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Development of Environment Friendly and Low Cost Unburnt Stabilised Soil Bricks

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Abstract— **This paper reveals the study related to feasibility of using sustainable material for the stabilized soil brick manufacturing. Mud brick construction is not a new technology. Burnt clay bricks are widely used as a fundamental building material in most countries. However, with rising awareness to reduce carbon footprint and promote sustainable development, earth-making has taken a different path to minimize the environmental impact. Various efforts have been directed to develop, environmental friendly and low-cost bricks, including the use of different binding agents, raw materials and technology. As part of the research effort, a series of trial samples were prepared with three types of stabiliser at different ratios using soil collected from the site. The prepared samples were tested for compressive strength, water absorption and density at the end of 28 days curing period. The test results were then analysed and compared with burnt clay bricks and fly ash bricks. The investigation results show that compressive strength and water absorption of unburnt clay bricks are improved by adding OPC. The report concludes that the soil with less clay content can be stabilised by adding stabilisers which increases its compressive strength and water absorption properties, simultaneously economical viable and environment friendly**

Index Terms— **Compressive Strength,Water Absorption,Density and Stabilised Soil.**

I. INTRODUCTION

The desire to build a reasonably good house of one's own with maximum possible amenities is cherished by one and all. However, with the rising cost of construction it is becoming increasingly difficult for people in the low-income group to build a house. Around 30% of the world's population and roughly 50% of the population of developing countries live in earthen structures (Easton,1998) , as they cannot afford the high cost of building materials which could produce better shelters. Building materials can account for as much 70-75% of the total cost of construction (Easther Obonyo et al., 2010). The manufacture of most conventional materials requires expenditure of non-renewable resources in various forms. Many of these manufacturing processes are detrimental to the environment. In addition, these conventional materials are usually transported over great distances thus contributing to the spending of fossil fuel energy (Easther Obonyo et al., 2010). Some of the ecological concerns can be addressed through adopting earth-based construction techniques.

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II. LITERATURE REVIEW

Literature study reveals that mud construction techniques have environmental benefits, structural stability and sustainable use.The main advantage of manufacturing unfired bricks is that it requires lesser energy than fired bricks, and hence the release of carbon dioxide into atmosphere is 80% less than fired bricks.Mud building material plays a major role in improving the environmental efficiency and sustainability of buildings and contributes to economic prosperity and infrastructural development in India and worldwide.

Edwards and Bennett (2003) reviewed the lifecycle concepts and considered recent developments. Works on the use of some secondary materials and waste types, as partial substitute for primary clay in the manufacture of fired bricks, in order to reduce the energy and firing cost of the clay brick production process was conducted by Boardman (2004), Kjarstad and Johnsson (2007) and Carter (2008). Other workers, Demir (2006) studied the potential for utilising processed tea waste in the production of unfired clay brick. Heath et al. (2009), Morel et al. (2007), Walker (1995) and Walker et al. (2008) worked on Portland Cement (PC) stabilised clay bricks and stress on the environmental benefits. Previous research studies (Heathcote, 1991, Walker, 2004 and Jayasinghe et al. 2007) reported on compressive strength and erosion characteristics of unfired clay bricks. Venkatarama Reddy et al. (2007) reported on enhancing bond strength and characteristics of unfired clay bricks made from PC-claymixture. Temimi et al. (1995) studied the possibility of producing low-cost unfired clay building bricks utilising PFA/lime clay mixture. According to Easton (1996), rammed earth (RE) construction is a cheap way of providing shelter since earth is an abundant resource. Frescura (1981) writes, "in addition to its political, economic, social and ecological advantages, earth has great cultural and architectural importance." Construction in earth has the uniqueness of manifesting the cultural heritage of any people and encouraging the continued use of the material helps to maintain and preserve the craftsmanship and cultural values embedded in earth building. According to Morton (2007), earth bricks and blocks can be a substitute for concrete blocks in most internal applications.

III. EXPERIMENTAL PROGRAMME

The testing is carried out to obtain the properties of the different constituent materials which is useful to classify the soil, ordinary Portland cement, lime , fly ash and water.

IV. SOIL

The sieve analysis of the soil used for the brick is carried out. The aim of this test was to determine the approximately amount of clay, silt, sand and gravel presence in the soil. Result of sieve analysis test was shown in Table 1.

Table 1: Sieve Analysis of Soil

IS Sieve	Mass of soil retained(gms)	% Mass retained	Cumulative % retained
4.75mm	0	0	0
2mm	1	0.5	0.5
1mm	1.94	0.97	1.47
0.6mm	0.64	0.32	1.79
425 µ	0.83	0.415	2.205
212 µ	4.55	2.275	4.48
150 µ	8.39	4.195	8.675
75 µ	98.22	49.11	57.785
Pan	84.43	42.215	100
	$\sum = 200$		

From Sieve analysis, it was found that the size passing the sieve size of 2mm is high. When the size of passing pan become smaller, then the mass of the soil retained become less. This can be said that the size of soil particles is very fine. The proportions of the soil are as follows:
Gravel = 0 %, Sand= 49 %
Silt = 27 %, Clay= 15 %
C.W. Graham et al.(2001), proposed that the ideal soil should composed of soil with a combined clay (15-20 %) and silt (powder) content of approximately 25-40% (by volume), and a sharp sand content of approximately 40-70 % (by volume). It reveals that if the clay content in the soil is lesser then binders can be added in this type of soil so that the strength of the soil can increase.

V. CEMENT

The cement use for the experimental studies was Ultratech 43 grade OPC conforming to IS 8112:1989.The various test performed on the cement and their values are shown in the Table 2.

Table 2: Characteristics Properties of Cement

Sr.No	Characteristics	Results
1	%Consistency of cement	29
2	Specific gravity	3.14
3	Initial setting time (minutes)	57
4	Final setting time (minutes)	195
5	Soundness (mm)	2.1
6	Compressive strength (N/mm^2) (i) 3 days (ii) 7 days (iii)28days	 24.85 34.62 44.53

VI. LIME

The hydrated lime was used as a stabilising agent in this research. Major chemical constituent of the lime is calcium hydroxide $Ca(OH)_2$. Before 24 hours of starting the production of bricks, water is added to the quick lime in sufficient quantity, a chemical reaction takes place. Due to this chemical reaction, the quick lime cracks and swells and falls into a powder form which is the calcium hydrate.

VII. FLY ASH

Fly ash obtained from a local thermal power station was used in this research. Fly ash is a byproduct from coal fired power stations. Coal is ground into a fine dust prior to combustion and it is the finer ash which is cementitious. Fly ash requires water and a source of alkali, usually calcium hydroxide, to stabilise soil, an application for which it has been used for many years (Harper, D. 2011).
Table 3 gives the characteristics of fly ash. Fly ash contains 88% of silica and alumina. The fly ash belongs to Grade I as per the I.S. 3812 code and class F as per the ASTM C618.

Table 3: Characteristics of Fly Ash

S.No.	Properties	Values
1	Chemical composition (% by mass) SiO_2 Al_2O_3 CaO MgO Fe_2O_3 Na_2O SO_3	 61.73 26.30 1.7 0.65 6 0.18 0.017
2	pH	10.91
3	Lime reactivity (MPa)	4.53
4	Loss on ignition (%)	1.58
5	Specific surface (m^2/gm)	0.553
6	Specific gravity	2.07

VIII. WATER

The water used in the concreting work was the potable water as supplied in the PG Structures lab of our college. Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete. As per IS 456-2000 Potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable tap water was used for the preparation of all concrete specimens.
The details of the mixes prepared for stabilized soil brick construction used in the present study are shown in table 4.

Table 4: Mix Design Proportion of Stabilised Soil Bricks

Type of stabiliser	Raw material	% Stabiliser		
		10%	**15%**	**20%**
		A	**B**	**C**
OPC and Lime	Soil	27 kg	25.5 kg	24 kg
	OPC	3 kg	4.5 kg	6 kg
	Water	5.5 litre	6.3 litre	6.9 litre
OPC and Lime		**D**	**E**	**F**
	Soil	27 kg	25.5 kg	24 kg
	OPC	1.5 kg	2.25 kg	3 kg
	Lime	1.5 kg	2.25 kg	3 kg
	Water	6.6 litre	7.6litre	8.5litre
Fly ash and		**G**	**H**	**I**
	Soil	27 kg	25.5 kg	24 kg

Lime	Fly ash	2.01 kg	3 kg	3.99 kg
	Lime	0.99 kg	1.5 kg	2.01 kg
	Water	7.5 litre	7.5 litre	7.8 litre

IX. CONSTRUCTION OF THE STABILISED SOIL BRICK:

The bricks were constructed using the following method.
In this experiment the clay soil was obtained and then soil was placed into a metal tray where they were broken into small particles. Then the soil and other raw material was weighed according to the quantity required for the each sample which is shown in the Table 4.
The measured quantity of water was then sprayed on to the mixture. The mixture was further turned with shovels until a mix of the required workability was obtained as shown in Figure1
The mould was lined with oil to prevent the brick from sticking to the mould.
The resulting mix was transferred to the steel mould of internal dimension 22.8 cm X 11.4 cm X 7.9 cm to half of the depth. This was tamped uniformly over the cross section of the mould.

Figure1:Homogeneous mixture

More soil mix was added and tamped until the mould was completely filled to the brim and excess was trimmed off. This was to ensure consistency in the specimen preparation procedure, as well as to eliminate the any adverse effect on the specimen densities.
The specimen was demoulded on the concrete floor as fresh brick and each fresh brick was clearly marked as shown in Figure 2.
The bricks were left to cure in the laboratory for 28 days prior to testing. The brick samples were cured by sprinkling water daily.

Figure2: Demouldingof bricks

X. TESTING OF STABILISED SOIL BRICKS

The specimens were tested in the laboratory to investigate the strength and durability of the bricks stabilized with different stabilisers. In this research three engineering properties have been investigated.
Compressive strength
Water absorption
Density

XI. DISCUSSION OF RESULTS

COMPRESSIVE STRENGTH

The compressive strength was conducted on various specimens of stabilized soil bricks as well as burnt clay and fly ash bricks which are bought from the market. The specimens were surface dried before testing the same on Universal Testing Machine of 200 tonnes capacity. The test results for all the samples of bricks have been shown in table 5.

Table 5 :Compressive Strength Test Results

Sample	Stabiliser	%	Compressive Strength(kg/m^3)
A	OPC	10	69.67
B	OPC	15	93.37
C	OPC	20	120.69
D	OPC and Lime	10	49.67
E	OPC and Lime	15	54.46
F	OPC and Lime	20	59.66
G	Fly ash and Lime	10	14.48
H	Fly ash and Lime	15	21.5
I	Fly ash and Lime	20	26.49
Z	Burnt clay brick	-	110.14
X	Fly ash brick	-	99.7

Figure 3 represents the variation of compressive strength of the bricks.

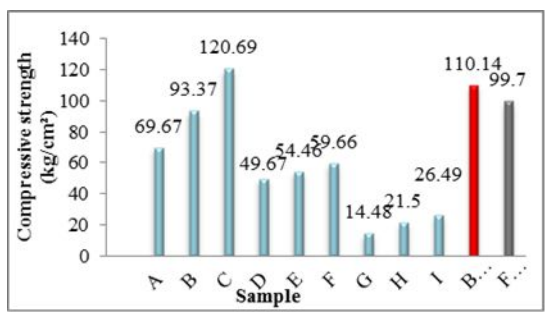

Figure 3:Comparison of the Compressive Strength of OPC Stabilised Bricks with Burnt Clay and Fly Ash Brick

XII. WATER ABSORPTION

The water absorption tests were carried out on stabilised soil bricks after 28 days of curing period, on burnt clay bricks and Fly ash bricks in the laboratory as per Indian Standards (IS: 3495 (part-2): 1992). Three specimens of each brick samples were weighed and soaked in water for 24 hours. Then they were weighed again for the water absorption test. The test results for all the samples of bricks have been summarized in

Table 6 and they are compared for their water absorption % by weight in figures from Figure 4.

Table 6: Water Absorption Results

Sample	Stabiliser	%	Water Absorption (% weight)
A	OPC	10	13.37
B	OPC	15	13.22
C	OPC	20	12.13
D	OPC and Lime	10	17.39
E	OPC and Lime	15	16.46
F	OPC and Lime	20	18.34
G	Fly ash and Lime	10	Damaged
H	Fly ash and Lime	15	Damaged
I	Fly ash and Lime	20	Damaged
Z	Burnt clay brick	-	13.99
X	Fly ash brick	-	24.1

It is also observed that the water absorption decreases with increase in percentage of cement content. This is on the expected lines because the clay has more affinity for water, more clay means more water absorption (Venkatarama Reddy, B.V. et al., 2013).

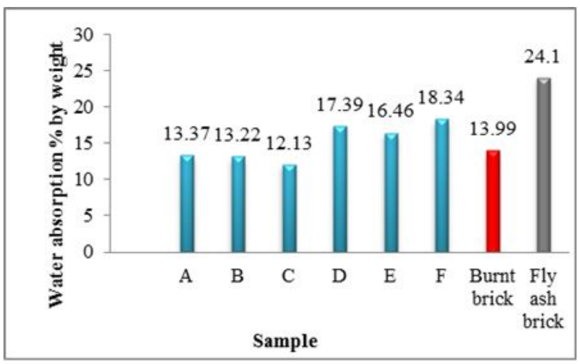

Figure 4:Comparison of the Water Absorption of OPC Stabilised Bricks with Burnt Clay and Fly Ash Brick

The OPC and Lime stabilised bricks (Sample D-F) exhibited higher water absorption than OPC bricks (Sample A-C) and burnt clay bricks but shows lower water absorption than fly ash bricks. However, the values are below 20% i.e. within the range as recommended in the Indian Standards.

XIII. DENSITY

The laboratory test was conducted to determine the density of the brick samples. For this test, weight and volume of the six bricks specimen were carried out and the results were recorded and the average of six specimens was computed for each sample which is shown in Table 7.

Table 7: Density Results

Sample	Stabiliser	%	Density (kg/m^3)
A	OPC	10	1769
B	OPC	15	1780
C	OPC	20	1804
D	OPC and Lime	10	1710
E	OPC and Lime	15	1658
F	OPC and Lime	20	1633
G	Fly ash and Lime	10	1612
H	Fly ash and Lime	15	1597
I	Fly ash and Lime	20	1562
Z	Burnt clay brick	-	1727
X	Fly ash brick	-	1406

Density of stabilised soil bricks are not very high (< 1805 kg/m³) and within the range of normal burnt bricks density (1300-2200 kg/m³). This may be considered as an advantage, when the bricks have to be transported over long distance.

The OPC stabilised bricks (Sample-A to C) exhibited higher density than all the samples but within the range of normal burnt bricks density (1300-2200 kg/m³). The density of OPC stabilised bricks increases as the percentage of stabiliser increased.

The density of OPC and Lime stabilised bricks (Samples-D to F) are lower than OPC stabilised bricks and burnt clay bricks but higher than Fly ash and Lime stabilised bricks.

CONCLUSIONS

COMPRESSIVE STRENGTH

The OPC stabilised bricks performed better than both OPC and Lime or Fly ash and Lime stabilised bricks. The OPC stabilised bricks (samples A-C) exhibited the highest compressive strength by a large margin which is within the range of 69.67-120.69 kg/cm². The Sample-C (20% OPC as stabiliser) exhibited a compressive strength greater than 100 kg/cm² i.e. 120.69 kg/cm² which is 9.58% and 21.1% higher than the burnt clay bricks and fly ash bricks respectively. In OPC and Lime stabilised bricks (Sample D-F), Sample-F (20% OPC and Lime as stabiliser) produced compressive strength up to 59.66 kg/cm². Whereas Fly ash and lime stabilised bricks performed least well with a compressive strength range i.e. 14.48 Kg/cm² for the 10% stabiliser to 26.49 Kg/cm² for the 20% stabiliser.

WATER ABSORPTION

The OPC stabilised bricks exhibits lower water absorption value i.e. less than 15% which is recommended for higher classes in Indian Standards (IS: 1077: 1992). The water absorption of Sample-C (20% OPC as stabiliser) is 12.13% which is 13.3% and 49.7% lower than burnt clay and Fly ash bricks respectively. In OPC and Lime stabilised brick samples, water absorption of Sample-D (10% OPC and Lime as stabiliser) is 17.39% whereas water absorption of Sample-F (20% OPC and Lime as stabiliser) is 18.34%; however the values are below 20% i.e. within the range as recommended in Indian Standards. As the percentage of stabiliser increases, percentage of water absorption of samples also increases. In Fly ash and Lime stabilized bricks, all the samples were damaged during the water absorption test.

DENSITY

In OPC stabilised bricks, the density of Sample-C (20% OPC as stabiliser) is 1804 kg/m³ which is 4.5% and 28.3% higher than burnt clay and fly ash bricks respectively. Whereas in OPC and Lime stabilised bricks, density of Sample-D (10% OPC and Lime as stabiliser) is 1710 kg/m³ which is higher than Sample E (15% OPC and Lime as stabiliser) and Sample-F (20% OPC and Lime as stabiliser) but it is 1%

lower than burnt clay bricks and 21.6% higher than fly ash bricks. In Fly ash and Lime stabilised bricks, out of three samples, Sample-G (10%Fly ash and Lime as stabilser) produced a higher density i.e. 1612 kg/m³ which is 6.7% lower than burnt clay bricks and 14.7% higher than fly ash bricks.

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