expansion of its infrastructure, but an important one in that it tackles an immediate need head on, while simultaneously setting up the NGO for future growth.
PROJECT CONCEPT

Phase 2 SOLAR/ICT PROJECT

Project description:

Volunteer Partnership for West Africa (VWPA) is constructing a Solar/ICT training Centre in Ghana that will train community youth from various parts of the country how to build small scale solar devices such as solar powered radios and lanterns - and installs small solar systems for community centres, medical clinics, schools and other such communal infrastructure. This is expected to equip them with skills and a career in Solar Technology in their communities.

The strategy will be to:

1. Focus on rural Eastern Region of Ghana, where the need is greatest. This will allow us to benefit from synergies as we develop a programme of activity that is geographically focused
2. Focus mainly on training rural youth, who reside in the most impoverished and marginalised from energy networks.
3. Focus on programme sustainability through a micro business approach that encourages trainee beneficiaries to develop their own solar or solar-powered businesses; sustainable technologies; and a gender approach.
4. Develop from the outset a solid system for monitoring and evaluation.

The Project will partner with solar agencies to provide resource and training materials for the training to commence in Ghana once construction and set up is completed.

Goals and objectives:

Our initiative is designed to train and create a sustainable business in ICT/Solar Technology for young people in rural Ghana who might otherwise think of migrating to the cities to look for non-existing job and might end up in social vices.

The main goals are to support economic participation of trainees, reduce green house emissions and promoting renewable energy, promote gender equality and improve economic welfare of the beneficiaries.

Methods:

The training programme will run with an average of 15 trainees per month in the first year and gradually increase as we expand our cope to bring more youth for the training programme.

The centre will be staffed with high quality trainers recruited with Solar agencies and supplemented by our International Network of Volunteers with experience in Solar Technology. We will give priority to training youth from rural Ghana and they are expected to be taken care of by the centre. Community Radio stations that provide free publicity to social responsible projects will be use to inform communities about the centre.

The computers sourced for the centre will have to be quite robust to deal with the climate also the amount of use. Earthwalk are a firm that supply rugged laptops that are housed in mobile labs, the laptops are charged through one power outlet, this can be easily linked to solar panels. This type of system would work really well in the Darmang centre.
SITE ANALYSIS

Site
Area: approx 35mX33m
Gradient: approx 4.3% 1500/35000

The site is situated just outside the village of Damang along a dirt road around 200m from the school. The site is next to the Weep Not Foundation, which is an orphanage and small school run as an ngo and already accepts volunteers. The site is sloping towards the road.

There is currently a structure on site housing an office for VPWA and a storage room for the Green Ghana Project there is also a small toilet and kitchen. The kitchen facilities will be adequate for the orphanage in phase 1. There is a well in the north western corner opposite the office.
SITE ANALYSIS

1. Darmang Village
2. House nr site
3. Main Road
4. Local Farm
5. Local School
6. Farm Shelter
DESIGN STRATEGY

DEVELOPING LOCAL MATERIALS

Long Term Goal - to develop different methods of sustainable building with the community in Darmang as part of the Green Ghana Project
DESIGN CONSIDERATIONS
SPACIAL REQUIREMENTS

Phase 1 – Orphanage and associated facilities
Initially the orphanage will be for 10 children, average age 3-10 years
Spaces/rooms
- Bedroom/domitory for children
- Playspace, dining space and covered outdoor area for children
- Outdoor covered area for children
- Toilets and washroom for children
- Accommodation for madame – close to the children
- Toilet and shower for madame

Key Issues to consider
Drainage on site – sloping site lots of rainwater to harness
Weep Not Foundation – important to consider this in relation to design
Views

Phase 2 – ICT Solar Centre
Spaces/rooms
- Classroom – seating around 15 students
- Workshop – for teaching around 10 students at a time
- Outdoor covered area – for eating lunch etc
- Additional accommodation for volunteers/teachers
- Lounge, bathroom and basic kitchen facilities for volunteers

Key Issues to consider
Solar panels – how are they attached also where are the batteries stored, how many solar panels will be needed for 10 computers? Security – solar panels and computers need to be secure – this may require hiring security.

Materials/Tools
Hand tools such as saws hammers and cutlasses are used in Darmang. These are available to buy in Nsawam. Power tools such as drills are not available locally but can be purchased in Accra

Local Labour
Darmang has both skilled and unskilled labour. Our team worked closely with a local carpenter and mason. In the local town of Nsawam there is a sawmill and skills such a metal workers

Humid Climate = Natural Ventilation
High Rainfall = Appropriate Drainage
Solar Shading
Mosquitoes= nets on doors and windows

CLIMATE
RESOURCES
PRECEDEENTS

Handmade School, Bangladesh, Anna Heringer
Rammed earth and bamboo, this school responds very well to climate/resources and surroundings

School in Harare, Zimbabwe, Ramcast
This school meets earth building codes in Zimbabwe the rammed earth walls support a roof with a span of 8 metres

Gando School, Burkina Faso, Francis Kere,
This school was developed by Kere, an architect from Burkina the earth blocks and steel bar were a response to the availability of materials and local skills

Addo Residence, Accra, Joe Addo,
This house in the suburbs of Accra blends traditional materials with modern design

Bamboo School, Kumasi Ghana, INBAR
This school uses locally sourced and treated bamboo for both walls and roof
LOCAL MATERIALS

Bamboo

Bamboo is abundant in the Eastern Region, it is mainly used in local village architecture and for scaffolding. The most common bamboo in Ghana is bamboo vulgaris, this type is quite susceptible to parasites which means it does not last very long when not treated. The treatment process is relatively simple but is not widely used.

The design team visited the Sabre Trust an NGO based near Cape Coast, they have recently been involved in a programme to treat Bamboo for primary schools which they are building with Arup an international engineering firm. They are planning to treat Bamboo with Borax solution which has also been used in the building of a bamboo school in Kumasi.

Through contacts in the village of Darmang a local Bamboo grower was identified as a good source for the project.

Earth

The earth in this tropical belt of Ghana is clay rich laterite and is used widely as a traditional building material. There are many different techniques of earth building in this region alone. In the village of Darmang at least three types were identified; earth block, wattle and daub and solid earth walls.

It should be noted that earth building in Ghana has developed a stigma of being rural and therefore not modern however there are a number of organisations and architects working on the ground using earth in increasingly more sophisticated ways.

The visit to the Sabre Trust School, also their associated eco lodge ‘stumble inn’ reinforces this statement. In recent years a material called ‘pozzghana’ has been developed at the building research centre in Kumasi as a cement substitute, this is earth heated using a reaction in palm nut kernels.
The focus of the initial design stage was to reflect the local architecture looking at courtyard/compound dwellings at the heart of village life. Creating natural ventilation and balancing indoor and outdoor areas were key issues these were talked through as a team and with local people also VPWA members and staff.
The purpose for conducting these experiments was to see whether the earth on site in Damang would be suitable for constructing rammed earth walls.

Two points were taken on the first site and one on the second, we also took a sample of the earth used to make the bridge on site that had been brought in from somewhere else.

The testing identified that the earth is extremely clay rich and would need mixing with some sand and lots of stone.

Formwork and a ramming pole was made by two local carpenters, the wood was sourced from a local sawmill, the fixings were brought from the nearest town, Nsawam.
RAMMED EARTH WORKSHOPS AND TEST WALLS

Key points –
- Best Mix: Earth : Sand : Ballast – 4:1:1
- Earth taken from ground Below 1ft deep Suitable
- Drop Test to Check for suitable moisture content
- 2 Ft maximum Between Bolts
- Start In Corners
- Mix Earth Near to Shuttering
- Leave end caps out to adjust size
- Chamfer Edges
- Ensure Form Work is Vertical
- DPC – DAMP PROOF COURSE
- Cover top after ramming.
- Dry out of direct sunlight
- Overlap Edges when moving up
- Fill 3” per ram
- Keep large stones in centre
- Ram in timber to form doors and windows
- Ram re-bar to take fanlight/ring beam at top of wall.
- Paint with glue mix after drying 3 : 1 : 1 (Water : PVA : Earth)

For further explanation see: Rammed Earth Structures: A Code of Practice
PHASE 1 PLAN
PHASE 1 FOUNDATION + SERVICES PLANS

Foundation plan 1 showing the positions of the pads and concrete column foundations. Plan 2 showing the single and double layers of sandcrete block (see details).
PHASE 1 SECTION A & B

These sections identify the steps needed to deal with the gradient on site.

Section AA

Section BB

Go to Detail Pages 1-6 for detailed drawings

Profile 1
Profile 2
Profile 3
Profile 4
VISUALS: COMPLETED PROJECT VIEW FROM TOP
**Details: Roof**

**Truss Perspective and Details**

- **2x6” softwood timber used throughout.**
- **Ridge plate connection:**
- **Ridge plate connection:**
- **Bamboo ceiling runs between walls with trusses on.**
- **Tin* roof supported by purlins which sit on rafters. (*durable metal sheathing)**

**Timber Connection Details**

- **Tie Beam Connection:**
- **Tie Beam Connection:**
- **Rafters cut at angle to meet. King post joined through rafters to plate to form.**

**Detail A**

- **Truss sits on ring beam which runs around top of all walls to help earthquake resistance.**
- **Rafters Extended at end with sandwiched timbers.**
- **Detail A**
DETAILS: ROOF AND WALLS

Top of Wall Details

- Earth press into bamboo to form ceiling
- Re-bar to go into rammed earth minimum 400mm (14"")
- Re-bar rammed into top of all walls to hold in place top timber
- Tops of Truss walls rendered for protection
- Re-bar fixings positioned to allow head tie beam to sit in between
- Bamboo cut to sit on edge of ring beam
- Walls that take trusses 1 lift higher to allow for installation of fan light
- Tie Beam To sit on Ring Beam in centre of wall
- 400mm/14" Min
- 400mm/14" Min
DETAILS: FANLIGHTS, DOORS AND WINDOWS

Timber Fittings

Fly Nets fitted across ALL openings

Re-bar fitted across fan lights for security

Fascia boards applied to front of fanlight to fix fly net

Re-bar rammed into earth to fix Fanlight in place

Nails hammered through timbers and then bent, before being rammed into end of walls to form frame for doors and windows

Painted shutters fitted to windows - Made on site.

Gaps left in walls to create doors and windows

Timbers rammed into earth to create frames for doors and windows
DETAILS: CEILING AND FAN LIGHTS

Bamboo Ceiling covered over with compressed earth.

Fascia board fitted to top of fanlight to hold in earth for ceiling and fix fly net in place

Re-bar rammed into wall to take fanlight

Plan Above Ceiling

Fanlight openings spaced in line with openings in wall, e.g. windows and doors.

Fanlights fitted to front and rear walls.

Plan Through Fanlight
DETAILS: FOUNDATIONS 1

METAL FOOTINGS: fabricated in Nsawam. 6x6' Head to take posts. Footing is set into concrete inside re-bar as shown below.

Profile 2 - Foundation Layout Under Rammed Earth walls
Profile 1 - Standard Foundations

DPC - DAMP PROOF COURSE - DO NOT FORGET
Cement/Sand Blocks - Made on Site And Stepped as ground level changes
Concrete Base to Foundations
Minimum Depth 1'Ft 6"

Post in-line with outer foundations
Bank Built up around edge for water run off

Screed/Tile Finished Floor
Render Level
Back Fill

METAL FOOTINGS: fabricated in Nsawam. 6x6' Head to take posts. Footing is set into concrete inside re-bar as shown below.
Profile 3 - Foundation Layout on Outside edge of building, with concrete pile for post footing set outside of foundation wall.

Profile 4 -- Long foundation section on inside of compound.

Post made up of two 2x6" timbers with one cut piece sandwiched in between to separate them creating 6x6' square

Footing set into concrete pile. Pile set outside of line of blocks to take walls

Sloped bank to edge with drainage canal made up of rocks and sand

Minimum Depth 1' Ft 6''

Line indicating position of truss supporting wall

Piles set so POSTS SIT IN MIDDLE of wall. This means they are set out of line with upright blocks

Fabricated metal footing to take posts

Screed/Tile Finished Floor

Render Level

DPC - DAMP PROOF COURSE - DO NOT FORGET.

Back Fill

Cement/Sand Blocks - Made on Site

Concrete Base to Foundations

Re-bar set into footing piles

Concrete pads situated under piles

Foundations step after each post

Details: Foundations 2

Minimum Depth 1' Ft 6''
CONSTRUCTION: PHASE 1 FOUNDATIONS

- Minimum Depth 1ft 6”
- Foundations Step with every 9” gain (e.g. the height of one block + mortar) in line with block work
- Pillars to sit in line with CENTRE of wall, therefore in centre of cross foundation, not in-line with upright block
- Double block (14”) foundations under Walls, Single block (5”) Elsewhere

SEE FOUNDATION DETAILS FOR FURTHER INFORMATION
The design team:

Benjamin Powell – Ba(hons) Architecture – UK – bonzo58@hotmail.com
Sophie Morley – Ba(hons) Architecture – UK – serafinamorley@aol.com
Laura Martinelli – Architect – Italy
Alex Davies – BSc Civil Engineering - UK

Our key aims for the project are to utilise local skills, and available materials to create a sustainable scheme that will help develop the local area, and suggest ways in which current building practice can be improved. In this respect it is a response to what we perceive to be a wider issue regarding sustainable development within a rapidly changing environment.

Our focuses during the design process were to design affordable and achievable spaces that could be built using local resources, would respond to local climatic conditions, and would provide a suitable living and learning environment for orphans and young adults.

We have spent time adapting the design to one which we believe corresponds with building techniques used locally. With the exception of rammed earth, all other techniques are common to the area.

We believe that the rammed earth workshops conducted on site will provide the local workers with sufficient understanding to build using this method. We hope that in the next phases of the building the use of treated bamboo an be introduced to replace timber. This will reduce the cost significantly, as well as demonstrating the strengths of a locally available material, and environmentally sustainable resource.

References:

Rammed Earth –
All design Specifications Taken from: Rammed Earth Structures: A Code of Practice - Julian Keeble - TDG Publishing 1 Jan 1996
Contact: Rowland Keeble – Ramcast CIC - Email: rowland@rammed-earth.info
APPENDIX 1: ENGINEERS NOTES
As per suggestions from the site, you may consider the following:

1. Foundation Considerations:
   - The site is sloping, so we need to consider the gradient of the slope.
   - The gradient of the slope means that the level flow surface of each step has to be at a compromise.
   - Geomembrane depth extends from the intersection of the internal wall and vertical wall.
   - Problem: Footing depth below where one or two courses are found.
   - Solution: Footing depth below the ground level.

2. Plan View:
   - Office
   - Road
   - Step 1
   - Step 2
   - Step 3
   - Step 4
To alleviate this concern we use reinforced concrete columns at each corner, under the roof columns. However, along the perimeter wall the foundation blocks will still lack P in one direction, as long as it is out the ground.

A way to reduce the Bending Force is to 'tie in' the foundations.

Problem 2

At the corner 2 the issues are not structural integrity but that of erosion. Having the top of the floor below ground level exposes the site to run-off rain water, as well as insects and fungi that could damage the R&W. Although the R&W will have a protective screed over the first 1 metre of the height, its specifications demand that the R&W are placed above ground level. Clearing and levelling the nearby ground may be required.

If a drainage ditch is required, it is recommended that it is at least 1/2 feet deep and filled with large stones to allow instant drainage.
STEPPING THE FOUNDATION

As the slope increases it is possible to reduce the four deep blocks to three, and then two. This is practiced to reduce digging and then number of blocks used.

The blocks must be at least 1½ blocks deep from the ground surface and never be shallower. However, as the slope increases in height and the depth of the blocks rises to 2½ deep, then a step may be used to reduce the trench depth. The height of the step must be the height of the foundation blocks plus 1 inch of mortar.

* The foundation depth cannot be reduced beyond 2 blocks. *

Stepping can be done in both slope directions.

PLACING THE REBAR

The rebar for the reinforced concrete pad must be placed just under the surface of the concrete pad where the rebar bends. This is tied to the column in with the pad.

Useful Data

- Undrained shear strength Cu kN/m² of clay = 75-100
- Bulk unit weight Wb kN/m³ = 17-20 (clay)
- Safe bearing capacity of soil 150-500 kN/m²
- Concrete specific weight γ kN/m³ = 24
- Foundation block specific weight γ kN/m³ = 15-20
- Concrete crushing strength fcu N/mm² = 150
- Foundation block crushing strength fcu N/mm² = 40

Considerations:

- The rebar length should be designed to reach the height of the floor level.
- If you step the foundations, then the rebar will need to be shorter by 9" each step for the up slope corner. Or you could dig the pad depth 9" deeper.
- It is better if the rebar is slightly longer than needed. The shorter, it can always be cut.
Looking at Newton's Law of Motion, we have equal and opposite forces acting on the foundation of each step.

**Problem 1:**

The forces acting on a single foundation block should be equal and opposite. The weight of the block, represented by the force acting vertically downward, is balanced by the reaction force exerted by the soil. The reaction force is the soil pressure, represented by the force acting upward.

If \( R > W \) (where \( R \) is the reaction force and \( W \) is the weight of the block), the soil will be able to resist the vertical load of the block. If \( R < W \), the block may sink into the soil.

**Foundation Materials:**

- **Soil:** Silt, Sand, Clay
- **Concrete:** Mass of the block

All these materials have one identical characteristic: They are strong in compression but very weak in tension. N.B. Earthquake takes their tensile strength more than their compressive strength.

**Analysis:**

- **Load:** \( P \), vertical force acting on the foundation block
- **Support:** \( R \), horizontal force acting horizontally

As \( R = P \) (vertical force), the block is in equilibrium. The lack of friction between the block and the soil means the foundation block will not move.

**Conclusion:**

Due to the block's weight, \( P \), the load is acting on the foundation block. As the load increases, the depth of the foundation also increases to support the weight.
INITIAL DESIGN

According to BS 5268 Preliminary sizing of timber elements.
For beams/purlins, \( L/10 \) to \( L/15 \)

as \( L = 8.8 \text{m} \), \( L/10 = \) a depth of 88cm (for softwood)
\( L/15 = \) a depth of 59cm (for hardwood)

Due to local constraints, the largest depth available is 6 inches or 15cm.

This meant that further columns were required to reduce the span of the beams. However, this did not meet the architectural criteria.

So the decision was taken to use the rammed earth wall as a load bearing member, and rest the beams on top.
WIND LOADING

According to BS 6399 a conservative quick scheme value for most UK buildings is 1.2 kN/m².

As we have no data for Accra wind loading we took this value.

- Wind loads on building - suction.

12 kN/m² → 0.4 kN/m²

0.6 kN/m² (open) 0.4 kN/m² (open) 0.4 kN/m² (open)

:\. looking on roof =
12 - 0.54 for suction = 0.66 kN/m²

As a worse case scenario for the wind loads; water (rain) loading; self weight of aluminium sheeting, truss beams, purlins and beams, 1.5 kN/m² was used.

\[1.5 \text{kN/m}^2 = 6 \text{kN/m UDL}^*\]

\[4.94 \text{ (kg/m}^5\text{)}\]

\[4 \text{m}^3 \text{ per m}^3\]

UDL = Uniform Distributed Load

Permissible Deflection for 5m beam, not including angled truss beam for 2x4 timber section = 15 mm.

According to calculations max. deflection = 14 mm

As horizontal beam is resting on rammed earthen wall, it will not deflect.
COLUMN DESIGN  TO BS 5268

The max height is 5.75m and the square section consists of 3 2x6 inch sections combined to form 6x6 inch section or 450mm x 450mm.

The load from the roof (ignoring the load from the gate going through the rammed earth wall) is 30kN and the bending moment is 100 kNm.

Slenderness Ratio

As both ends of column are fixed \( L_e = 0.7 \)

\[
\lambda = \frac{L_e}{i} \quad L_e \times \text{height} = 4025 \text{mm}
\]

\[
i = \sqrt{\frac{k^2}{12}} = 129.9
\]

\[
\lambda = \frac{4025}{129.9} = 30.9 < 180 \quad \text{so OK.}
\]

Grade Steel for D30 (using lowest strength class of hardwood)

- Bending parallel to grain \( \sigma_{mg,11} = 9.0 \)
- Compression parallel to grain \( \sigma_{cg,11} = 8.1 \)
- Modulus of elasticity \( E_{mg} = 6000 \)

Modification Factors

\[
k_3 = 1.5
\]

\[
k_7 = \left( \frac{300}{575} \right)^{1.1} = 0.93
\]

\[
k_{12} = \frac{E_{mg}}{\sigma_{cg,11}} = \frac{6000}{8.1} = 494 \quad \text{and} \quad \lambda = 30.9
\]

Using graph, by interpolation \( k_{12} = 0.837 \)

Axial Load Capacity

\[
\sigma_{ck,12} = \sigma_{cg,11} k_3 k_{12} = 8.1 \times 1.5 \times 0.837 = 10.17 \text{ kN/m}^2
\]

- Long term capacity = 101.7 kN > 30kN \quad \text{so OK.}
Compressive and Bending Stresses

Permissible bending stress is 
\[ \sigma_{\text{b, perm}} = \frac{Mk}{I} \leq \sigma_{\text{u, perm}} \]

Critical stress is 
\[ \sigma_c = \frac{\pi^2 E}{(12k)^2} \]

So, OK

Applied bending stress is 
\[ \sigma_{\text{b, appl}} = \frac{M}{I} = \frac{350 \times 300}{563 \times 10^3} = 0.62 \text{ N/mm}^2 \]

Compressive stress is 
\[ \sigma_{\text{c, appl}} = \frac{F}{A} = \frac{30000}{950^2} = 0.15 \text{ N/mm}^2 \]