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STABILITY OF COMPRESSED EARTH BLOCKS BY USING LOCAL ADDITIVES

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ABSTRACT

The study involved investigating the performance of ordinary Portland cement (OPC) stabilized soil blocks by cement amended with sugarcane bagasse ash (SBA) and wheat straw (WS). Locally available soil was tested for its properties and characterized as clay of medium plasticity. This soil was stabilized using 5% OPC by weight of dry soil for manufacture of blocks of size 19 cm × 9 cm × 9 cm. The blocks were admixed with 4%, 6%, 8% and 10% SBA & WS by weight of dry soil during casting, with plain OPC stabilized blocks acting as control. All blocks were cast to one target density and water content followed by moist curing for a period of 28 days. They were then subjected to compressive strength and water absorption tests in accordance with Bureau of Indian standards (BIS) specifications. The results of the tests indicated that OPC stabilization resulted in blocks that met the specifications of BIS. Addition of SBA and WS increased the compressive strength of the blocks and slightly increased the water absorption but still met the standard requirement of BIS code. It is concluded that addition of SBA & WS to OPC in stabilized block manufacture was capable of producing stabilized blocks at reduced OPC content that met the minimum required standards.

I. INTRODUCTION

The advantages of compressed earth block construction include easy availability of material, economy, ease of use, fire resistance, beneficial climatic performance, and low energy consumption whereas its limitations include low durability, low tensile strength,low impact resistance, low abrasion resistance, and low acceptability. One of the major advantages of compressed earth blocks is their low energy consumption.

1.1. Sugar Base ASH (SBA)

Sugar Base Ash is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India production is over 300 million tons/year that cause around 10 million tons of bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from, about 40-45 percent fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat or power generation leaving behind 8 -10 percent ash as waste, known as bagasse ash (SBA).

1.2. Wheat Straw

Wheat is one of the primary sources of food for 2.45 billion people. In 2014, the annual global production of wheat was around 705 million tons, out of which 75% was produced by 18 countries while around 20% was

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produced by EU-27. According to the statistical data, India is ranked at 7 with 3.5% share to the world wheat production. As per Pan and Sano, the average yield of straw is around 1.3–1.4 kg per kg of grain. This places the global estimate of wheat straw at around 534 million tons and for India this value is around 18.46 million tons. The current use of this abundant supply of wheat straw, as described by Zhang et al., is limited to feeding stuff, pulp and paper, nanomaterials, bioethanol, fertilizer, and construction of mud houses. However, in some parts of the world and especially in underdeveloped and developing countries, wheat straw is burnt in open field causing environmental issues and health problems. Huge amount of ash, obtained after burning of wheat straw, probably has no use and getting rid of it is also a problem.

II. LITERATURE REVIEW

Some of the major findings/recommendations from the studies, regarding production and properties of soil cement blocks have been summarized below:

a) Sandy soils containing predominantly non-expansive clay minerals (like kaolinite) are ideally suited for the production of soil-cement blocks. It is desirable that such soils have sand content >65% and a clay fraction of about 10%. Soils with higher clay fractions can be reconstituted by adding inert materials like sand/stone quarry dust/mine wastes etc. to bring down the clay fraction of the mix.

b) Soil-cement blocks produced using high clay soils are prone for damage due to rain impact and possess poor durability characteristics.

c) Strength of the block is sensitive to its density and preferable to obtain greater than 1.8 g/cc dry density for blocks. Wet to dry strength ratio for the blocks will always be less than unity.

d) Compressive strength of soil-cement blocks increases with the increase in cement content. Soil-cement mixes with 7% cement give sufficient wet compressive strength for the blocks to build two-storeyed load bearing residential buildings. Block strength can be easily manipulated by adjusting the cement content.

Consoli et al. (2002) worked on engineering behavior of sand reinforced with plastic waste. They found that, the polyethylene terephthalate fibre reinforcement improved the peak and ultimate strength of both cemented and un-cemented soil and somewhat reduced the brittleness of the cemented sand. In addition, the initial stiffness was not significantly altered by the inclusion of fibres.

Mesbah et al. (2004) proposed development of a direct tensile test for compacted earth blocks reinforced with natural fibres. By using the direct tensile test, it was possible to quantify the tensile reinforcing effects of randomly distributed sisal fibres in earth blocks. Benefits of the inclusion of the natural fibre reinforcement include both improved ductility in tension in comparison with plain earth blocks and the inhibition of tensile crack propagation after initial formation. Prior to cracking, the fibres appeared to have no noticeable effect on the material behavior.

Parichartpreecha (2015) have adopted SBA as a replacement for cement in their study. Nevertheless, it may be possible that higher cement content adopted in the investigation may also be an added reason for reduced effectiveness of SBA. This can be inferred from the steep drop in strength till a stabilizer content ratio of 0.43 corresponding to a cement content of 10%. On further increase in SBA content and corresponding decrease in cement content, the slope of the curve flattens in comparison, indicating SBA to be effective at lower cement

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content. The primary objective of this study is to analyze the performance of cement stabilized earth blocks admixed with SBA in terms of compressive strength, water absorption, and efflorescence.

III. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. Grain Size Analysis

Table 1.1: Grain size analysis results of the soil

Diameter of the sieves (mm)	Soil Retained (g)	Percent Retained	Percent Passed
4.75	31.5	6.3	93.7
2	46	9.2	84.5
0.85	88.5	17.7	66.8
0.425	51	10.2	56.6
0.25	52.5	10.5	46.1
0.125	41.5	8.3	37.8
0.075	25	5	32.8
Pan	164	32.8	0

The percentage passed from 4 number Sieve is 93.7%. 10 no. sieve is 84.5%, 20 no. sieve is 66.8%, 40 no. sieve is 56.6%, 60 no. sieve is 46.1%, 140 no. sieve is 37.8% and 200 no. sieve is 32.8%.

From the above Grain Size experimental result, there is 6.3 % gravel, 60.9 % sand and 32.8% fine (silt + clay) in the soil. And, from UN recommendation range of particledistribution suitable for building of earth block is: 40 - 75% sand and 25-60% fine (silt + clay). This implies that the sample soil which was taken for the current study fulfills this requirement. So, the experimental result range for this soil sample is acceptable and suitability for stabilized earth block production. In other word, the soil is considered as suitable for mud house construction.

3.2. Total Water Absorption Test

Table 1.2: Total water absorption for stabilized earth block

Types of samples	samples	dry mass (g)	wet mass (g)	Water absorption (%)	Average Water absorption (%)
S	1	2013	2465	22.5	22.2
	2	2028	2472	21.9	
	3	2019	2469	22.3	
S1	1	2095	2398	14.5	15.3
	2	2085	2412	15.7	
	3	2074	2402	15.8	
S2	1	2035	2298	12.9	12.8
	2	2021	2286	13.1	
	3	2048	2304	12.5	
S3	1	1989	2418	21.6	21.6
	2	1998	2422	21.2	
	3	2001	2439	21.9	
S4	1	2008	2270	13.0	13.2
	2	1999	2268	13.5	
	3	2017	2281	13.1	
S5	1	2045	2298	12.4	12
	2	2043	2284	11.8	
	3	2045	2288	11.9	

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Above table shows that, an increase in additive content with fixed quantity of cement has the effect of reducing the water absorption value of the blocks. The percentage decrease in water absorption with addition of SBA & wheat straw is 31% for 5%cements +95% soils, 42% for 5%cements +4% SBA+4% WS+87% soils,3% for 5%cements +6% SBA+6% WS+83% soils,41% for 5%cements +8% SBA+8% WS+79% soils and 46% for 5%cements +10% SBA+10% WS+75% soils with respect to the only soil. This shows that the increase in additive content at a fixed content of cement in the mixture results intoa reduction in water absorption. In contrary, at a particular proportion of the SBA and wheat straw fiber content i.e. 6% results into a reduction in mean water absorption of 3%. This shows that the increase in additive content results in reduction of water absorption but only up to particular extent, but it has no much insignificant effect as the cement does. Therefore, from the result the other samples fulfill the recommended value i.e. 15%.

3.3. Shrinkage in Drying Process

~~Table 5.3 Average value of shrinkage after drying of the stabilized blocks~~Table 1.3: Average value of shrinkage after drying of the stabilized blocks

Samples	Average shrinkage(cm^3)	Percentage shrinkage (%)
S	262	17.0
S1	144	9.4
S2	100.4	6.5
S3	140.7	9.1
S4	130.6	8.5
S5	109.45	7.1

Hence, the percentage shrinkage values for the various samples tested were 17% for only soil, 9.4% for 5%cements +95% soils, 6.5% for 5%cements +4% SBA+4% WS+87% soils , 9.1% for 5%cements +6% SBA+6% WS+83% soils , 8.5% for 5%cements +8% SBA+8% WS+79% soils and 7.1% for 5%cements +10% SBA+10% WS+75% soils .

3.4. Compressive strength test result and analysis

Table 1.4: Average dry compression strength of stabilized blocks

Samples	DCS (MPa)			Avg. DCS (MPa)	%age change w.r.t S (Sx-S)x100/S
	Sample 1	Sample 2	Sample 3		
S	0.92	0.75	0.82	0.83	
S1	1.51	1.75	1.87	1.71	106
S2	3.05	2.95	2.99	3.00	261
S3	3.92	4.37	4.87	4.39	429
S4	4.41	4.33	4.51	4.42	432
S5	3.97	4.24	4.11	4.11	395

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According to Table 1.4., an increase in additive content at 5% of cement has the effect of increasing the compressive strength value of the blocks. The dry compressive strength is 0.83MPa for only soil sample, 1.71MPa for 5%cements +95% soils, 3MPa for 5%cements +4% SBA+4% WS+87% soils, 4.39MPa for 5%cements +6% SBA+6% WS+83% soils, 4.42MPa for 5%cements +8% SBA+8% WS+79% soils and 4.11MPa for 5%cements +10% SBA+10% WS+75% soils with respect to the only soil.

Table 1.5: Average wet compression strength of stabilized blocks

Samples	WCS(MPa)			Avg. WCS (MPa)	%age change w.r.t S (Sx-S)x100/S
	Sample 1	Sample 2	Sample 3		
S	0.58	0.44	0.62	0.55	
S1	1.33	1.04	1.29	1.22	122
S2	1.78	1.58	1.69	1.68	206
S3	2.06	2.17	2.21	2.15	290
S4	2.31	2.58	2.49	2.46	347
S5	2.89	2.87	2.79	2.85	418

According to the table 1.5; an increase in additive content at 5% of cement has the effect of increasing the wet compressive strength value of the blocks as observed in case of dry compressive strength. The wet compressive strength is 0.55MPa for only soil sample, 1.22MPa for 5%cements +95% soils, 1.68MPa for 5%cements +4% SBA+4% WS+87% soils, 2.15MPa for 5%cements +6% SBA+6% WS+83% soils, 2.46MPa for 5%cements+8% SBA+8% WS+79% soils and 2.85MPa for 5%cements +10% SBA+10% WS+75% soils.

The above results shows that the only soil sample has very less compressive strength and the compressive strength increases 122% with addition of 5% cement in the soil. The wet compressive strength increases a lot with the addition of additives as SBA & Wheat straw but this %age increase was very less in comparison to dry compressive strength. Thisincrease was 206% when 4% of both additives were added in addition to 5% cement in soil. The further increase in content of the SBA & wheat straw as 6% with fixed amount of cement as 5% increases the wet compressive strength abruptly as 290% in comparison to ordinary soil. Further increase was observed with increase in dosages of both additives as 8% at fixed cement content of 5% as 347%, the trend continues even with further enhancement in the additives as water reach with the pozzolanic materials to produce binding properties. The result shows that the further increase in amount of additives has enhanced the wet strength just opposite to that of dry case. The strength was increased to 418% in comparison to only soil with further addition of SBA & WS as 10% whereas the amount of cement was kept fixed as 5% for all the cases. This increase was more than that obtained by the addition of 8% of additives which shows that the binding of the material take place with addition of water due to pozzolanic behavior of SBA and straw acts as fibre reinforcing material.

IV. COST COMPARISON BETWEEN CSEB AND FIRED BRICKS

[1] The compressed stabilized earth blocks are much less energy consuming than fired bricks nearly four times less and is much less polluting than fired bricks.

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[2] CSEB are consuming 11 times less energy than country fired bricks:
CSEB produced on site with 5 % cement = 548.32 MJ/m3
Country fired bricks = 6,122.54 MJ/m3

[3] CSEB are polluting 13 times less than country fired bricks:
CSEB produced on site with 5 % cement = 49.37 Kg of CO2 /m3
Country fired bricks = 642.87 Kg of CO2 /m3

[4] CSEB are most of the times cheaper than fired bricks and concrete blocks. A finished m3 of CSEB masonry is always cheaper than fired bricks: between 15 to 20% less than fired bricks.

[5] There is a saving of labour of about 45% (mainly in soil sieving and block making), Raw material about 27%, cement about 25% and equipment nearly 3% in CSEB than the fired bricks and concrete blocks.

V. CONCLUSION

1. The Grain Size experimental result showed that there is 6.3 % gravel, 60.9 % sand and 32.8% fine (silt + clay) in the soil. And, from UN recommendation range of particle distribution suitable for building of earth block is: 40 - 75% sand and 25-60% fine (silt + clay). This implies that the sample soil which was taken for the current study fulfills this requirement.
2. An increase in additive content with fixed quantity of cement has the effect of reducing the water absorption value of the blocks.
3. The increase in additive content at a fixed content of cement in the mixture results into a reduction in water absorption. In contrary, at a particular proportion of the SBA and wheat straw fiber content i.e. 6% results into a reduction in mean water absorption of 3%.
4. The increase in additive content results in reduction of water absorption but only up to particular extent, but it has no much insignificant effect as the cement does.
5. When the amount of the cement and the straw fiber is increased, the shrinkage value will decrease or vice versa.
6. The dry compressive strength increases many folds with the addition of additives as SBA & Wheat straw.
7. The optimum dry compressive strength was observed at 8% addition of sugar Base ash and wheat straw at a fixed cement content of 5%.
8. An increase in additive content at 5% of cement has the effect of increasing the wet compressive strength value of the blocks as observed in case of dry compressive strength.
9. The wet compressive strength increases a lot with the addition of additives as SBA & Wheat straw but this percentage increase was very less in comparison to dry compressive strength.
10. This increase in wet compressive strength was more than that obtained by the addition of 8% of additives which shows that the binding of the material take place with addition of water due to pozzolanic behavior of SBA and straw acts as fibre reinforcing material.

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