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Large-scale dissemination of stabilised soil blocks – A case study of GoodEarth eco-homes

Stabilized soil blocks (also known as stabilized compressed earth blocks) are low embodied carbon materials suitable for load bearing masonry construction. Apart from low embodied energy, use of local soil and decentralized production at site using manual machines are the other major advantages of this technology. Cement stabilized soil block (CSSB) was exploited for the construction of 342 loadbearing homes in the Bangalore city metropolitan region in India. This project by Malhar GoodEarth eco-homes is in the final stages of completion with homes already occupied in the first two phases of the project.

The salient features of the project include use of low-energy materials, clustered planning, efficient management of water and wastes, recycling of black/grey water and demonstration of eco-friendly low-rise development. The paper narrates details of this project including planning, design, water and waste water management and the construction methodology. Details of utilising local soil to manufacture over 5 million stabilised earth blocks in a decentralised fashion and the analysis of embodied energy has been discussed. The project has in-built systems for harvesting rainwater and recycling of wastewater for secondary applications.

Introduction

Traditional earth construction techniques have evolved through ages. Varieties of earth construction technologies have been used in different parts of the globe. There is a growing interest in developing modern earth construction technologies because of the benefits of low embodied carbon, GHG emission reduction and sustainability. There are two types of earth constructions: (a) un-stabilised earth and (b) stabilised earth. Some of the major disadvantages of un-stabilised earth (such as loss of strength on saturation and erosion due to moisture ingress) are circumvented by using stabilisation techniques. Compressed earth blocks and rammed earth are the two emerging modern earth construction techniques. Generally, compressed earth blocks are stabilised with inorganic binders (such as cement, lime, etc.), in order to improve the strength and durability characteristics.

Stabilised soil bricks are used for the construction of load bearing masonry buildings. Cement stabilised soil brick (CSSB) is a low carbon material used for building construction throughout the world (Fitzmaurice 1958, Lunt 1980, Heathcote 1991, Houben and Guillaud 1994, Walker & Stace 1997, Reddy and Latha 2014, and others). CSSB technology was profusely used in the construction of houses in the Goodearth eco-homes project. Manually operated machines were employed in the large scale production of CSSB in a decentralised manner in this project. The paper will highlight the details of this project including the energy/carbon savings achieved.

Scope of the project

The eco-homes project involved planning, design, manufacture of materials, construction and integration of water and waste management, and several resource conservation techniques. The scope of the project involved:

1. a challenging planning and design exercise involving managing of sloping site to generate soil for the production of CSSB for load bearing walls, which formed the bulk of the materials used and mass of the buildings,
2. housing the facilities for harvested rain water and a system to house black/grey water treatment & storage/circulation was another challenging task in the planning exercise,
3. design for passive space conditioning, managing natural light and creating green spaces through

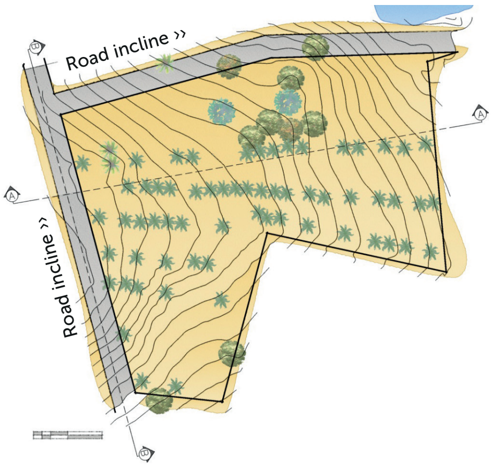

Fig. 1 Site plan with contours for the phase 1 called "footprints"

Fig. 2 Clustered planning with separate pedestrian & vehicular paths (Phase 1: footprints)

courtyard clustered planning with seamless service connections,

4. organisation of decentralised CSSB block production at site using local materials and minimising the use of heavy machinery for the construction,
5. establishing project monitoring group for ensuring quality and speed of construction.

The GoodEarth eco-homes project details

Location and ground conditions

The project is situated in Bangalore, India (12.97° N and 77.60° E). Figure 1 shows the contour map of the land on which 342 eco-homes were being built. The land has a steep slope. The difference in the elevation from the ridge portion to bottom most point touching the river is 26 metres. The falling contours were conveniently used to create a terraced cluster development facilitating scooping of large quantity of soil for the production of CSSB blocks and housing the rain water storage and grey water management facilities conveniently. Also, facilitated in terraced cluster planning of the houses. Creating naturally ventilated and well lit spaces adaptive to the users requirements. The choice of materials was based on sourcing them locally, minimum transportation, less processed and low embodied energy. The designs reflected sustainability in all aspects rather than introducing sustainability as an element.

Planning and design of homes and infrastructure

The site was developed as community housing where infrastructure and amenities are shared by the individual homes. The project adopts the following planning and design concepts:

- Clustered planning with seamless connectivity (Fig. 2). Land ownership is 60% private, 40% shared.
- The buildings of different sizes ranging between 150 and 220 m^2 constructed in plots of size ranging between 120 and 200 m^2. Low rise structures (maximum of two storeys) to respond to the scale of human beings and comfort.
- The planning and landscape explored the potential of natural sloping terrain, orientation and micro-climate.
- The basement car park roofs created large scale open spaces shared by different clusters. A hierarchy of open spaces evolved from the individual courtyard, to the cluster park to the basement top park and the transitions between these are spontaneous and organic.
- The project had to conserve and rejuvenate existing features such as water bodies, streams, indigenous trees, insect and bird habitats while respecting the importance of environment.
- Water management and sewage treatment was integrated into the master plan.
- The architecture reflects a blend of contemporary with the traditional style. The layout has only pedestrian layer separated from the vehicular movement (Fig. 2), this helps the pedestrian to experience far more open spaces at an intimate scale.
- The open spaces are either parks or planted to reduce the heat-island effect.

Technologies adopted and eco-friendly features

The project site is on a slope with a difference in height of 26 m. This slope was advantageously utilised to scoop out soil creating terraces, underground parking spaces and other service units. Since there was a scope for generating soil locally, the technology of stabilised earth blocks came in handy. The following innovative technologies were adopted in this project.

- Stabilised earth blocks
- Rammed earth
- Unreinforced masonry vaults
- Filler slab floor and roofing systems
- Mud concrete pavements
- Random rubble masonry using local stones
- Rainwater harvesting
- DEWATS system for decentralised sewage treatment

Management of water and other services

Sewage and grey water

Decentralised Wastewater Treatment System (DEWATS) designed by Ludwig Sasse (1998) has been implemented in this project to treat the sewage water called grey water. DEWATS consists of four treatment systems integrated into a single compact unit. The four treatment systems are (a) Sedimentation and primary treatment in sedimentation ponds, septic tanks or Imhoff tanks, (b) Secondary anaerobic treatment in fixed bed filters or baffled septic tanks (baffled reactors), (c) Secondary and tertiary aerobic/anaerobic treatment in constructed wetlands (subsurface flow filters) and (d) Secondary and tertiary aerobic/anaerobic treatment in ponds. The cross-section and a view of the DEWATS system installed in one of the clusters having 96 houses (Footprints – phase 1) is shown in Fig. 3. This system is designed to handle/treat 21,000 m^3 of black (sewage) and grey water per year. The treated water was recycled for the toilet flushing and gardening purposes.

Rainwater harvesting and ground water recharge

The region receives an average annual rainfall of about 900 mm. The rainwater harvesting system consists of (a) guiding the surface flow into open water storage tanks (b) creating percolation pits along the slopes, and (b) harvesting the roof water and storing in specially built underground water tanks. The surface water storage tanks and percolation pits allow for natural ground water recharging through percolation into the ground. The harvested rain water from the roof top meets the 2-3 months demand of total water requirement in a year and 80% of the water is re-used in the system. Fig. 4 illustrates rainwater cycle followed in the project.

Fig. 3 Sewage and grey water treatment systems (DEWATS)

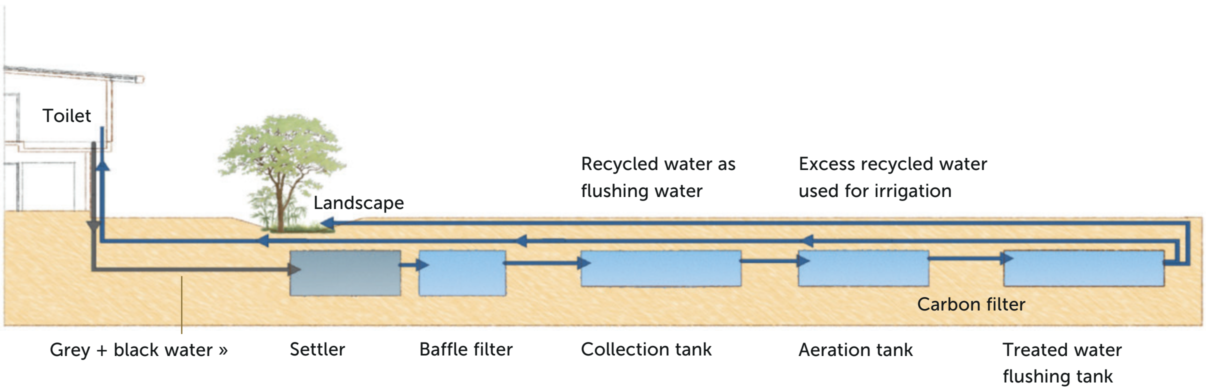

Fig. 4 Rain water harvesting and management

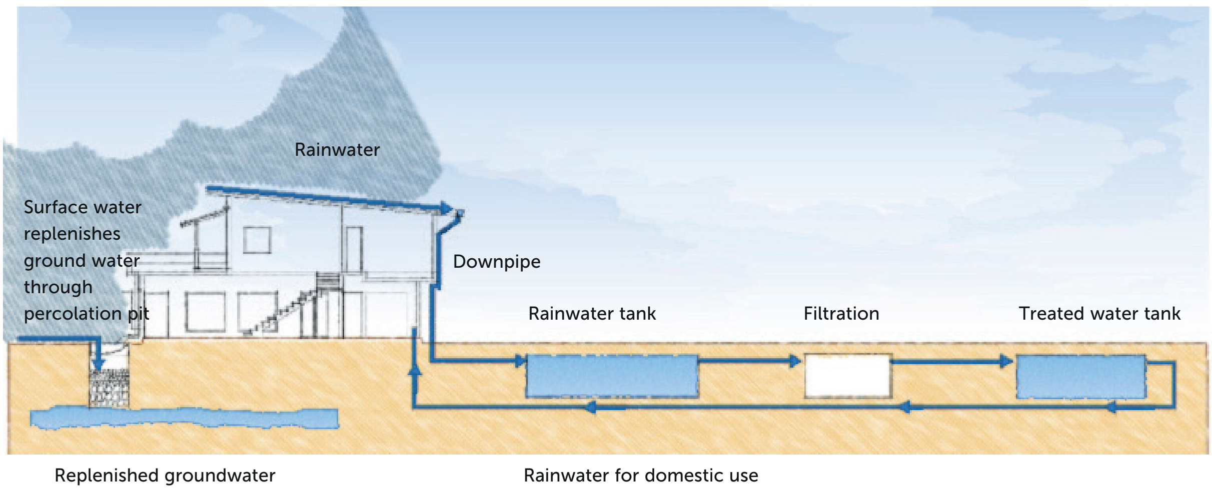

Fig. 5 Typical CSSB block production unit

Decentralised material production systems

Construction of the buildings was carried out by using the materials prepared at the site. Bulk of the materials used include cement stabilised soil blocks, stones, flooring tiles, roofing tiles, cement, aggregates and steel, apart from timber, paint and felt sheets. Locally available granite stones (both irregular shape and sized) were used in the foundation and parts of the super structure. Walls constitute more than 60% of the volume of materials consumed. Except random rubble masonry in certain portions of the walls, the entire masonry walls of the 342 buildings were constructed using cement stabilised soil blocks.

Cement stabilised soil blocks

Over 5 million CSSB blocks (equivalent to 12.5 million conventional bricks) were manufactured at the construction site using ten teams of manually operated machines. Fig. 5 shows one of the block production unit at the construction site. Such units were distributed across the project construction site. CSSB's were consumed at the place of production without much transportation. These operations are very good examples of decentralised block production systems.

CSSB's produced were of size 230 × 204 × 90 mm. Special types of blocks such as corners rounded and brick red coloured texture were also produced for niche applications. Locally excavated soil and stone dust (a waste product from aggregate industry) was used in the block production. Soil and stone dust were mixed such that the reconstituted mix contains optimum clay content of about 15%. Levelling the sloping ground and creation of underground parking facilities greatly helped in getting major chunk of the soil used for block production. The stabiliser was 9% (by mass) ordinary Portland cement.

The typical block production unit consisted of a team of eight persons working with one machine. Soil preparation, block making, curing and related activities were manually carried out. Each block production unit produced about 700 – 800 blocks per day. In a span of about three years the ten block making teams produced over five million CSSB's. The mean wet compressive strength (saturated) of blocks was 9.1 MPa. Figs. 6 and 7 show the typical residential buildings in phase 1 of the project.

Embodied energy/carbon savings and environmental benefits

A number of innovative technologies and design concepts wereadopted in the construction of 342 residential buildings. Table 1 illustrates the embodied energy of four typical buildings sampled in each of the four phases of the project. The total built-up area of the residential buildings, parking facilities and other common facilities of the entire project is 82,306 m^2. Considering an average EE of 2.145 GJ/m^2 (from Table 1), the total EE of the entire project works out to 176,546 GJ. Table 2 gives a summary of the EE of the current project with alternative low embodied ener-

Table 1 Embodied energy (EE) of typical buildings

Sl. No.	Building type	Built-up area m^2	Total EE GJ	EE GJ/m^2
1	Type A	239	532.2	2.23
2	Type B	232	514.9	2.22
3	Type C	344	740.7	2.15
4	Type D	382	755.2	1.98
Average EE				2.145

Fig. 6 CSSB masonry buildings from GoodEarth Phase 1

Fig. 7 Exposed CSSB masonry buildings

gy materials and the conventional energy intensive technologies. The EE of the buildings in the GoodEarth project is about 2 GJ/m^2. A similar construction using burnt clay bricks will have EE of more than 3 GJ/m^2 (Reddy and Jagadish 2003, Praseeda et al. 2016). EE of burnt clay brick load bearing masonry buildings is about one-third more than that of buildings using CSSB masonry. The conventional reinforced concrete frame structure with masonry infill have more than double the EE of CSSB buildings.

Summary

Different facets of design and implementation of low embodied energy and environment friendly housing project was discussed. Low embodied carbon CSSB bricks required in large quantities were manufactured using manually operated machines. Over five million CSSB blocks (equivalent of more than 12.5 million conventional bricks) were manufactured in a span of three years using manually operated processes. The embodied energy (EE) of the load bearing CSSB masonry buildings is one third less than that of conventional burnt clay brick masonry buildings and 60% less than that of conventional reinforced concrete frame structure buildings. This project is a fine demonstration of low EE and eco-friendly homes and an excellent example for the decentralised production of CSSB blocks utilising the local soil.

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Table 2 Comparison of EE and carbon emissions for the project

Sl. No.	Details		GoodEarth eco-homes	Conventional load bearing burnt clay brick masonry*	Conventional reinforced concrete framed structure*
1.	Embodied energy	Total	176546	246918	411530
		GJ/m^2	2.145	3.0	5.0

**Reddy & Jagadish 2003, *Praseeda et al. 2016*