"COMPARATIVE STUDY OF PERFORMANCE OF RECONSTITUTED BLACK COTTON SOIL STABILIZED ADOBE WITH M SAND AND RED SOIL."

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Abstract:

*Soil is one of the most abundantly available natural construction material. The usage of soil in construction industry reduces the impact on environment due to its eco-friendly nature. There are different types of soils available on earth, out of which red soil, black cotton soil (BCS) and laterite soil are mainly used in construction. The presence of excess clay in BCS results in swelling and shrinkage of soil due to this property, BCS is termed as expansive soil. However, BCS is abundantly available in large part of central India and a part of south India. By using this locally available material in construction, the overall cost of the project is reduced which is economical. In the present study, the expansive nature of the BCS is reduced by reconstituting the soil by adding M-Sand in various percentages. The present study focuses on the replacement of M-Sand by red soil. Combination of BCS and Red soil is termed as Hybrid Soil. Also, the performance of the reconstituted soil by adding different types of stabilizers like cement and lime, is being studied. The blocks are prepared by traditional method of pugging the reconstituted stabilized soil by adding water to its consistency and dashed into the mould (190*90*90) mm from a height of 0.5m and blocks are cured for 28days. This process of making blocks is termed as Adobe. These prepared soil blocks by process of adobe are termed as soil stabilized adobe (SSA) blocks. The performance of SSA blocks is tested for various test like Dry compressive strength, Wet compressive strength and Water absorption test. From the above-mentioned tests, it is observed that the replacement of M- Sand by Red soil to BCS, variation in strength lies within 10%. Lime as a stabilizer shows improvement in strength compared to cement and combination of cement and lime as a stabilizer.*

***Keyword**: Black cotton soil (BCS), Red Soil, M Sand, Reconstituted Soil, Soil Stabilized Adobe.*

1. INTRODUCTION

The need of the hour is to protect planet Earth from fast growing jungles wherein the use of naturally available materials is minimal. To address the issue of never ending large-scale construction of structures built using the more advantageous concrete elements, it is required to substitute the construction materials with eco-friendly and sustainable alternatives. (Ashwin and Basutkar,2019) Holistically, through an analysis of India's geology we can summarize the various types of soils such as alluvial soil, black soil, red soil, laterite soil or arid soil, forest and mountainous soil and marshy soil. From, the soil profile of India, it is evident that black soil or regur soil covers nearly 15% of the total land area of the country, spread over an extensive area of 3,00,000 square kilometers. Black soil is widespread over parts of Deccan plateau, Gujarat, Maharashtra, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and considerable portions of Northern Karnataka. (Nadgouda and Hegde, 2010) To cannibalize the abundant availability of Black soil present in various regions of Karnataka an extensive study is necessary to materialize the shortcomings encountered during constructive activities which can benefitted by

employing Black Cotton soil into the process of manufacturing masonry units.

The plentiful abundance of Black soil paves its way into the preparation of Adobe blocks bringing sustainability in the construction industry. There is considerable supremacy of Adobe blocks over other concrete elements in terms of damage to the environment, economy and the simplicity engaged in the manufacturing process. (Reddy, et al., 2007). The simple process of preparing Adobe blocks involves the optimum quantity of water, kneading the soil mix until a workable mix is achieved which is further encased within a standard mould size conforming to IS standards.

In the present investigation Black cotton soil is being used predominantly for the preparation of Adobe blocks, but the percentage of clay present in Black cotton Soil (BCS) is instrumental in comprehending the strength and durability characteristics of Adobe blocks. Since, the role of clay is critical in Black cotton soil as it induces immoderate shrinkage and swelling in the Adobe blocks. Confronting adobe block failures such as cracking, brittleness, excessive swelling and shrinkage and to mitigate the consequences of impact of clay, Black Cotton Soil is reconstituted by replacing partially by M-Sand which will reduce the clay content and avoid drastic volume changes. Also, it is demanding that the Adobe blocks be stabilized for increased strength. Hence, we require reconstitution and stabilization of Black cotton soil either chemically or mechanically enabling it to be utilized as a suitable construction material which enhances the performance under the pretext of strength, durability and minimalistic dimensional changes There are various methods of soil stabilization which encompasses stabilized adobe, soil stabilized mud blocks, cob, wattle, rammed Earth and stabilized mud concrete to name a few. The role of stabilizer is decisive in relation to the parameter of strength gain and weather resistance.

In the current study the reconstitution of BCS is done by replacing BCS partially by Red Soil in place of M-Sand as Red Soil consists of minimal quantity of Clay and it is more economical compared to M-Sand. The BCS soil which is been reconstituted by partially replacing by Red Soil is termed as Hybrid Soil. Now Hybrid soil consists of BCS and Red Soil. Also, to increase the strength of the Adobe prepared by reconstituted Black Cotton Soil, conventional stabilizers such as lime, and cement of optimum quantity as per IS standards were blended with Black cotton soil in different combinations were used.

2.MATERIALS

Materials used in this study include Black Cotton Soil, Red Soil, M-sand, cement and lime. Basic properties of these materials were examined.

2.1 Soil

For the present study, Black Cotton soil was collected from Mysuru district of Karnataka state, India (12°18’31” N, 76°39’11”E). Similarly, Red soil was collected from Ramanagara district of Karnataka state, India (12°71’N 75°28’E). Black cotton soil and red soil were tested for geotechnical properties such as Sieve analysis, Hydrometer analysis, specific gravity, Atterberg limits, compaction per IS 2720:1980 standards were tested and presented in Table 1.

2.2 M Sand

M-sand was procured from local vendors and tested for its basic properties as per IS:1725-1982 and presented in Table 2.

2.3 Cement

Cement (Birla Super) of 53 Grade is used as a Stabilizer. Cement was procured from a local store and the following tests were conducted as per IS: 4031-1988 and presented in Table 3.

Table 1: Properties of Black Cotton Soil and Red Soil.

Physical properties		**Black cotton Soil**	**Red soil**
Specific gravity, G		2.56	2.54
Atterberg Limits (Consistency limits)	Liquid limit (W_L)	48.83%	33.26%
	Plastic limit (W_P)	23.41%	-
	Plasticity index (I_P)	25.42%	-
	Shrinkage limit (W_S)	12.39%	14.94%
Particle Size Distribution	Gravel (%)	0.67	1.4
	Sand (%)	35	60.2
	Silt (%)	46.74	37.77
	Clay (%)	17.59	0.63
Compaction Characteristics	Optimum moisture Content-OMC (%)	16.5	13.5
IS Classification		CI	SM
Compaction Characteristics	Max. Dry density-MDD (g/cc)	1.72	1.84
Free Swell index		40%	-
pH		6.1	5.85

Table 2: Properties of M-Sand

Physical properties		**M-Sand**
Specific gravity, G		2.62
Particle Size Distribution	Gravel (%)	6.40
	Sand (%)	92.80
	Silt (%)	0.80
	Clay (%)	-
Natural moisture content (%)		3.20
IS Classification:		SP
Fineness modulus		2.93

Table 3: Properties of Cement used in present study

Characteristics	**value**	**IS:12269-2013 Recommendation**
Fineness (%)	3	<10%
Normal consistency (%)	28	----
Specific gravity	3.1	----
Setting time A) initial setting (min) B) final setting (min)	55 480	30.00 (min) 600.00(max)
Soundness A) Le-Chatelier Expansion (mm)	- 4.0	0.8(min) 10.0(max)

2.4 Lime

Lime is a versatile product manufactured from a very high calcium burnt limestone. Powdered lime is used in the present study as a Stabilizer. The basic properties of lime were tested as per IS:6932-1973 for the following chemical properties presented in Table 4.

Table 4: Chemical Characteristics of lime as per IS:6932-1973

Particulars	**Results**
Loss on ignition, (% by mass)	26.93
Silicon dioxide (SiO_2) (on dry basis, % by mass)	8.84
Magnesium Oxide, (on ignited basis, % by mass)	1.77
Ferric oxide (Fe_2O_3) (on ignited basis, % by mass)	1.26
Alumina (Al_2O_3) (on ignited basis, % by mass)	4.21
Calcium Oxide (CaO) (on dry basis, % by mass)	55.79
Calcium Hydroxide Ca(OH) (on dry basis using calculation method, % by mass)	71.70
Calcium Carbonate ($CaCO_3$) (on dry basis using calculation method, % by mass)	99.56
Sulphur Trioxide (SO_3) (on ignited basis, % by mass)	0.016
Alkalis a) Sodium Oxide (Na_2O) (% by mass) b) Potassium Oxide (K_2O) (% by mass)	 0.10 0.42
Others	0.67

3. PARAMETERS CONSIDERED IN THE STUDY.

The various parameters considered in the present study of Performance of SSA blocks of BCS are:

Various Replacement level of BCS by M-Sand – 10%, 20%,30%40%,50%. Various Replacement level of BCS by Red Soil – 10%, 20%,30%40%,50%.

Stabilizers- Cement -8%, Lime -8% and Combination of Cement + Lime, each 4%

The various mix proportion of Black cotton soil with M-sand or Red-soil and stabilizer in SSA block and their designations used in the present study are presented in Table- 5.

4. PREPARATION OF SOIL STABILIZED ADOBE BLOCK (SSAB)

Black cotton soil is mixed with M-sand or Red Soil in different proportions to reduce the clay content. Along with, Cement or Lime is being added as stabilizer to increase the strength of the Soil Stabilized Adobe (SSA).

Required quantity of materials –Black cotton soil, Red Soil, M-sand and Stabilizers – Lime, Cement was weighed and the pre-determined optimum water content was added to the mixture.

The pre-determined optimum water content is based on Ball consistency. (*Ball consistency is the determination of optimum water content required for making adobe. This is being found out after pugging the soil with sufficient quantity of water, a small quantity of pugged soil is*

taken and rolled into glossy ball between the hands and dropped from a height of about 0.5 meters. The ball when dropped it should not crumble.)

By adding optimum quantity of water to the required mixture of materials of Black Cotton Soil with M-Sand or Red Soil and Stabilizer is thoroughly mixed in a Pan mixer. The well mixed soil stabilized materials were then manually pugged for about 5minutes till the stabilized soil attains the ball consistency (Fig 1). Then stabilized soil was compacted well by making smooth balls and by dropping them from a height of 0.5 meters into the mould smeared with oil to avoid soil sticking to the surface. This procedure of preparing blocks is known as Adobe. The corners and edges were given special attention and hence was compacted manually to avoid honeycombing. The surface was leveled using a trowel and then hand finishing was done. The mould is of size,190mm x 90mm x 90mm (Fig .2) as per IS:1077-1992. De-moulding was done on a level platform by tilting the mould upside down and ejecting the plate and lifting the mould slowly.

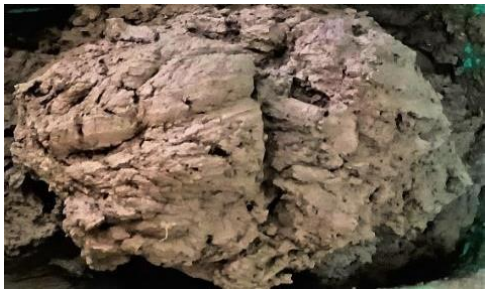

Figure 1: Mud ball after pugging.

Figure 2: Mould used for preparation of adobe (190*90*90) mm.

Curing

To achieve maximum strength, compressed SSA blocks need a period of damp curing, after two or three days, depending, on the local temperatures, SSA blocks complete their primary cure. The blocks were de-moulded and freshly de-moulded blocks were laid out in a single layer on a non-absorbent surface Fig.3 and was cured by covering with wet gunny bags for period of 28 days (four weeks). SSA blocks after curing were tested for its strength.

Figure 3: Fresh adobe blocks.

Figure 4: Curing of SSA blocks by covering with wet gunny bags for period of 28 days.

Table 5: Different Proportions of BCS, Red Soil, and M-Sand with Stabilizers- Cement and Lime used in Soil Stabilized Adobe

Abbr.	Description
B10MC	90% BC SOIL+ 10% M-SAND+ 8% CEMENT
B20MC	80% BC SOIL+ 20% M-SAND+ 8% CEMENT
B30MC	70% BC SOIL+ 30% M-SAND+ 8% CEMENT
B40MC	60% BC SOIL+ 40% M-SAND+ 8% CEMENT
B50MC	50% BC SOIL+ 50% M-SAND+ 8% CEMENT
B10ML	90% BC SOIL+ 10% M-SAND+ 8% LIME
B20ML	80% BC SOIL+ 20% M-SAND+ 8% LIME
B30ML	70% BC SOIL+ 30% M-SAND+ 8% LIME
B40ML	60% BC SOIL+ 40% M-SAND+ 8% LIME
B50ML	50% BC SOIL+ 50% M-SAND+ 8% LIME
B10MCL	90% BC SOIL+ 10% M-SAND+ 4% CEMENT+ 4% LIME
B20MCL	80% BC SOIL+ 20% M-SAND+ 4%CEMENT+ 4% LIME
B30MCL	70% BC SOIL+ 30% M-SAND+ 4% CEMENT+ 4% LIME
B40MCL	60% BC SOIL+ 40% M-SAND+ 4% CEMENT+ 4% LIME
B50MCL	50% BC SOIL+ 50% M-SAND+ 4% CEMENT+ 4% LIME
B10RC	90% BC SOIL+ 10% RED SOIL+ 8% CEMENT
B20RC	80% BC SOIL+ 20% RED SOIL+ 8% CEMENT
B30RC	70% BC SOIL+ 30% RED SOIL+ 8% CEMENT
B40RC	60% BC SOIL+ 40% RED SOIL+ 8% CEMENT
B50RC	50% BC SOIL+ 50% RED SOIL+ 8% CEMENT
B10RL	90% BL SOIL+ 10% RED SOIL+ 8% LIME
B20RL	80% BC SOIL+ 20% RED SOIL+ 8% LIME
B30RL	70% BC SOIL+ 30% RED SOIL+ 8% LIME
B40RL	60% BC SOIL+ 40% RED SOIL+ 8% LIME
B50RL	50% BC SOIL+ 50% RED SOIL+ 8% LIME
B10RCL	90% BC SOIL+ 10% RED SOIL+ 4% CEMENT+ 4% LIME
B20RCL	80% BC SOIL+ 20% RED SOIL+ 4% CEMENT+ 4% LIME
B30RCL	70% BC SOIL+ 30% RED SOIL+ 4% CEMENT+ 4% LIME
B40RCL	60% BC SOIL+ 40% RED SOIL+ 4% CEMENT+ 4% LIME
B50RCL	50% BC SOIL+ 50% RED SOIL+ 4% CEMENT+ 4% LIME

5. TESTING OF SSA BLOCKS.

In this present study, these prepared SSA blocks were tested for following test.

5.1 Compressive Strength

The compressive strength characteristics of SSA blocks were evaluated as per IS 3495:1992(Part I).

Figure 5: compressive test on SSA blocks.

5.1.1 Dry compressive strength

The SSA blocks were prepared and cured for 28 days. To test the blocks for dry Compressive strength it was oven dried for 24 hours and tested in the Compression testing machine, the peak Compressive load (crushing load) resisted by the SSA block was noted and Dry Compressive Strength was calculated.

5.1.2 Wet compressive strength

SSA block moist cured in water for 28 days were immersed in water for 24 hours and surface dried. These blocks were tested under the Compression testing machine and the crushing load was recorded and the Wet Compressive Strength was calculated.

5.2 Water Absorption

The rate of water absorption of SSA blocks was evaluated as per IS 3495:1992(Part II). Dry weight of the block was recorded and then the blocks were soaked in water for 24 hours, the saturated blocks were weighed again. The difference in weight gain due to water absorption was calculated to obtain the percentage of water absorption.

Figure 6: Water absorption test on SSA blocks.

6. RESULTS AND DISCUSSION

The Performance of SSA block of black cotton soil partially replaced by M-Sand compared with partially replaced by Red Soil in varying percentages (10, 20, 30, 40, 50) with different Stabilizers Cement , Lime and Cement + Lime are discussed with respect to Dry compressive strength (DCS), Wet Compressive strength (WCS) ,Water absorption (WA) test.

6.1 Dry Compressive Strength

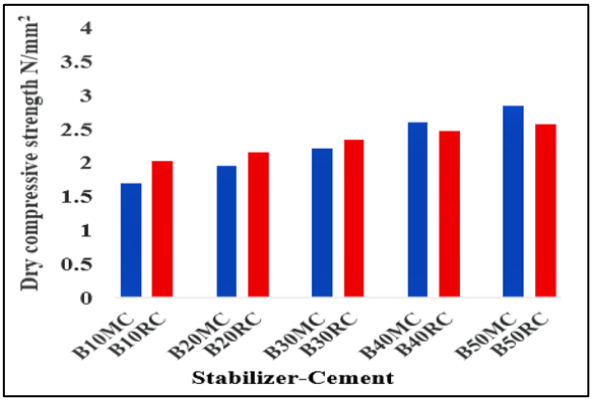

Figure 7: Comparison of DCS of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with Cement alone as Stabilizers.

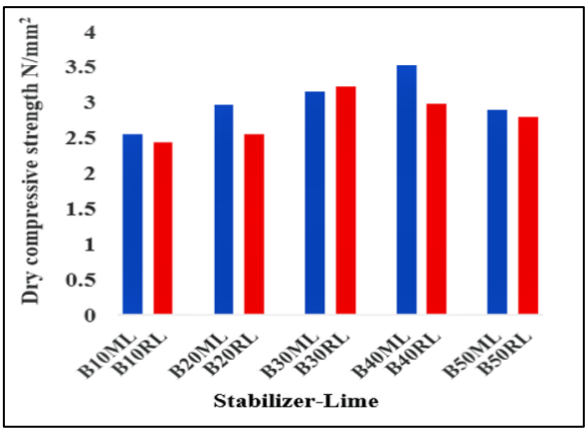

Figure 8: Comparison of DCS of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with lime alone as Stabilizers.

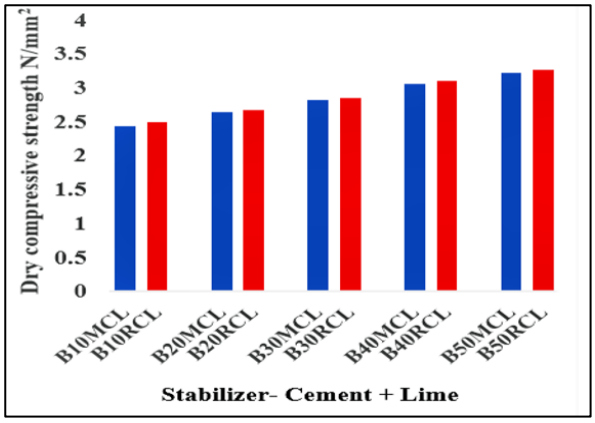

Figure 9: Comparison of DCS of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with combination of Cement + lime as Stabilizers.

Fig 7 The Dry Compressive strength of SSA of BCS replaced by M-Sand or Red Soil with Cement alone as stabilizer showed an increase in strength with increase in percentage of replacement of MS or Red Soil. But DCS of SSA of BCS replaced by Red Soil shows higher strength than BCS replaced by M-Sand by an average of 12% upto 30% of replacement, further increase in replacement level greater than 30% shows marginal decrease in strength by 8%.

Fig. 8. The Dry Compressive strength of SSA of BCS replaced by M-Sand or Red Soil with Lime as stabilizer upto 40% replacement of M-Sand and 30% replacement of Red Soil has shown increase in strength. With further increase in replacement of M-Sand or Red Soil strength of SSA blocks decreases. This may be because lime as a stabilizer with BCS reacts well and helps in enhancing of strength of SSA blocks, hence with increasing the replacement of M-Sand or Red Soil decreases the quantity of BCS which intern reduces the strength of SSA blocks. It is also observed that for every percentage of replacement of red soil compared with M-Sand there is marginal decrease in strength by an average of 5%.

From fig.9, It is observed that DCS of SSA blocks of BCS replaced by M-Sand or Red Soil with combined stabilizer of cement + lime, shows gradual increase in strength with increase in percentage of replacement of M-Sand or Red Soil. It is also observed that DCS of BCS replaced with Red Soil compared with corresponding replacement of m sand is almost same (variation is within 1%) for all percentage of replacement of M-Sand and Red Soil.

From fig 7, 8, 9. It is observed that the DCS of BCS replaced with M-Sand and Red Soil for all percentage of replacement (10% to 50%) is higher with lime alone as stabilizer compared with cement alone and cement + lime as stabilizer.

6.2 Wet Compressive Strength

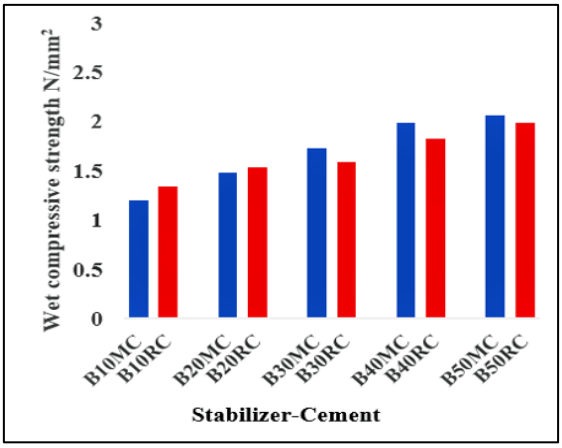

Figure 10: Comparison of WCS of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with Cement alone as Stabilizers.

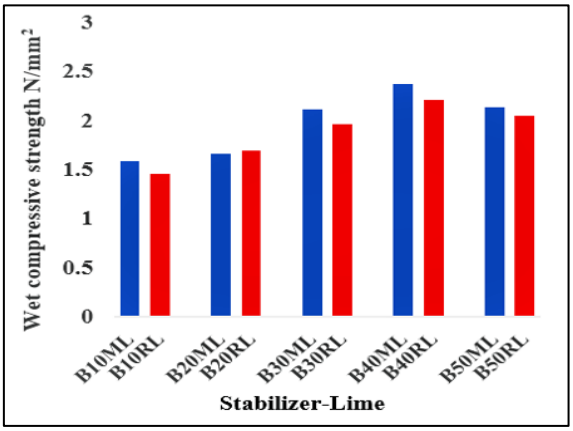

Figure 11: Comparison of WCS of SSA block of BCS partially replaced by M-Sand or Red SOIL in varying proportions with lime alone as Stabilizers.

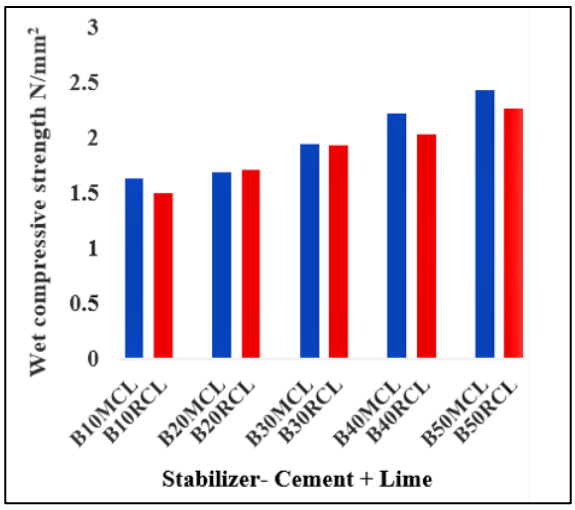

Figure 12: Comparison of WCS of SSA block of BCS partially replaced by M-SAND or RED SOIL in varying proportions with combination of Cement and lime as Stabilizers.

Fig 10, 11, 12. represents the behavior of Wet Compressive strength(WCS) of SSA blocks of Black cotton soil (BCS) partially replaced by M-Sand and Red Soil in varying proportions with different Stabilizers such as cement, lime, and combination of cement + lime is similar to the DCS of SSA blocks. However, the WCS compared to the DCS is lesser by an average of 33%.

6.3 Water Absorption.

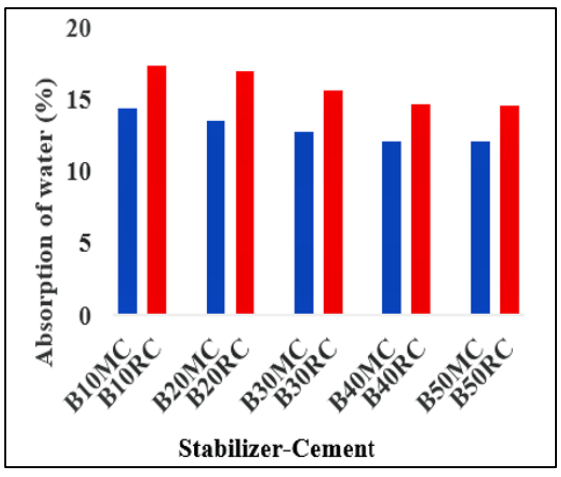

Figure 13: Comparison of WA of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with Cement alone as stabilizers.

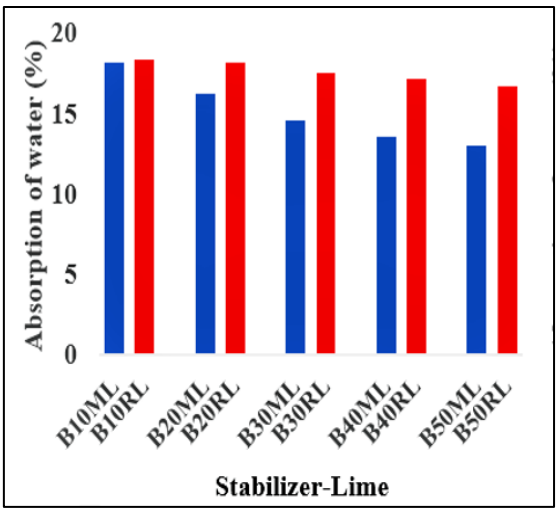

Figure 14: Comparison of WA of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with lime alone as Stabilizers.

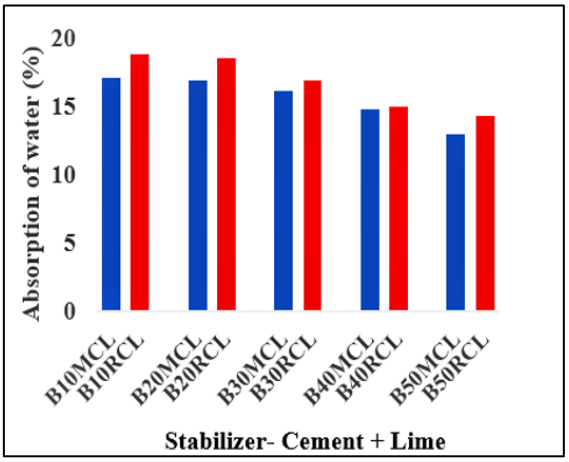

Figure 15: Comparison of WA of SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with combination of Cement + lime as Stabilizers.

The Fig 13, 14, 15 represents the comparison of water absorption (WA) SSA block of BCS partially replaced by M-Sand or Red Soil in varying proportions with different Stabilizers such as cement, lime and combination of cement + lime. From, these fig. we can observe that the WA of blocks made by lime alone as stabilizer shows higher rate of water absorption followed by combination of cement + lime and cement alone as stabilizer. As the percentage of replacement of M-Sand and Red Soil increases the rate of WA decreases. Comparing WA of SSA of BCS replaced by M-Sand with replacement of Red Soil is

nearly same with combination of cement and lime as stabilizers. Whereas with cement alone and lime alone as stabilizers BCS with Red Soil shows higher rate of WA compared to BCS with M-Sand for all percentage of replacement of M-Sand and Red Soil, by an average of 15%.

7. CONCLUSION:

1. From the following study, it is found that by using Red Soil as an alternative to M-Sand in the preparation of SSA blocks with BCS are economical and the strength is marginally higher up to 30% replacement which is hence recommended. However, with 40% and 50% replacement of M-Sand or Red Soil with BCS shows marginal reduction in strength.
2. However, the SSA blocks of BCS with partial replacement of M-Sand or Red Soil with combination of cement + lime as stabilizer shows same strength for all percentage of replacement.
3. SSA blocks of BCS partially replaced with M-Sand or Red Soil yields higher strength for all percentage of replacement with lime alone as stabilizer compared to cement alone and combination of cement + lime as stabilizer.
4. The rate of WA is higher in BCS with Red Soil compared to BCS with M-Sand with cement alone and lime alone as a stabilizer, however with cement + lime as stabilizer is marginally higher. But the rate of WA of these SSA blocks are with in permissible limit of 20% as per IS 3495:1992(Part II).
5. Hence BCS partially replaced with Red Soil which is called as hybrid soil with cement + lime as stabilizer is been recommended for SSA blocks of BCS.

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