
Experimental Studies of Flyash and Construction Waste based Stabilized Rammed Earth Block

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Abstract

Paper presents the study and check suitability of available local non swelling soil, as a rammed earth construction material. As per the previous study red lateritic soil deposits are considered to be the best material for rammed earth construction. Major deposit found in central India is black cotton soil which has high swelling and shrinking properly where as non availability of such lateritic soil. In this study the investigation of the local soil is used to develop rammed earth material and its suitability using industrial waste. Since rapid urbanization and innovations in technology generates huge amount of solid waste, which creates irreversible environmental harm. Construction Industry is one of the biggest industries which can reuse such waste as a construction material. Construction material like cement, steel, vitrified tile etc. required huge energy in their manufacturing also emits carbon. Soil and waste material from industries as a replacement of natural sand is used in study, which may require little financial investment. Nearly 50% reduction in embodied energy of buildings through use of low-energy consumption materials in conventional and alternative building systems.[4]

The properties of cement and lime stabilized and un-stabilized rammed earth blocks were studied in terms of their wet and dry density, wet cube compressive strength, water absorption property etc. To restrict the density of blocks, all the test samples were prepared by dynamic compaction method using steel rammer and mould. The blocks were prepared by using available non-swelling red soil as base material which is blend with fly ash, construction waste and optimised mix was stabilized with various percentages of cement and lime as 8 and 4%. The test results show that, increase in the strength of the rammed earth blocks up to 25 % percentage of fly ash of total mix. Further increase in fly ash may reduce the strength, as the material become more heterogeneous. It is also reported that percentage of stabiliser and curing period increases the strength of blocks.

Keywords

Non Swelling Soils, Rammed Earth Blocks, Wet Compressive Strength, Stabilized Blocks

Introduction

Every day innovations in technological progress leads in industrialized products and in their optimisation, huge amount of waste is generated; however to meet the demand of raw material in production of new materials results in extraction of natural resources. Sand is one of the natural resource which has been restricted to used in construction industry, so the suitability of such granular material which can replace sand may study. Fast growing industrialization generates waste that is not being used, which cause irreversible environmental harm. Construction industry is the biggest industry which use large amount of material and manpower. The material required in such industry ex. cement, iron, aluminium and tile manufacturing consumes large energy, also the transportation of such products from large distance cause carbon emission. Another problem in hot aired region, like India, day by day increasing in temperature increases the operational cost of building. Solutions in such problems which reduces the environmental degradation and at the same time raw construction material is need not to transport from large distance, local soil and waste generated from surrounding industry can utilised in construction. The reuse of waste material from various industries is the another major concern, Fly ash is the waste generated from thermal power plants which is low density material, suspended particles of it in air may causes pollution also due to inadequate space their disposal cause hazardous effect over the surrounding atmosphere. Such material has a pozzolonic property which can be used as a replacement of cement. As per the ancient history earth constructions proves more energy efficient and thermally massive material than all other construction materials. Efforts are taken to develop sustainable material and construction technique which provides rational use of natural resources and can be used for low cost load bearing structure.

Red earth with non expansive nature is often preferable for such construction due to its smooth finish and strength. This technique consists of well graded soil mixed with more granular particle. To develop good bond around 14–16% clay content [3] is considered to be optimum clay content. These constructions are mainly classified as stabilized and un-stabilised; Great Wall of China is the example of un-stabilised rammed earth. When earth is blended with small amount of stabiliser, lime or cement are most commonly used in practice to improving their mechanical property and its weathering characteristics[10]. The well graded soils are mix in dry condition with small amount of cement or lime, to achieve maximum dry density, optimum moisture content obtained from standard proctor test is added. The processed soil is compacted by static or dynamic method in layers inside a formwork by restricting the constant density of material. The construction such houses is rapidly

gaining popularity around the world, especially among the people seeking environmentally sustainable building alternatives.

Materials and Methods

As per the previous study red lateritic soil deposits are considered to be the best material for rammed earth construction. In central India non availability of such soils, efforts have been made to developed material and technique, locally available non-swelling red soil is obtained from Bhandara district, does not shows swelling and shrinkage behavior with seasonal changes. The various test are performed on soil, the specific gravity is found to be 2.4. Particle size plays an important role in such construction, the wet sieve analysis is done, soil found to be well graded as shown in figure 1 where clay finer contents less than 75 micron is found to be 52% . Plasticity test are performed as per [8], where liquid limit and plasticity index is found as 40% and 5.15% respectively. According to Indian Soil Classification System (IS: 1498, 1970) soil classified as silt and clay with low compressibility and is designated as ML as per IS classification. The maximum dry density of soil is calculated as 18.7 kN/m³ at optimum moisture content of 13.5 %.

Red brick dust used for project work is obtained from construction site. Specific gravity of brick dust obtained as per [8] Mortar is composed of sand and cement and is normally considered as Non-hazardous waste. Specific gravity of mortar waste obtained as per IS: 2720 (PART-3)-1964. [9]

In the present study fly ash is collected from Koradi thermal power plant, Koradi, Nagpur, India. An ordinary Portland cement of 43 grades was used as a binding material. This type of cement should confirm according to IS: 8112-1989. Lime used for the study was obtained from shop. In the study lime was used as per technical guidance of Bureau of Indian Standard (IS: 712, 1984). [10] Hydrated Lime is the chemical calcium hydroxide (Ca (OH)₂). Potable water is used to mix these materials.

Experimental Program

Sample Preparation

To improve strength properties, cement and lime is used as stabilizer. The fly ash, construction waste, cement was mixed with the soil in dry state and make homogeneous mix. Potable water was added slowly in mix and the mixing was carried out by trowel. The mix is matured for some time, then compound mix was placed in mould in three layers, each layer is compacted by giving blows of hammer shown in figure.

Production of Test Samples

Five different groups of soil based rammed earth materials in terms of fly ash and construction waste content (i.e., 0, 10, 15, 20, and 25% fly ash and 0, 20, 30, 40 and 50 % Dem waste) were undertaken as shown in table No.1. The percentage of fly ash is restrict to 25% from previous study, as increase in fly ash reduces the density of mix and ultimately the strength of blocks, the strength is mostly influence by dry density of soil referring to the study by B.V. Venkatarama Reddy, strength increases with increasing value of dry density, it should be within the range of 17 to 18 kN /m³.

First the dry soil mixing was done and mixes are prepared with optimum moisture content. First the unconfined compressive strength test is performed for pilot study, and the optimum combinations are further tested with stabilizer for cube compressive test. The cubes of size 10 X 10 X 10 cm are taken for consideration, the inner surface of the cube mould was oiled and the processed soil was compacted in three separate layers. According to (Bahar et al. 2004), the study shows dynamic compaction give better mechanical stabilization as compared with a static or vibro-static compaction. To achieve uniform compaction, dynamic method was adopted with a rammer weight of 2.6 kg with height of fall 300 mm and the mould is prepared with in accordance with IS 4332 Part 5 (Indian Standard 2006-b) and equipment for block-making rammed as shown in Figure 2.

Sr. No.	Sample	Red soil (%)	Fly ash (%)	Construction waste (%)
1	GA-5	100	0	50
2	GB-5	100	10	50
3	GC-5	100	15	50
4	GD-5	100	20	50
5	GE-5	100	25	50

Table 1: Mix Proportion

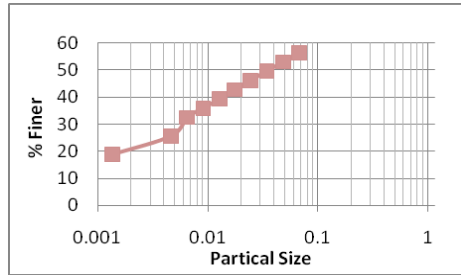


Fig 1: Grain-Size Distribution Curve for Soil

While preparing the cubes restricts the density of blocks to achieve uniform density of blocks. The prepared cubes are cured for 7 and 28 days in wet burlap. Before testing the samples were immersed in water for 48 hrs. and surface dry as per IS code (1992).The blocks were placed in between two metal plates, and tested in unconfined compression tester as shown in Figure 3.



Fig 2: Model of Soil Compaction

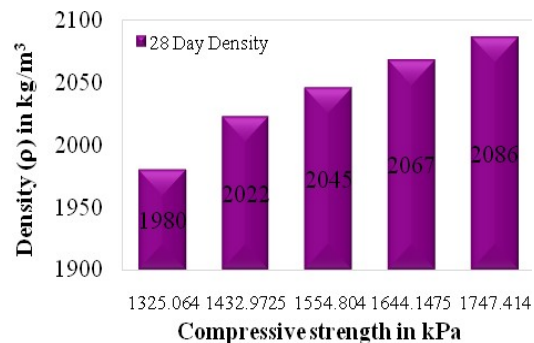
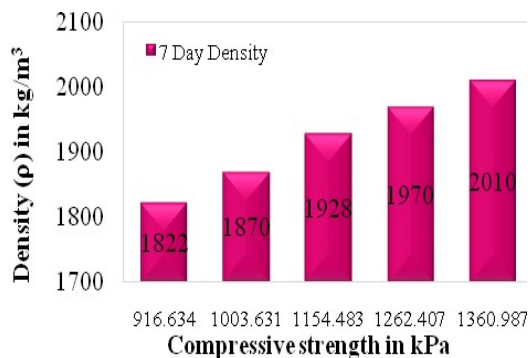


Fig 3: Setup for Compression Strength Test

Results and Discussion

Density

The density of the material block was calculated. The cubical test specimens are prepared as per the proportions given in the table 1. The wet weight and moisture content of all the blocks are taken before testing and dry density of samples are determined. The density of the rammed earth blocks is increases with increase in construction waste due to increase in weight of waste. Due to the addition fly ash and cement, particles come closer and increase the binding effect results in increase density of mix. The curing period is an another important factor which increases the compressive strength of rammed earth blocks, it is also noticed that strength increases with curing period, strength after 28 days is achieved maximum for all combination. The density of the rammed earth blocks prepared by blending with lime is in the range of 18.64 to 21.09 kN /m² and 18.26 to 20.86 kN /m³ when blended with cement for 7 and 28 days.



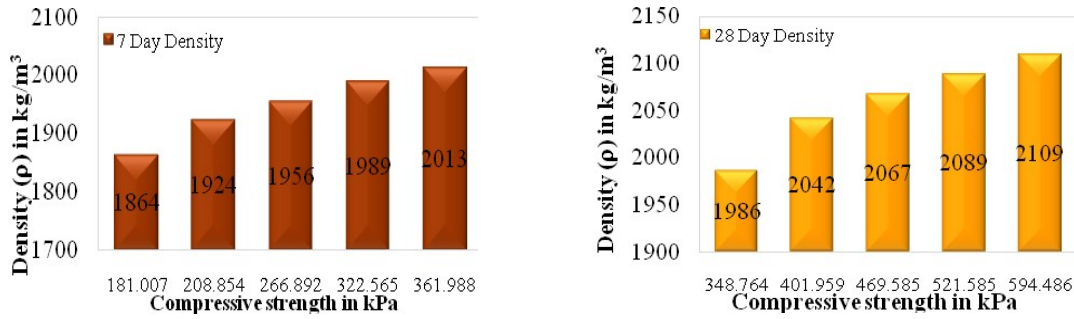


Fig 4: Dry Density and Compressive Strength Relation for All Groups Blended With (A) Cement (B) Lime

Unconfined Compressive Strength

The unconfined compressive strength behaviour of the proposed rammed earth material with stabilizer cement and lime is obtained for all groups (i.e. GA-5, GB-5, GC-5, GD-5 and GE-5) after 7 and 28 days of testing is shown in the following figure 3. The unconfined compressive strength for each sample tested after 28 days curing, is found higher than the sample tested after 7 days curing for all mix combinations. The strength of cement stabilized material is much higher than that of lime stabilized material. The UCS values are in the range of 916.634 kN/m² to 1360.987 kN/m² for 7 days’ testing and 1325.064 kN/m² to 1747.414 kN/m² for 28 days’ testing when blended with cement. Whereas for lime stabilized material the range is 181.007 kN/m² to 361.988kN/m² for 7 days’ testing and 348.764 kN/m² to 594.486 kN/m² for 28 days’ testing.

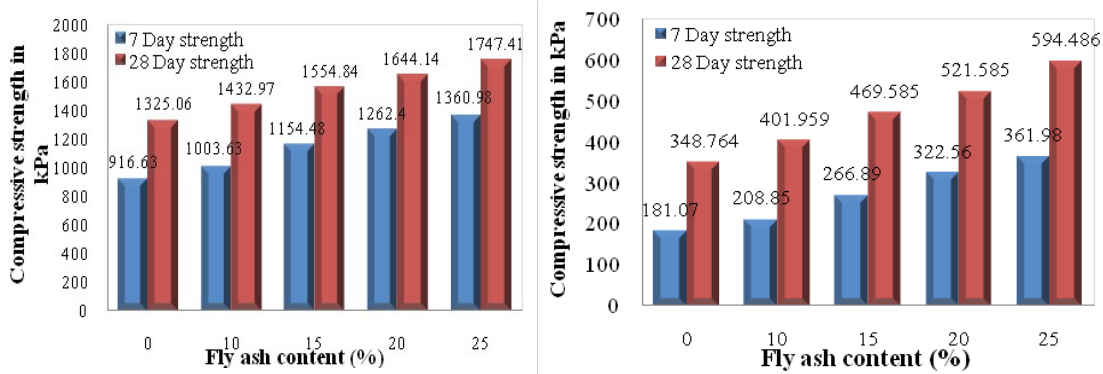


Fig 5: Unconfined Compressive Strength Behaviour of All Groups (A) Blended With Cement (B) Blended With Lime

Initial Tangent Modulus (Ei)

The initial tangent modulus values of the rammed earth material are found to be increase with increase in the percent of fly ash and construction waste for all the mix combinations as shown in figure 6. The well fitted linear relation is observed between Ei and compressive strength where equation between them is expressed as, $E_i = 2.9979\sigma_c - 89.717$. The strength and stiffness shows higher value with increasing fly ash and construction waste and also with curing period and binder content. From stress-strain curve it is observed that failure pattern changes from ductile to a brittle behaviour. Stiffness of rammed earth blocks increases with its strength. The initial tangent modulus (Ei) of the rammed earth material is in the range of 70 to 600 kN/m².

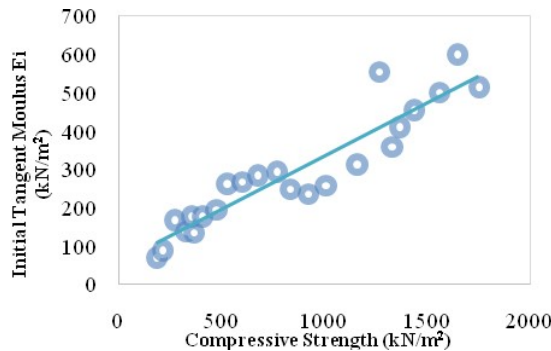


Fig 6: Correlation Between (Ei) and (σc) for All Specimens of Rammed Earth Material

Secant Modulus (E_{50})

E_{50} values of the rammed earth material are found to be increase with increase in the percent of fly ash and construction waste for all the mix combinations. The Secant modulus of the rammed earth material increased from 7 and 28 days of curing. Correlation between secant modulus and strength can be fitted with a power function and coefficient of correlation R^2 is a shown in Figure 7. Secant modulus (E_{50}) of rammed earth material increases with increase in strength and it ranges from 68 to 600 kN/m^2 which is not much less than tangent modulus. As the difference between initial tangent modulus (E_i) and Secant modulus (E_{50}) is less it indicates that the proposed rammed earth material is stiff enough as a building material.

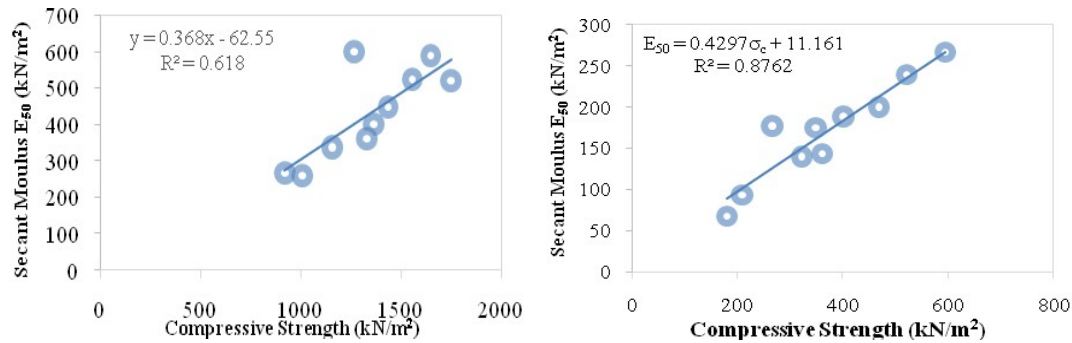


Fig 7: Correlation between Secant Modulus (E_{50}) and Compressive Strength (σ_c) for Cement and Lime

Conclusion

From the above study results the following conclusions are made:

1. The density of the CSEBs prepared is in the range of 18.6 to 21.1 kN/m^3 and 18.3 to 20.8 kN/m^3 when blended with cement and lime for 7 and 28 days.
2. The best results are obtained at 50% Construction waste and 25% Fly Ash with 8% cement and 4% lime by weight. Also it is observed that with the addition of 8% to 10% cement there is very marginal increased in strength value, so 8% of cement is suggested to use as a rammed earth material.
3. Higher unconfined compressive strength and stiffness is observed with increasing Fly ash content and the stress-strain curve changes from a ductile to a brittle behaviour. The nature of stress-strain curves is found to be similar for both 7 and 28 days of testing. The stiffness of CSEBs increases with strength.
4. Without utilization of stabilizer, the strength of CSEB obtained is very less or negligible. So, mixing of stabilizer with non-swelling red soil, fly ash and construction waste in CSEB is must.
5. The compressive strength of rammed earth brick is also observed that the strength is much better as compare to red brick, so used as a construction material.
6. The CSEBs prepared using lime and cement in proportions has clearly brought out the effectiveness of lime with cement in improving the long-term build-up of strength better than using cement alone.
7. The above material is suggested to the best alternative for load bearing wall or construction with rammed earth blocks for low cost and houses, local material is used for construction reduces embodied energy.
8. In hot aired region such material are observed to be thermally massive, reduces operational cost of building throughout its lifespan, also in such construction there is large potential for utilization of industrial and construction waste to be used as construction material for promoting sustainable construction.

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