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

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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)

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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]. Table1 illustrates various research studies reported on stabilization of soils.

Table 1. Studies on soil stabilization

Researcher	Reference	Stabilization agent		Recommended percentage
		Additive	Binder	
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 husk ash	Lime	1:1 ratio
Alhassan and Mustapha	[7]	Rice husk ash	Cement	4 -6%, 8%
Aymerich et al.	[8]	Wool		2 - 3%
Estabragh et al.	[9]	Resin	Cement	0 - 10%, 5 - 20%
Catalina et al.	[10]	Coal ash & Cassava		< 5%

		peels		
Tallah et al.	[11]	Date palm fibers	Cement	0.05%, 8%
Bouhicha et al.	[12]	Barley straw		1.5%
Danso et al.	[13]	Agricultural fibers		0.5%
Roslan et al.	[14]	Oil palm fibres	Cement	0 - 30% (by cement), 10%
Omar et al.	[15]	Geo-polymer	Cement	10 - 12%, 8%
Aguwa	[16]	Coir		0.25%
Sekhar and Nayak	[17]	Granulated blast furnace slag	Cement	20%, 6 - 10%

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.

Table 2. Characterization of lateritic soil.

Sl. N	Properties	Result
1	Compaction characteristics	
	Optimum moisture content (%)	19
	Maximum Dry Density (g/cm^3)	1.64
2	Atterberg's limits	
	Liquid limit (%)	37
	Plastic limit (%)	22
	Plasticity index (%)	15
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. 8.5kg 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.

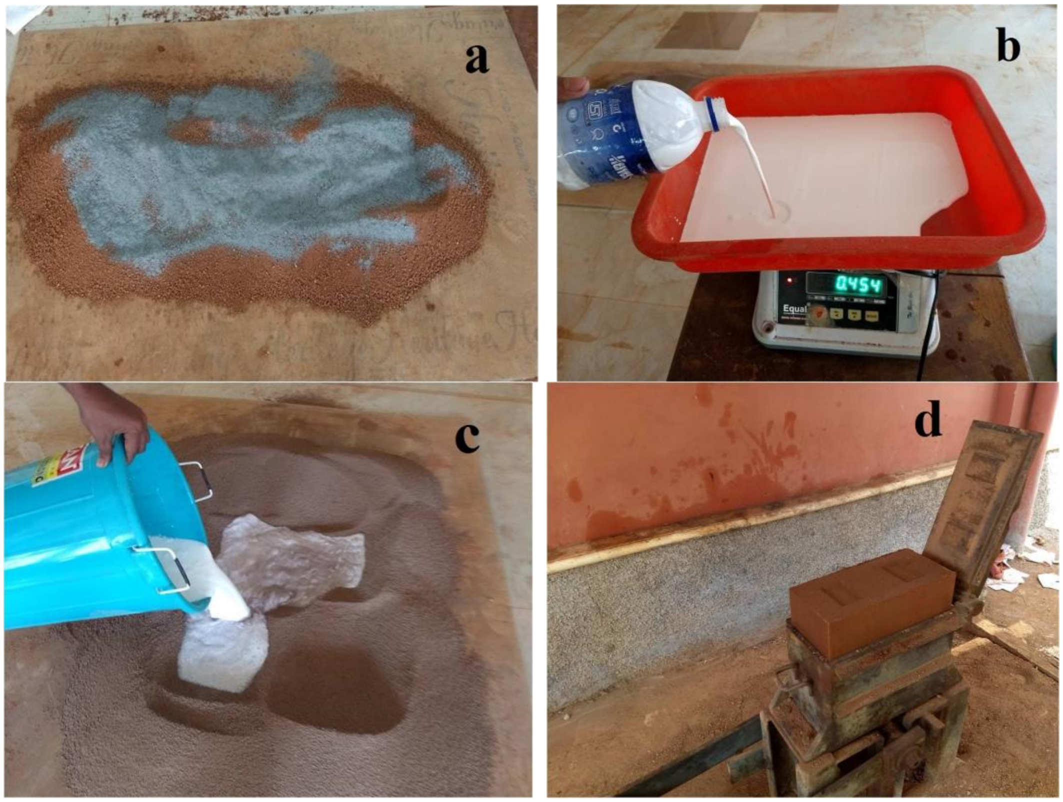

Figure1. (a) Spreading of soil and cement. (b) Weighing of NP. (c) Mixing of Soil-cement with NP-water Mix. (d) Block moulding in pressing machine.

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.

Table. 3. Engineering properties of modified 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	%	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 personals 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.

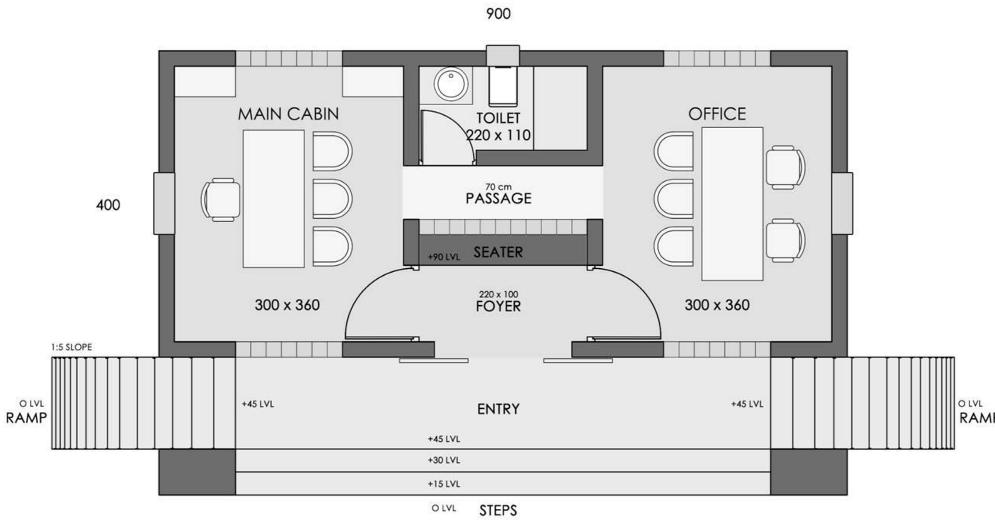

Figure 2. Floor plan of proposed building.

Figure 3. 3D elevation of proposed building.

Components of building.

Different components of the building are chosen such a way to minimize the 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 45cm below ground level
2	Plinth beam	RCC M20 grade using 20mm nominal size aggregates, Msand and cement mixed in 1:2:4 proportion throughout below masonry.
3	Masonry	Using interlocking CSEB of suitable size.

4	Lintel	RCC M20 grade using 20mm nominal size aggregates, M-sand and cement mixed in 1:2:4 proportion throughout superstructure.
5	Roof	Barrel vault construction using CSEB.
6	Plastering	Only outside roof plastering for protection against dampness.
7	Windows and doors	Wooden/ Bamboo panels.
8	Toilet fixtures/ plumbing	Basic ceramic toilet fixtures and PVC pipes for plumbing line.
9	Floor	Floor concrete using 40mm nominal size metal, Msand and cement mixed in 1:4:8 proportion and finished with red oxide above concrete.

Comparison of alternate construction with conventional RCC building.
Performance efficiency evaluation was carried out by comparing various factors such as embodied energy of masonry blocks, construction cost and construction time of proposed pilot project.

Embodied energy comparison of masonry blocks.
Embodied energy of different masonry materials are outlined in Table 5. All masonry materials are of varying sizes and thus for the ease of comparison, equivalent energy of all materials compared to size of burnt clay bricks was taken. It can be seen that, the embodied energy of soil based blocks were the minimum and this adds to the sustainability in construction.

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.

Table 6. Comparison of construction cost between pilot project and conventional building

S. No.	**Item of work**	**Budget expected for pilot project**		**Item of work**	**Budget expected for conventional building**	
		INR	USD		INR	USD
1	Earth Work	4789	67	Earth Work	4789	67
2	Foundation - Laterite masonry	69176	961	Foundation - Laterite masonry	69176	961

3	Plinth beam - RCC	27413	381	Plinth beam - RCC	27413	381
4	Masonry - NP - CSEB	86700	1204	Masonry - Burnt clay bricks	112375	1561
5	Lintel and Sunshade - RCC	27216	378	Lintel and Sunshade - RCC	27216	378
6	Roof : NP -CSEB Vault masonry	62172	864	Roof- RCC slab	191015	2653
7	Plastering	50127	696	Plastering	50127	696
8	Doors and Windows	38000	528	Doors and Windows	38000	528
9	Toilet	20000	278	Toilet	20000	278
10	Floor concreting and finishing	14407	200	Floor concreting and finishing	14407	200
	Total	**400000**	**5556**	**Total**	**554518**	**7702**

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 helps 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 prove to be more economic, energy efficient and time saving and than conventional building construction with burnt clay bricks and RCC.

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