Case study: construction of rammed earth house

13 June 2011

Introduction

This case study documents the construction of a rural house, using rammed earth construction technique, which took place during June 2011. It has been undertaken with support from the Australian High Commission, British Women’s Association and Housing and Hazards. It details our participatory approach and provides technical information about our techniques and the associated costs.

SAFE is a small NGO working in the Dinajpur district of Bangladesh to:

Reduce the vulnerability of low income households to environmental hazards such as flooding and strong winds.

We do this through promoting improved and appropriate house building techniques – using cheap, locally available materials, and environmental initiatives such as tree planting. With stronger houses that last longer, households in the long run save time and money and are less vulnerable to environmental hazards.

We aim to increase community self-reliance by creating skilled and informed local builders, craftsmen and house owners. We do this through a programme of workshops, construction of demonstration houses and material subsidies.
**Participatory Approach**

We recognise the importance of participation if our new techniques are going to be accepted and spread within the local population. This house has been built through a partnership between SAFE and the household. Both parties contributed labour and materials in an approximately 50/50 split. This split was agreed at the outset and a simple hand written contact outlining each party's responsibilities was signed.

The size and type of house was decided by the household based on available materials and space requirements.

The house included some new techniques and we made sure that the household and builders understood these fully. As part of this we organised a 1-day building-for-safety workshop for households in the local area, students and local builders. These workshops included practical demonstration of these new techniques.

**Improved Construction Techniques**

The house has been built with the household of Udoi and Doiya Rani Roy in Baniar Para, Sundarban village, Dinajpur. The house was built to replace an existing sleeping room which was in poor condition. The house comprises of one room of outside dimensions 17.5ft by 8.5ft. The house is built on brick foundations. The structure is made rammed earth with bamboo reinforcement. The roof is of hipped (cho-chala) construction and made with bamboo frame and corrugated iron (CI) sheet. SAFE has used added several low cost improvements to this traditional house and these are as follows:

Refer to construction drawings in Appendix A.

*Foundation*

A layer of plastic sheet has been used to provide a damp proof layer between the top of the brick foundation and the mud walls.

*Walls*
Vertical and horizontal bamboo reinforcement used.

Walls are made used rammed earth with cement stabilised mud, a techniques which make the wall much stronger and more resistant to water. The mud was mixed with 5% cement\textsuperscript{1,2} (refer to footnotes for more information on this technique). Cement stabilised earth was used only for the bottom 6ft (bottom two layers) of the wall – above this, protection from rain is given by the roof overhang.

The forms were constructed on site of dimensions 6’8” x 3’ with made using 1.5” thk timber boards. See pictures.

An overhanging layer of bricks has been built into the wall approximately half way up. Any water which comes into contact with the wall above these bricks will drip clear of the lower section of the wall – reducing damage.

Ventilation – 3 windows and ventilation holes have been used to provide adequate ventilation within the house.

A bamboo ring beam has been constructed at the top of the walls fixed to the vertical reinforcement.

\textit{Roof}

The roof is secured to the walls using the bamboo vertical reinforcement. Overhang of approx 2” is given to give adequate protection from rain. Nylon rope has been used over jute rope for its longevity.

\textbf{Costs}

A cost comparison has been carried out between the rammed earth and brick walled house. It is assumed that the foundations and roof, and other costs such as the door and window

\textsuperscript{1} Iftekar, K.A. Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh, ADPC 2005. Available at \texttt{www.sheltercentre.org}

\textsuperscript{2} Norton, J. Building with Earth, A Handbook, Practical Action, 1997

\textbf{SAFE} Case study: construction of improved rural house in Dinajpur, Bangladesh
frames to be of similar construction and so have been discounted. It is also assumed that the household can provide 3-4 labourers during construction at no cost, however skilled labour for the setting of the rammed earth formwork will be required and is included.

Refer to the cost comparison in Appendix B. The total cost of the rammed earth walls comes Tk12,769 or 28Tk per sqft. The brick wall cost comes to 51Tk/sqft – approx 55% of the cost of using brick wall construction.

For more information contact:

Azit Roy, T: +880 (0)1726 007 343, E: azit_sorkar@yahoo.com
John Arnold, T: +880 (0)1753 858 660 E: johnarnold700@yahoo.co.uk

In the UK:

Robert Hodgson (Housing and Hazards), T: +44 (0)1884 821239
R.L.P.Hodgson@exeter.ac.uk

Arched windows formed using bricks

Single layer of protruding bricks provide extra protection to erosion from rain water.

Floor structure for loft storage + bamboo ring beam
Appendix A – construction drawings
UD01's RAMMED EARTH HOUSE  16.04.11/JA.  PAGE 1/3

- 4" dia holes formed in wall to accommodate the veranda.
- Construction joints (horizontal bamboo reinforcement placed at each joint).

**For Typical Roof Layout see Section A-A & Details B**

**Detail A**

**Front Elevation**

**Side Elevation**

**Damp proof layer between brick & mud.**

**Ventilation cut-out on both elevations 5.5x3.**

**1 Course brickwork extending 3/4" from face of wall; all sides except front elevation.**

Scale: 10mm:1'0
Boundary Wall

Plan at Window Lvl.

Verandah

Con. Shed

Detail A

Detail B

Boundary Wall

Wall plate fixed to vertical reinforcing with nylon rope or GI wire.

Vertical reinforcing adjacent to all opening & corners.

Bamboo socket set in wall to take horizontal tie for adjoining boundary wall.

Bamboo timber set in wall to fix door/window frame for all windows.
SECTION A-A  PAGE 3/3

2x1 Purlin @ 2'8" c/c MIN.

Rafter, 2"x2" @ 2'1" c/c

CI Sheet (Min. 0.35mm Gauge)

Bamboo, cemented in place after wall construction to support verandah.

Ties, 2x2" 3 no. evenly spaced; or to suit storage requirements.

Bamboo wall plate (ring beam); secured to vertical reinforcement & fixed at corners.

APPROX. GROUND LVL.

SAND LAYER ON FORMATION OF FIRM SILTY SAND

APPROX. GROUND LVL.

SEE DETAIL 'B'

DETAIL B (SCALE 1"=2MM)
Appendix B – Cost comparison of cement stabilised rammed earth against brick wall
Assumptions
Foundations are assumed to be same as mud block wall and are not included
RC lintel is added for stability
Plaster for one side is included
Lowest quality bricks used

Brick size
Standard brick size = 25 x 7.5 x 12cms
incl. mortar joint = 26 x 8.5 x 13cms

<table>
<thead>
<tr>
<th>Convert</th>
<th>25</th>
<th>9.8 in</th>
<th>26</th>
<th>10.2 in</th>
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</thead>
<tbody>
<tr>
<td>7.5</td>
<td>3.0 in</td>
<td>8.5</td>
<td>3.3 in</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4.7 in</td>
<td>13</td>
<td>5.1 in</td>
<td></td>
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</table>

Volume of 1 brick without mortar course 0.079 cuft
Volume of 1 brick with mortar course 0.10 cuft

Cement
Cost of cement - 50kg bag 360 Tk
Convert to volume @1500 kg/m3 0.033223 m3
Convert to cuft @1m3 = 35.32cuft 1.172757 cuft per 50kg bag

Labour
Skilled eg. mason 200 Tk/day
Labourer 120 Tk/day

Size of Wall
Plan area 10.63 sqft
Volume of wall 95.63 cuft

Calculate no. bricks
Brick volume incl. mortar joint from above 0.10 cuft
Total bricks 942 no.
Cost of bricks @ Tk5/brick 4712 Tk

Mortar
Sand - 1 trailer at Tk400/ load 100 Tk
Use rule of thumb 0.3m3 mortar per 1000 bricks
Volume of mortar 0.28 m3
Convert to cuft @ 1m3 = 35.32cuft 10.0 cuft
Volume of cement @ 1:4 2.0 cuft
No. bags cement 1.7 no.
Cost of cement (using rate above) 613 Tk

Labour - laying bricks
say 3 days for mason (Tk200/day) and labourer (Tk120/day) 960 Tk

Plaster
Cement - say 1.5 bags @ 360/bag 540 Tk
Sand (use load from before) 100 Tk
Labour - say 1 mason, 1 labourer for 2 days 690 Tk

Lintel
M5 Reinforcement, 8kg @ Tk44/kg 352 Tk
Tying wire 70 Tk
Cement - say 1 bag @Tk360/bag 360 Tk
Brick chips (80 no. bricks @ Tk4/brick) 320 Tk
Sand 100 Tk
Labour - say 1 mason, 1 labourer for 1 day 320 Tk

Total cost 8278 Tk

Total wall length 18 ft
Wall height 9 ft
Area 162 sqft
Cost per sqft. 51 Tk/sqft
## Cost of Rammed Earth Technique

### Unstabilised mud

**Assumptions**
- Assume house size of 8.5ft x 17.5ft with 9ft high walls
- Shuttering cost not included
- Scaffolding cost not included
- Assume construction in 3 layers
- Assume that in 3 days, 2 men will construct 1 layer
- Use 1 skilled labour and 1 labourer
- Household is required to prepare and carry earth and assist with ramming - 2/3 people for duration of construction
- Earth is assumed to be available locally with no transport costs.
- Any minor repair/finishing to be done by household

<table>
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<th>Labour</th>
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<td>Skilled</td>
<td>200 Tk/day</td>
<td>3 no.</td>
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<tr>
<td>Labourer</td>
<td>120 Tk/day</td>
<td>11 days</td>
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<tr>
<td>Total daily cost of labour</td>
<td>320 Tk</td>
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<tr>
<td>No. of layers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>No. of days for construction*</td>
<td>11 days</td>
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<tr>
<td>Total labour cost</td>
<td>3520 Tk</td>
<td></td>
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<tr>
<td>Bamboo for reinforcement</td>
<td>1500 Tk</td>
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<tr>
<td>Cost of consumerables eg. rope for shutters</td>
<td>500 Tk</td>
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<tr>
<td><strong>Total cost</strong></td>
<td><strong>5520 Tk</strong></td>
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**Unit cost**

- Total length of wall: 50 ft
- Height of wall: 9 ft
- Area of wall: 450 sqft
- Cost per ft of wall: 12 Tk/ft

### Extra cost of cement stabilisation

**Assumptions**
- Only bottom 2 layers are stabilised as top layer will be protected by roof overhang
- Wall is 10” thick
- 1-2 extra labourers required during construction - assume 1 is paid @ 120 Tk/day and one is provided by household

<table>
<thead>
<tr>
<th>Cement cost</th>
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<tbody>
<tr>
<td>volume of walls</td>
<td>250 cuft.</td>
<td></td>
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<tr>
<td>assume compaction of</td>
<td>1.5</td>
<td></td>
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<tr>
<td>volume of earth</td>
<td>375 cuft.</td>
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<tr>
<td>volume of cement @ 5%</td>
<td>18.75%</td>
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<tr>
<td>volume of 50kg bag cement</td>
<td>1.17 cuft/bag</td>
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<tr>
<td>total cement required</td>
<td>16 bags</td>
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<tr>
<td>Cost per bag</td>
<td>370 Tk</td>
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<tr>
<td>Total cost of cement</td>
<td>5929 Tk</td>
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</table>

**Extra labour**

- No. of days of construction: 11 days
- Labour cost: 1320 Tk

| **Total cost** | **7249 Tk** |

**Unit cost**

- Total length of wall: 50 ft
- Height of wall: 9 ft
- Area of wall: 450 sqft
- Cost per ft of wall: 16 Tk/ft

| **Total cost - rammed earth + stabilisation** | **12769 Tk** |

**Unit Cost**

- Total length of wall: 50 ft
- Height of wall: 9 ft
- Area of wall: 450 sqft
- Cost per ft of wall: 28 Tk/sqft