
Experimental Study of Industrial Waste in CSCE Block

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Abstract

In recent years innovations in technology and increasing demand of materials in construction industry have led to the exploitation of natural resources. Also due to rapid industrialization a huge amount of waste is generated which creates several problem on environment, the safe disposal and reuse of such waste is a major concerned. In this study, the effective and optimum use of such waste to replace natural sand is studied. On the other hand day by day increase in temperature to climate change increases the operational cost of a building to overcome such situation natural soil can be use as an ideal construction material, which has potential to reduce carbon footprint. In this study locally available non swelling soil is selected for investigation. Cement stabilised compressed earth (CSCE) blocks are prepared at varying percentage of demolishing waste (DW) to replace natural sand and Fly Ash (FA) to improve strength property of block. The optimum percentage of DW with soil is investigated. Optimum combination obtained further studied for effect of FA. The cube compressive strength and secant modulus is varying with fly ash content and curing period, there is negligible deviation in dry density mostly within 10% of FA. Due to pozzolonic effect cube compressive strength increases with increase of FA up to 10%. Further increase in fly ash reduces density of material and ultimately strength of CSCE blocks.

Keywords

Cement Stabilized Compressed Earth Block; Non Swelling Soil; Fly Ash; Cube Compressive Strength; Initial Tangent Modulus

Introduction

In recent year, rapid urbanisation and infrastructural development all over the world which required energy in their manufacturing and transportation process. The construction material like cement, steel etc. requires huge amount of energy and produce high level of greenhouse gas. Especially the modern infrastructures are energy intensive and produce massive carbon dioxide [20]. To fulfil the day by demand of construction industry, large amount of material like sand and aggregate are required, cause exploitation of natural resources results to scarcity of building materials. Therefore the replacement of such courser material by the material which can be waste product of different industries such as granulated blast furnace slag, mine tailings, demolishing waste etc is required. Recycling and reuse is the another important key concerned for sustainable development. As it is well known, Thermal power plants produces ample quantity of fly ash which is in suspended form due to its low density, in atmosphere causing irreversible environmental harm. Construction industry is the biggest industry which utilises fly ash as a replacement of cement by supplementary cementing material has to be utilized in construction industry.

The country like India soil is available abundantly which can be utilised as construction material due to its number of benefits. Rammed earth is the ancient and most widely used construction technology in human history, and more popularly used in all over the world for hundreds to thousands of years [15,14]. The raw material required for the construction is locally available which save the cost of transportation of raw material. Rammed earth construction technique is used for wall and other building units like blocks, bricks, paver blocks etc. Rammed-earth constructions are simple to construct, non combustible, thermally massive, strong, and durable. The technique is based on, compressing the processed soil to achieve required density of block. The soil may stabilised or un-stabilised is compacted in progressive layers in formwork or in mould. Soil used for the construction should well graded loamy soil with optimum clay content leading to maximum strength is in the range of 14–16% [4]. Red soil is often preferable for such construction due to its strength, non swelling characteristics and good appetence. In this earth is stabilised with small amount of lime or cement with the aim of improving their mechanical resistance and durability [14,15]. The compressed soils are energy efficient and the embodied energy of buildings using these technologies is less than half of the energy consumed by conventional buildings [4,5]. The present study is aimed at understanding the influence of granular material on strength properties of cement stabilized earth blocks also the effect of fly ash on the soil-cement block characteristics.

Materials and Methods

Soil

A locally available non swelling red soil is collected from site, after performing the wet sieve analysis sand content is found to be 15% .The most important is clay content, optimum clay content leading to maximum strength is in the range of 14–16%; [7] which is observed as 13%., The other physical properties of the soils are determined according to Indian Soil Classification System (IS: 1498, 1970). Specific gravity of soil 2.25, Liquid limit and plasticity index for the soil are 34 and 5.7%, respectively, soil is designated as ML as per IS classification system is preferable. The soil is found to be non swelling and posses low plasticity property. Maximum dry density of the soil is obtained to be 16.8kN /m³ from Standard Proctor test, the strength gaining parameter is dry density of soil referring to the study by B.V. Venkatarama Reddy dry density should be within the range of 17 to 18 kN /m³.

Demolishing Waste

Brick and mortar were collected from construction site at Nagpur. It is crushed by rammer and the fraction passing through 10 mm and retained on 75 micron IS sieve, is considered as replacement of natural sand was used as a secondary material added to the base soils in the investigation. The courser particles are within the range of medium to fine size and well graded in nature. The specific gravity the material is 2.4.

Fly Ash

In the present study fly ash is collected in dry state from Koradi thermal power plant, Koradi, Nagpur, India. An ordinary Portland cement of 43 grade was used as a binding material. This type of cement should confirm according to IS: 8112-1989. Minimum compressive strength requirements for the blocks readily achieved using soils, stabilized with 5–10% cement,[3] Optimum strength both wet and dry is reached when for 8 % cement [5].Therefore optimized the 8 % cement of base material as a stabilizer for all soil mixes.[3].Specific gravity of FA is 2.0.

Experimental Programme

Reconstituted Soil

As there is a lack of granular material in the original soil, and pertaining to efficient utilization of materials and resources, natural sand is replaced by recycled demolished building wastes, which have different percentage of sand silt and clay. The prepared soil mix has been designated as M1, M2, M3, M4 and M5 (Table 1).

Rammed soil cement blocks stabilised with cement are manufactured by using above soil mix. As it is well known fact that dry density blocks greatly affects the strength of the block therefore dry density is kept constant and the range of it is 17 to 18kN/m³. The size of is blocks decided as 100 X 100 X 100 mm for the investigation. Static compaction method of block making is become more efficient than dynamic compaction by means of falling weight impact on material [16,17]. But in this study dynamic Compaction method is used to get uniform compaction and ultimately the density of soil, processed soil is placed in three uniform layers and compacted as per IS 4332 Part.

The soil mixes are first mixed uniformly with cement in dry condition and optimum moisture content is added in soil. The prepared blocks are removed from mould are shown in figure 1.The blocks are further cured for 7 and 28 days in wet burlap.

Sr. No.	Mix designation	Quantity Mix in % (With 8 % Cement)		OMC (%)	Dry density (kN/m ³)
		Silt + Clay	Dem. Waste		
1	M1	60	40	17.24	17.5
2	M2	55	45	17.1	17.72
3	M3	50	50	16.89	17.9
4	M4	45	55	16.65	18.01
5	M5	40	60	16.50	18.22



Table 1: Proportions of Soil Mixes and their Properties

Figure 1: Prepared Rammed Earth Blocks

Test on Blocks and Reconstituted Soil

Various properties of soil cement blocks and wet cube compressive strength is determined after 7 and 28 days. The cured samples are immersed in potable water for 48 hrs and surface dry before testing as per IS code (1992). The blocks were placed in between two wooden plates, and tested in unconfined compression tester; the failure pattern of the block is shown in Figure 1.

The wet cube compressive strength of blocks and its stress strain behaviour is observed, the similar failure pattern of the maximum blocks are observed as shown in Figure 2 after 28 days of curing.

The best results obtained from the above mixes are considered for further investigation, M4 and M5 mix are found satisfactory with respect to its density and strength. Thermal power plants generate solid wastes in bulk quantities, which are another pozzolanic material and used as a supplementary cementing material in soil-cement mixture. FA is added in 5, 10, 15, and 20% by weight in M4 and M5 soil mixes and the cement percentage is curtailed to 1% of a total weight of mix to enhance their strength and to minimise the cost of stabiliser.

Result and Discussion

The wet cube compressive strength and stress strain behaviour is of blocks is shown in Figure 3. For specimen cured for 28 days showed higher compressive strength than 7 days cured specimen with similar behaviour in stress strain relationship and failure pattern is observed after 7 and 28 days curing. In case of block with 60% soil for M1 group wet compressive strength is 2.06 MPa and it is 3.7 MPa with 40 % soil in M5 group. As there is an increase in soil content, the strength is reduced, and maximum strength is achieved at higher coarse material like sand. It is also observed that the density of blocks increases with an increase in granular content and ultimately the strength of earth blocks. But after a certain percentage increase in coarse material, the cohesion is reduced, which makes the material heterogeneous, resulting in a reduction in the strength of blocks.



Figure 2: Setup for Compressive Strength Test

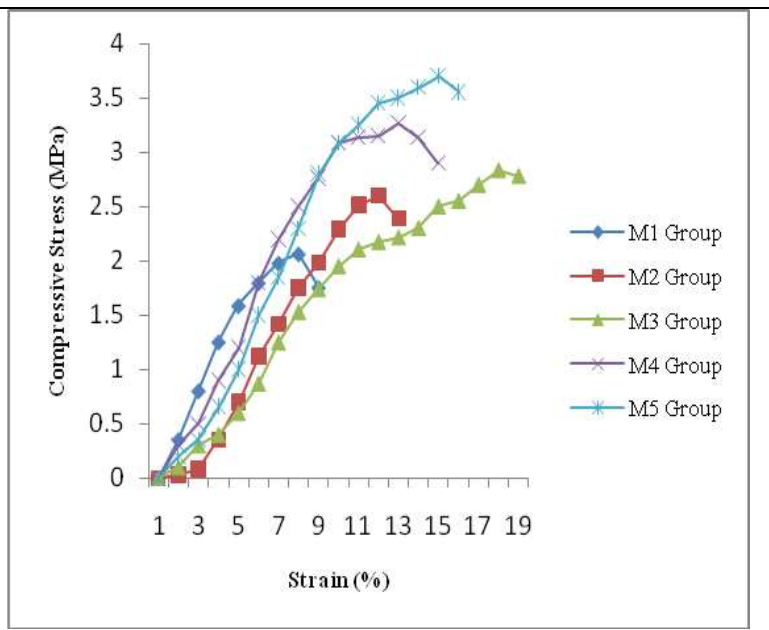


Figure 3: Stress Strain Curve for Different CSCE Blocks

Wet compressive strength of modified soil cement blocks with addition of fly ash content is obtained after 28 days curing, stress strain curve of both M4 and M5 mixes shows similar behaviour as shown in Figure 4 and 5. Load bearing capacity of soil cement blocks increases with an increase in FA content due to its pozzolonic effect, reaches a peak value at 15 % of FA for 45% soil and 55 % DW and drops further at 20% FA. The same trend was observed in M5 group also peak value is attained at 10% FA for 40% soil and 60% FA and drop sharply at 15 % FA as shown in figure 5.

In case of 8% cement blocks the wet compressive strength varies from 2.06 MPa for 60 % soil to 3.7 MPa for 40% soil. At 7 % cement and 10% FA the strength is found to be 4.35 MPa for 40 soils in this combination wet strength is increased by nearly 18%. Further increase in FA reduces the density of blocks which results in a reduction in strength. Same trend is observed in M4 group for 55% DW and 45 % soil in this at 8 % cement wet strength is 3.26 MPa where as at 7 % cement and 15% FA it is found to be 4.13 MPa which is 27 % more than 8% cement.

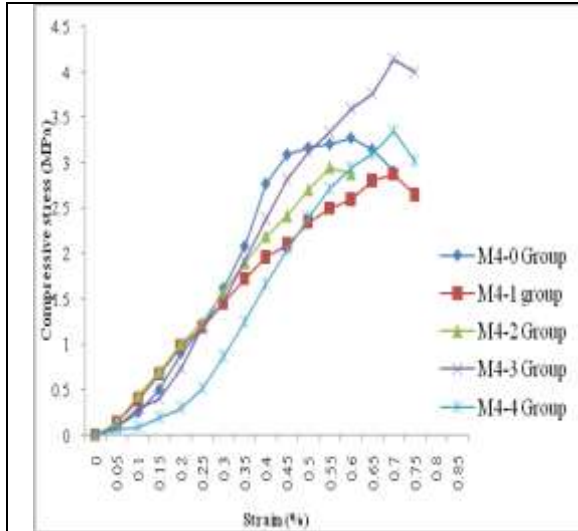


Figure 4: Stress Strain Curve for M4 Group CSCE Blocks

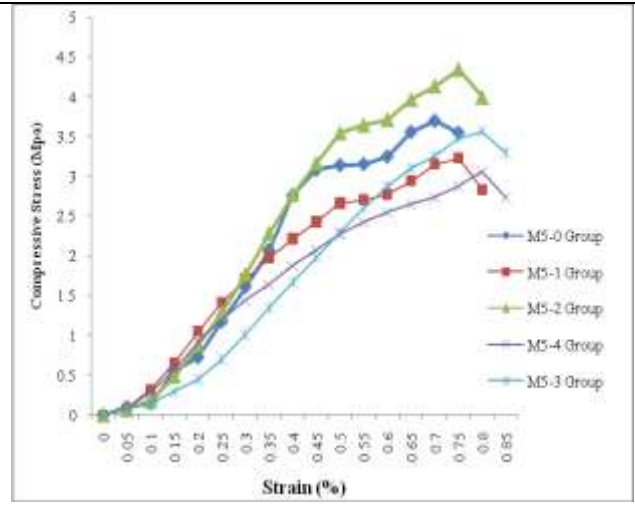


Figure 5: Stress Strain Curve for M5 Group CSCE Blocks

Wet compressive strength of modified soil cement blocks with M5 group is more in all percentage of FA as compared to M4 group; around 20 to 22% more strength is observed 60 % DW and 40% soil. In M5 sample maximum strength is found at 10% FA where as in M4 group it is observed at 15 % of FA as shown in figure 6. In FA adhesion capacity is more as compared to soil so addition of it starts to bind soil particle close to each other and hence decrement in the voids of blocks, and decrement in voids ultimately increases its load carrying capacity. In M4 group amount of soil is more and hence more fines which increases the specific area therefore optimum results are obtained at 15% FA; where as in M5 group soil content is less i.e.38 % of total mix, therefore the optimum results are obtained at 10% FA. The maximum strength in M5 group is 4.35MPa with 10% FA which is 21% more than M4 with 15 % FA.

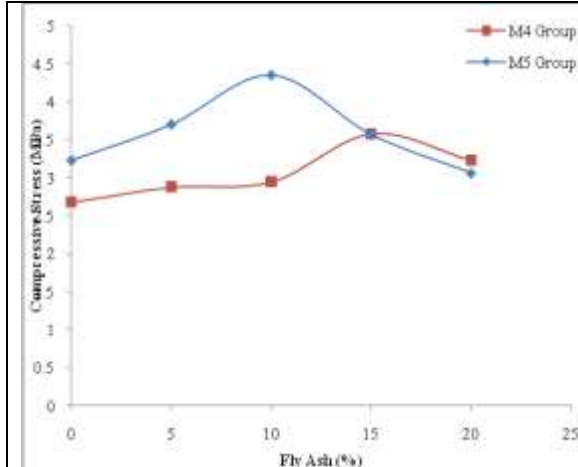


Figure 6: Effect of FA on Strength of Rammed Earth Block

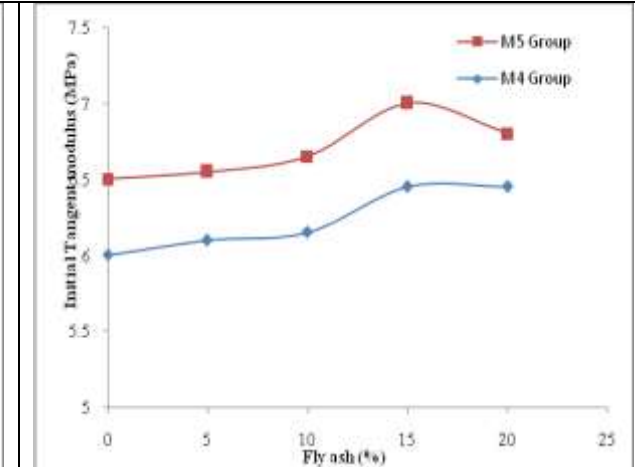


Figure 7: Correlation between Initial Tangent Modulus (Ei) and Wet Cube Compressive Strength

Initial Tangent Modulus

Initial tangent modulus (Ei) is an important parameter of the rammed earth material because it characterizes the stiffness of material. It is determined as the slope of the tangent line to the origin of the stress-strain curve. Higher compressive strength leads to the higher initial tangent modulus and ultimately the toughness of material and also increases post failure capacity of a material. It can be seen that the Ei values range from 4 to 8.5 MPa in wet condition also it depends on the curing period.

Figure 8 shows the relation between Initial tangent modulus (Ei) and wet cube compressive strength (sc) for all rammed earth material specimen. The correlation between Ei and compressive strength is well fitted by a linear relation and can be expressed as $E_i = 1.249 sc + 2.238$ and the coefficient of correlation R^2 is 0.86. The Ei of M5 group is more as compared to M4 group.

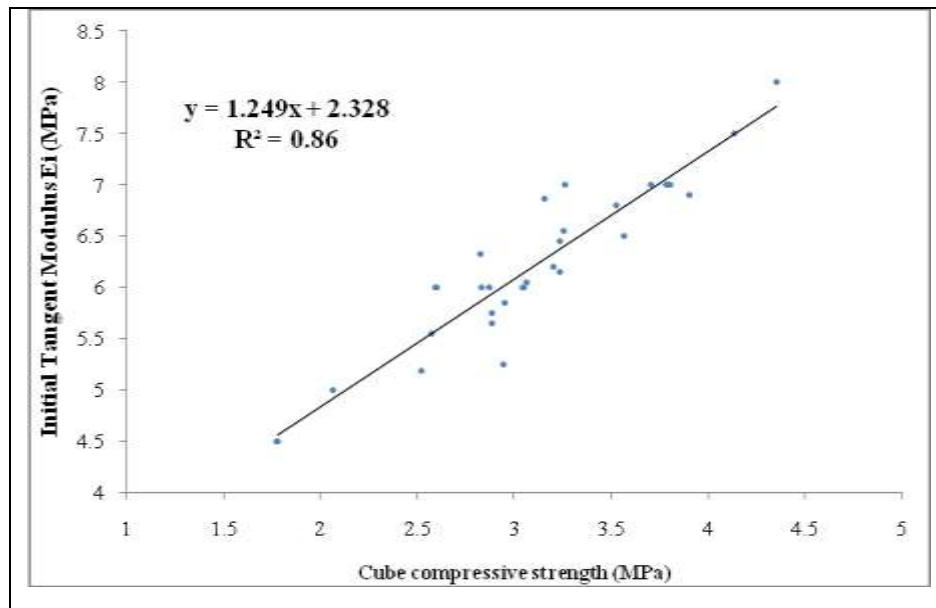


Figure 8: Relation between Initial Tangent Modulus (Ei) & Wet Compressive Strength (sc)

Conclusion

A laboratory experimental study was performed on compressed earth blocks consisting of local non swelling soil, Demolishing waste fly ash, and cement. From the study, the following conclusions are drawn.

- In the trail experimental studies wet strength is obtained just by taking the different percentage of local soil and demolishing waste stabilised with 8 % of cement of total weight of mix. The best results are obtained at 45 and 40 % of soil (M4 & M5 group). Further these groups are added with 5, 10 and 15 % of FA just curtail the cement by 1% as a partial replacement of cement.
- As addition of FA increases the density up to certain extent further increase of FA reduces the density of mix and it more heterogeneous and ultimately its strength. The addition of FA up to 10-15% may suggest using in the blocks for sustainable construction.
- Demolishing waste can be effectively used in such construction as a replacement of natural sand to restrict the mining of natural material. Also recycling and reuse of such material provides the ideal solution of waste management.
- On 7 days curing, the rammed earth material can attain the wet compressive strength up to 25%–52% higher than those uncured material whereas on 7 to 28 days of curing the rammed earth material can gain 51% – 73% of strength when blended with cement.
- The cube compressive strength values are in the range of 160 to 406 kPa for 7 days curing and 200 to 435 kPa for 28 days curing when blended with cement and FA.
- Higher compressive strength and stiffness is observed with increasing fly ash and DW and also with curing period and cement and the stress-strain curve changes from a ductile to a brittle behaviour.
- As non availability of red lateritic soil in central India, The surrounding soil can provide better solution for rammed earth construction, and can be used for load bearing structure. Earth material shows better thermal performance therefore suggested to use for low cost housing or in hot aired region which reduces the operational construction of building for entire life span of the structure.
- Use of local material reduces the cost of transportation, the manufacturing of construction material is energy intensive whereas unprocessed material save energy and also reduce carbon footprint.

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