ALTERNATE CONSTRUCTION USING POLYMER MODIFIED STABILIZED EARTH BLOCKS: A PILOT PROJECT TO DEMONSTRATE ECO-FRIENDLY AND SUSTAINABLE HOUSING

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Received: 01.03.2020 Revised: 03.04.2020 Accepted: 05.05.2020

Abstract

Construction using natural soil is being promoted in present world with a motive to promote sustainable construction and to minimize the environmental impacts. Laterite soil occur in tropical regions worldwide and is popularly used in manufacturing of Compressed Stabilized Earth Blocks (CSEB) in masonry applications. The acute issue of CSEB blocks in masonry applications has been reported due to high water absorption and durability issues. This study explores modification of CSEB using natural polymer (NP) latex as admixture and a comparative study of engineering properties with ordinary CSEB. This paper also illustrates the details of a pilot project using modified CSEB to be constructed in National Institute of Technology Calicut. A comparison on various aspects such as embodied energy, construction cost and time of construction is also being presented. The study provides an efficient solution for housing by utilization of locally available earth and agricultural product for modified CSEB production, addressing all the critical issues of ordinary CSEB and it promotes small scale industrial production units all over the globe.

Keywords: natural soil, Compressed Stabilized Earth Blocks (CSEB)

INTRODUCTION

Increase in population and natural calamities has shown its toll on the housing needs and disaster rehabilitation requirements in India. Scarcity of natural materials and environmental issues arising out of quarrying has led to escalation in construction cost in the recent years. Increased construction activities and unscientific conventional building techniques result in environmental/ecological issues. Rising occurrence of calamities point to the need for use of alternative materials and sustainable construction techniques to combat future needs. Conventional construction using burnt clay bricks and reinforced concrete ought to be replaced by energy efficient, and environmental friendly sustainable techniques. Soil being abundant and easily available resource for construction offer potential for building applications with less energy and environment impacts. Usage of earth construction for housing is time tested being cost effective, environmental friendly and low energy consumption promotes sustainability. Though construction practices using soil existed for ages, its acceptance as an efficient masonry material is not opted by common people due to its low durability and strength. Variation in properties, lack of scientific data based on regional studies and standardization are other challenges for its popularity. Researchers world-wide has undertaken studies to improvise the masonry characteristics of soil blocks. Strengthening and stabilization of soil using suitable additives or binders and by compaction has been well established [1]. Table 1 illustrates various research studies reported on stabilization of soils.

| Researcher            | Reference | Stabilization agent | Recommended percentage |
|-----------------------|-----------|---------------------|------------------------|
| Bahar et al.          | [1]       | Cement              | > 8%                   |
| Walker                | [2]       | Cement              | 5 - 10%                |
| Reddy et al.          | [3]       | Cement              | 4 - 8%                 |
| Guettala et al.       | [4]       | Lime                | 5 - 12%                |
| Reddy and Lokras      | [5]       | Lime                | 11%                    |
| Muntohar              | [6]       | Rice huskash        | 1:1 ratio              |
| Alhassan and Mustapha | [7]       | Rice huskash        | 4 -6%, 8%              |
| Aymerich et al.       | [8]       | Wool                | 2 - 3%                 |
| Estabragh et al.      | [9]       | Resin               | 0 - 10%, 5 - 20%       |
| Catalina et al.       | [10]      | Coal ash & Cassava  | < 5%                   |
This paper reports properties of Compressed Stabilized Earth Block (CSEB) using laterite soil modified using Natural Polymer (NP) for masonry applications in Calicut, Kerala, India. Laterite soil is a popular soil in developing countries located in tropical world. Kerala being known as type locality of laterite, this study becomes more relevant. This paper also illustrates the details of a pilot project proposed at National Institute of Technology Calicut campus using natural polymer modified CSEB blocks using laterite soil. A comparison of various aspects of construction such as embodied energy, cost, and construction time is outlined in this paper. This study assumes top priority due to the appalling condition of global climatic changes.

**Method of manufacturing NP Modified CSEB.**
Local laterite soil from calicut city was used for manufacturing the blocks. Characterization of lateritic soil was done and the results are displayed in Table 2.

| Sl. No. | Properties                        | Result          |
|--------|-----------------------------------|-----------------|
| 1      | Compaction characteristics        |                 |
|        | Optimum moisture content (%)      | 19              |
|        | Maximum Dry Density (g/cm³)       | 1.64            |
| 2      | Atterberg's limits                |                 |
|        | Liquid limit (%)                  | 37              |
|        | Plastic limit (%)                 | 22              |
| 3      | Particle size distribution        |                 |
|        | Gravel + Sand (%)                 | 46.2            |
|        | Silt size (%)                     | 37.8            |
|        | Clay size (%)                     | 16              |
| 4      | Specific gravity                  | 2.45            |

The soil was dried in an oven to remove the natural moisture content so as to enable them to be sieved. Dried soil was sieved through 4.75mm IS sieve. Cement content of 10% by the weight was added to the soil for making CSEB. Optimum water quantity as in Table 2 was added for mixing. Natural polymer (latex) used for the study was collected directly from rubber plantations in Kunnamangalam area of Calicut and was used directly without any processing. NP was added at a ratio of 3% by weight of water. The soil sieved and weighed was spread on a leveled impervious platform to add corresponding quantity of cement as per mix design. Soil and cement were mixed dry to obtain uniform mixture. Measured quantity of NP was mixed with water and stirred well for uniform dispersal. The NP-water mix was then added to the soil-cement mix and all constituents were turned well to obtain a homogeneous mix. 0.5kg of the mix was weighed for making each block and filled in the mould of manual pressing machine. Moulded blocks were stacked and was cured by spraying water for seven days continuously. The method of block preparation is shown in Fig. 1.
Determination of Engineering properties of modified CSEB blocks.
The average values of engineering properties of ordinary CSEB, modified blocks and their respective reference standards are shown in Table 3. It can be observed that NP modified CSEB is efficient in terms of strength and durability compared to ordinary CSEB.

| Engineering Property      | Unit       | Ordinary CSEB | NP modified CSEB | IS Standards adapted |
|---------------------------|------------|---------------|------------------|----------------------|
| Dry Density               | kg/m$^3$   | 1750          | 1738             | IS 1725 - 2013       |
| Water Absorption          | %          | 18            | 16               | IS 3495 (part 2) 1992|
| Compressive strength of CSEB | N/mm$^2$  | 3.5           | 3.8              | IS 3495 (part 1) 1992|
| Weathering (Weight loss)  | %          | 2             | 1.1              | IS 1725 - 2013       |

Pilot project: Structure for Security Office
The aim of the project was to demonstrate a simple structure by constructing an office building for security personal and staff inside NIT Calicut campus, Calicut, Kerala, India using modified CSEB. The main feature of the construction was to demonstrate alternate technique using vaulted masonry structure using CSEB modified CSEB conventional concrete roof is replaced by. The total plinth area of the building measured 36 sq.m. and estimated time of construction was estimated to 90 days. The floor plan and the 3D elevation of the proposed building is illustrated in Fig. 2 and 3 respectively.
Components of building.
Different components of the building are chosen such a way to minimize the usage of cement and concrete to reduce embodied energy and environmental impacts without compromising the functional needs and structural performance. The details of various components and the materials used for the construction is illustrated in table 4.

Table 4. Components of proposed building.

| S. No. | Item      | Description                                                                 |
|--------|-----------|-----------------------------------------------------------------------------|
| 1      | Foundation| Using laterite blocks for a depth of 45 cm below ground level                 |
| 2      | Plinth beam| RCC M20 grade using 20 mm nominal size aggregates, Msand and cement mixed in 1:2:4 proportion throughout below masonry. |
| 3      | Masonry   | Using interlocking CSEB of suitable size.                                    |
**Table 5. Comparison of embodied energy of masonry materials.**

| Type of Block         | Size (mm)              | Energy in one block (MJ) | Energy per brick equivalent | Block energy % |
|-----------------------|------------------------|--------------------------|----------------------------|----------------|
| Laterite Block        | 330x200x200            | 0                        | 0                          | 0              |
| Burnt clay bricks[18] | 230x105x70             | 4.25                     | 4.25                       | 100            |
| Ordinary CSEB         | 230x190x100            | 3.5                      | 1.35                       | 32             |
| NP Modified CSEB blocks | 305 x 143x 100       | 3.5                      | 1.35                       | 32             |
| Hollow concrete blocks [18] | 400x200x200       | 15                       | 1.62                       | 38             |

**Construction cost comparison.**

Average construction cost was estimated by an evaluation of market study and the rates are pertaining to Indian context. The cost estimation of proposed pilot project were compared with cost estimation of a similar building with conventional construction technique (RCC structure). The comparison is shown in Table 6. It is evident that there is around 28% cost saving in pilot project when compared to conventional construction.

| S. No. | Item of work          | Budget expected for pilot project INR | USD | Item of work          | Budget expected for conventional building INR | USD |
|--------|-----------------------|--------------------------------------|-----|-----------------------|-----------------------------------------------|-----|
| 1      | Earth Work            | 4789                                 | 67  | Earth Work            | 4789                                          | 67  |
| 2      | Foundation - Laterite masonry | 69176                             | 961 | Foundation - Laterite masonry | 69176                                         | 961 |
Comparison of construction time.
Estimated duration for pilot project completion is 75 days. However, conventional construction technique takes up to 95 days for completion, i.e., 26% extra time. The comparison of time schedule for proposed pilot project and conventional building is shown in Table 7.

Table 7. Construction time comparison.

| Item of work                | Duration (Pilot Project) (days) | Duration (Conventional Building) (days) |
|-----------------------------|---------------------------------|----------------------------------------|
| Site Clearance              | 1                               | 1                                      |
| Earth Work                  | 3                               | 3                                      |
| Foundation                  | 5                               | 5                                      |
| Plinth beam                 | 5                               | 5                                      |
| Wall masonry                | 7                               | 15                                     |
| Lintel and sunshade         | 7                               | 7                                      |
| Roof                        | 13                              | 25                                     |
| Plastering                  | 12                              | 12                                     |
| Doors and windows           | 7                               | 7                                      |
| Toilet and plumbing         | 7                               | 7                                      |
| Floor concreting            | 6                               | 6                                      |
| Finishing and cleaning      | 2                               | 2                                      |
| **Total**                   | **75**                          | **95**                                 |
The reduction in total construction time is attributable to two major activities, wall masonry and roof construction. Masonry using CSEB can reduce the time as they are easy to handle and the size of a single block is larger than that of burnt clay brick. Also, the interlocking frogs help to increase the bonding. Conventional RCC roof construction involves long deshuttering time of around 10 days. Vault construction using CSEB masonry avoids such delay in construction.

CONCLUSION
The study presents low-rise building construction using soil cement blocks modified using natural polymer and the comparison with conventional building materials in Indian context. The following conclusions can be drawn from the study:

- Soil cement blocks modified using NP can effectively replace burnt clay bricks and other conventional masonry materials without compromising on performance.
- Modified CSEB blocks can be used for vault construction in low-rise building and can reduce the use of RCC to a great extent.
- The embodied energy of modified CSEB blocks is much lesser than that of burnt clay bricks and thus aiding sustainability.
- Construction using modified CSEB for walls and roofs proves to be more economic, energy efficient and time saving than conventional building construction with burnt clay bricks and RCC.

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