An economical and environment-friendly building material

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For the past couple of years, a shortage of conventional building materials, especially sand, has adversely affected the construction sector. While the resultant price increases have made construction unaffordable to a wider portion of the society, heavy reliance on conventional building materials has aggravated environmental problems. For example, excessive sand mining in rivers promotes flooding, river-bank collapses, and salt-water intrusion. The situation was adverse in both social and environmental fronts.

Then, on 26 December 2004, the tsunami 12/26 made the situation far worse, demolishing many buildings, including about 100,000 houses. If the consequent rise of demand for conventional building materials is not addressed wisely, social and environmental problems will further aggravate in the post-tsunami era. Therefore, the need for economical and environmentally friendly alternative building materials is now at its highest.

The cement-stabilized soil block is such a viable alternative, gaining acceptance in Sri Lanka as well as in other countries. By 1999 there were 600 single-storey houses and 6 two-storey houses in Sri Lanka. This block requires no sand, which is quite short in supply nowadays. The main constituent of the block is latertie soil, an inexpensive material available in plenty. It requires cement, which is relatively expensive. However, the cement content is quite low, less than 6% in most cases.

The following article is based on a study conducted by Dr AADAJ Perera and Dr (Ms) C Jayasinghe in the late 1990s at the Department of Civil Engineering of Moratuwa University (www.mrt.ac.lk) on the use of cement-stabilized soil block as a load-bearing building material, especially for two-storey houses. Titled "Studies on load-bearing characteristics of cement stabilized soil blocks", the paper was published at the Annual Sessions 1999 of the Institution of Engineers Sri Lanka (Pages 63-72 of the Proceedings).

The cement-stabilized soil block

The constituents of the cement-stabilized soil block are laterite soil, cement and water. Laterite soil – the main raw material – is made from gravel, sand, silt and clay. The total amount of silt and clay is called the fines content, which has a strong influence on the properties of the cement-stabilized soil block.

Stabilization of soil is required to improve the strength of the blocks. Stabilization alters the properties of soil in such a way that it does not substantially lose its strength on saturation. Moreover, stabilization reduces the volume of voids, fills the voids that cannot be eliminated and increases the bond between the grains of soil (i.e., particles of soil). Means available for stabilization include mechanical compaction, physical means such as sieving, and chemical means such as mixing with cement, lime, bitumen, pozzolana, gypsum, rice husk.

Cement is the most widely adopted chemical stabilizing agent due to its wide availability and its suitability for stabilization of laterite soil. When mixed with soil and water, cement reacts with the water in the mix, forming an insoluble cementitious colloidal gel. Dispersing itself filling the pore spaces, the gel forms a continuous matrix surrounding the soil particles, binding them together.

The block-making process is simple and is as follows. Firstly, the suitability of the soil should be checked by a simple field test called "Jar test". Soil is sieved using a 12mm mesh to eliminate lumps, facilitating proper mixing of cement with soil. After mixing the measured quantities of soil and cement in dry state, the measured amount of water is sprinkled onto the mix, mixing the mix again. The mould of the block-making machine is filled with the mixed soil and is then compressed. The finished "green" block is taken out of the mould and left for drying. Curing of the blocks is started next day and is continued for two weeks.

Experimental program

To establish the design parameters for cement-stabilized soil blocks made from laterite soil, a comprehensive experimental

program was conducted at the Department of Civil Engineering, University of Moratuwa in the late nineties. Testing was carried out both on cement-stabilized soil blocks and wall panels constructed using cement-stabilized soil blocks with 1:6 cement: sand mortar.

The properties of cement-stabilized soil blocks are mainly dependent on the fines content, the cement content and curing. In the experimental program, the compressive strength and bending strength of blocks were measured, varying these parameters. The adopted fines contents were 20, 25, 30, 40 and 45% while the adopted cement contents were 2, 4, 6 and 8%, both by volume.

For testing, blocks were produced from laterite soil, using the Auram Press 3000 block-making machine. Giving a compaction ratio of 1.65 for blocks of height 90mm, the machine can produce blocks of two sizes: 290x140x90 block (290mm long, 140mm wide, 90mm high block) and 240x240x90 block (240mm long, 240mm wide, 90mm high block). Manufactured for heavy use, this machine can produce about 500,000 blocks with little maintenance.

Among the key observations of the experimental program are:

- For a given fines content, the average compressive strength of blocks increases with the increase of cement content.
- Blocks cured with water achieved higher strength than uncured blocks.
- The characteristic compressive strength of the blocks significantly drops when the fines content is above 40%.
- For a given fines content, the characteristic wall panel strength increases with the increase of cement content of the blocks used for its construction.

Cement-stabilized soil blocks for load-bearing construction

The key results of experimental program can be summarized as in the Table at the end of the article. It shows that the cement-stabilized soil block can be used for load-bearing construction in single storey and two-storey houses. The wider block (i.e., 240x240x90 block) is recommended for the ground floor of two-storey houses and the other one (290x140x90 block) for single-storey houses or the upper floor of two-storey houses.

For a properly designed two-storey house, the design strength required at the plinth level of the ground floor is about 0.8 to 0.9 N/mm^2. When constructed with cement-stabilized soil blocks of cement content 6% and above and fines content 20 to 30%, the 240mm-thick block wall's strength is about 0.9 N/mm^2. Therefore, it is adequate for the load-bearing requirements of the two-storey house. Note that blocks of 4% cement content gives a wall panel strength of 0.85 N/mm^2. So, while using blocks of cement content 6% and above up to a height of 1.5m from the plinth level of ground floor, 4% cement content blocks can be used beyond that height, safely. The safety margin can be increased by using blocks of higher cement content, say 8%.

For a single-storey house, the design strength required at the plinth level is about 0.25 to 0.40 N/mm^2. When constructed with cement-stabilized soil blocks of cement content 4% and above and fines content 30% or less, the 140mm-thick block wall's strength is 1 N/mm^2. Therefore, it is clear that this block can satisfy the load-bearing construction requirements of the single-storey house and the upper floor of a two-storey house with a wide margin of safety.

For load-bearing construction, an upper limit of 30% should be maintained for fines content. When high-fines soils are encountered, the fines content can be lowered by introducing sand. However, its addition should be controlled to maintain an adequate green strength for handling of the block in wet state.

'Good practices' in load-bearing construction with cement-stabilized soil blocks

There are several 'good practices' that should be adopted in load-bearing construction with cement-stabilized soil blocks.

Firstly, simple building systems should be adopted. Openings on a wall (e.g. windows) should be evenly placed. Length of an opening should not exceed 1.2m. Overall length of openings on a wall should not exceed 35% of the length of the wall. On a particular wall, the area of openings should not be more than one third of the wall area. The minimum distance from the edge of the wall to the adjacent edge of the opening is 1m. When two adjacent openings form a pier, the pier should be at least 0.6m in length.

The blocks though cement-stabilized are desirable to enjoy some level of protection from excessive moisture movement, which is the main cause of degradation. Protection is possible through large eaves or water repellent coatings. For resistance to rain penetration, bond strength of the mortar is more important than its compressive strength. Therefore, use of lime in mortar is desirable for a stronger bond. Moreover, a coat of sodium silicate can enhance the water resistance of the wall. For exterior walls, three coats of sodium silicate at two-day intervals are recommended.

For economical reasons, low cement contents are adopted in cement-stabilized soil blocks. Therefore, the safety margins imposed by the masonry design codes are satisfied at a "minimum" level, necessitating some level of quality control during production of the blocks. Laboratory testing of blocks is not practical, especially in remote areas. However, using a simple machine provided with the Aurum Press 3000 block-making machine, the bending strength of the blocks can be tested. This bending strength value can be related to the compressive strength of the blocks.

Cost comparison

When a cement content up to 4% is used for stabilization, the cost of 140mm block wall is lower than that of half brick thick wall. When a cement content up to 6% is used for stabilization, the cost of 240mm block wall is lower than that of one-brick thick wall.

The machine-produced cement-stabilized soil blocks have neat edges and smooth, flat surfaces. Therefore, the block wall can be kept bare, avoiding the expensive plaster. Then, however, a surface coating of 1: 1: 6 cement: lime: soil is recommended as a water proofing coating on the external surfaces.

Summary

The cement-stabilized soil block is an economical and environment-friendly alternative building material that contributes to the solution of the problems of the shortage of conventional building materials.

An experimental program conducted at Moratuwa University in the late nineties using machine-produced cement-stabilized soil blocks has revealed that the compressive strength of the blocks increases with the increase of cement content and that a fines content above 40% causes a significant reduction of the compressive strength of the blocks.

The study shows that the machine-produced, cement-stabilized soil block can be used for load-bearing construction of both single-storey and two-storey houses. For single-storey houses and the upper floor of two-storey houses, the study recommends the 290mm long, 140mm wide, 90mm high block with cement content 4% and above and fines content 30% or less. For the ground floor of two-storey houses, the study recommends the 240mm long, 240mm wide, 90mm high block with cement content 6% and above and fines content 20 to 30%.

There are several good practices that should be adopted when using the cement-stabilized soil blocks for load-bearing construction: an adoption of simple building system, some level of protection for building elements, and quality controlling in block-making.

The cost of cement-stabilized soil block walls is less than the equivalent brick walls.

If adopted on a wide scale as a viable alternative to conventional building material, the cement-stabilized soil block production will generate a massive demand for soil. Quarrying for soil should be done in a systematic way to prevent environmental degradation. Therefore, a relevant state institution should open soil quarries to supply soil in an environmentally friendly manner.

NOTE

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	Wall panel thickness		
	240mm (Made from 240x240x90 block)		**140mm** (Made from 290x140x90 block)
Cement content of blocks	4%	6% and above	4% and above
Fines content of blocks	20 - 30%	20 - 30%	20 - 30%
Suggested characteristic strength of wall panel	0.85 N/mm^2	0.9 N/mm^2	1 N/mm^2