CEMENT STABILIZED RED EARTH AS BUILDING BLOCK AND STRUCTURAL PAVEMENT LAYER

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ABSTRACT

Red Earth is most commonly used as material in the building and road construction. Many a times, the red earth found in various quarries is found not suitable for construction. Cement of 4 and 8% of dry mass of red earth was added to improve its suitability as building block and structural pavement material. To know the influence of waste plastic fiber on cement stabilized red earth, 1% fiber was also added to the mixture. It is shown that the compressive strength of cement stabilized red earth blocks was improved with seven days of curing. The addition of cement to red earth enhanced soaked CBR value. The soaked CBR value of fiber reinforced cement stabilized red earth was about 1.3 to 1.5 times that of unreinforced cement stabilized red earth.

*Keywords***:** red earth, cement, stabilized earth

REZUMAT

Pământul roşu (*Red Earth*) este utilizat în general în construcţia drumurilor şi clădirilor. De multe ori, pământul roşu din diferite cariere nu este adecvat pentru construcţii. S-a adăugat ciment în procent de 4 şi 8% din masa uscată pentru a îmbunătăţi calităţile pământului roşu în utilizarea ca blocuri pentru construcţii sau ca material pentru pavaje. Pentru a determina influenţa fibrei din deşeuri de plastic asupra pământului roşu stabilizat cu ciment, s-a adăugat de asemenea un procent de 1% fibre. Se arată că rezistenţa la compresiune a blocurilor de pământ roşu stabilizate cu ciment s-a îmbunătăţit după şapte zile de tratare. Adăugarea de ciment în pământul roşu a crescut valoarea indicelui CBR în stare umedă. Pentru pământul roşu stabilizat cu ciment armat cu fibre, valoarea CBR a fost de 1.3 până la 1.5 ori mai mare decât cea pentru pământul roşu stabilizat cu ciment nearmat.

Cuvinte-cheie: pământ roşu, ciment, pământ stabilizat

1. INTRODUCTION

Red Earth also called *Murrum* / *Moorum* is formed in the tropics through the weathering process that favors the formation of iron, aluminum, manganese and titanium oxides. Iron and aluminum oxides are prominent in Red Earth, and with the seasonal fluctuation of the water table, these oxides result in the reddish-brown color. Red Earth was found in the southern parts of India where this soft, moist soil was cut into blocks of brick size and then dried in the sun. The blocks became irreversibly hard by drying and were used as building bricks. Red Earths are widely distributed throughout the world in the regions with high rainfall, but especially in the inter-tropical regions of Africa, Australia, India, South-East Asia and South America, where they generally occur just below the surface of grasslands or forest clearings [1]. Red Earth is a low grade marginal material for road construction and has generally low bearing capacity and high water absorption value in comparison to conventional aggregates [2]. Red Earth possesses all bad qualities of black cotton soil such as water absorption, softening, high plastic nature, expansiveness and easy compressibility [3, 4].

Cement and lime treatment has become an accepted method for increasing the strength and durability of soils. Cement could be effectively used to stabilise Red Earth. Several researchers have reported that cement stabilized red earths can be used in road and building construction [4-9]. Engineering properties such as compressive strength and CBR were markedly improved. It could be concluded that formation of reaction product such as Calcium Silicate Hydrate (C-S-H) contributed to strength development of the cement stabilized earth [10]. Moorum admixed with 3% ordinary Portland cement (OPC) is preferable on account of being comparable to conventional Wet Mix Macadam (WMM) in terms of California Bearing Ratio (CBR) value, relating its permeability and affording maximum cost savings [2]. The suitability and lime stabilisation requirement of some selected lateritic soil samples as pavement construction materials have been studied by Amu et al. [11].

Earth or Mud is perhaps the only traditional material used by Man ever since he started building his shelter, for protection against natural vagaries of weather [12]. Stabilized earth is an alternative building material that is significantly cheaper than using conventional brick and concrete, and is also environmentally sustainable. Cement is the most common stabilizer [13]. Development of material and technology for low cost housing is the need of the hour. One such material in the recent times is the soil cement block [14]. cement stabilized block is of better quality in terms of compressive strength, water absorption and durability than those stabilized with lime [15]. It is now clear that if one wants to build a two or more story building, stabilization of soil becomes essential to attain adequate compressive strength. Blocks of Grade 2.5 (wet compressive strength 2.5-3.0 MPa) may be used for non load-bearing walls in framed buildings and in single story structures in rural areas [13]. A block with 7.0 MPa strength can be comfortably recommended for four story load bearing masonry. As a rule, a minimum wet compressive strength of 3.0MPa is desirable for a two story house construction [16]. On the whole, this paper studied suitability and cement stabilization requirements of red earth as a building block and pavement construction material. Red Earth was stabilized with 4 and 8% of cement. Further, in the present investigation 1.0 % of waste plastic fiber was added to soil-cement mixes to know the effect of waste plastic fiber on the soil-cement mixes.

2. MATERIALS USED

2.1. Soil (Red Earth)

The soil used in this investigation was collected from a borrow pit at a depth of 0.5 m to 1.0 m from Gollenapalli Quarry (Fig. 1) which was about 30 km to Vijayawada, Andhra Pradesh, India. The area was largely covered by red soils. The collected soil was a reddish brown soil with inclusions of white mottles and it was completely disintegrated into sandy granules from rocks existing at the site. People call it as *Murrum* or gravelly soil. They constitute mixture of weathered rock pieces in varying sizes, sand, silt and clays. The property of the soil was evaluated according to the ASTM standards and results were presented in Table 1. Liquid limit, plastic limit, and plasticity index of the soil were evaluated as per ASTM D4318-10 [17]. The soil was classified as SM as per Unified Soil Classification System [18].

Fig. 1. Gollenapalli Gravel Quarry largely covered by Red Earth

Table 1. Properties of Soil

Property	Value
Gravel (%)	27.00
Coarse sand (%)	19.50
Medium Sand (%)	33.82
Fine Sand (%)	5.942
Fines (Silt+ Clay) (%)	13.70
Liquid Limit (%)	34.30
Plastic Limit (%)	NP
US Classification of Soil	SM
Differential Free Swell Index	10
Maximum Dry Density (g/cc)	2.015
Optimum Moisture Content (%)	10.39
Soaked CBR Value (%)	7.00

2.2. Cement

Cement used in the current study was commercially available Ordinary Portland Cement of 53 grade.

2.3. Waste Plastic strips

The waste plastic strips used in the present study were chopped from discarded packaging plastic threads. The length of the strips was about 6-12 mm and the diameter was of 3 mm. Plastic strips used in the present study are shown in Figure 2.

Fig. 2. Plastic strips used in the present study

3. TESTS CONDUCTED

The Modified Proctor Compaction tests were conducted on soil (Red Earth) with and without adding cement of 4% and 8% of dry mass of soil. Compaction tests were also conducted on 1.0% of waste plastic fiber reinforced soil-cement mixes. Cement treated soil blocks, cured for seven days, were tested to evaluate compressive strength. One sample was made for conducting each test. Soaked CBR tests were conducted on soil and soil added with 4 and 8% cement. Soaked CBR tests were also conducted on 1.0% of waste plastic fiber reinforced soil-cement mixes. Splitting Tensile Strength tests were conducted on Soil+8%cement mix with and without addition of 1% fiber.

4. RESULTS AND DISCUSSIONS

4.1. Compaction Characteristics Tests

Compaction tests were conducted on Red Earth and Red Earth mixed with 4 and 8% cement respectively. Compaction tests were conducted according to the procedure laid in ASTM D1557-12 [19]. Compaction curves are shown in Figure 3. Compaction characteristics, namely Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) were observed from compaction curves and were presented in Table 2.

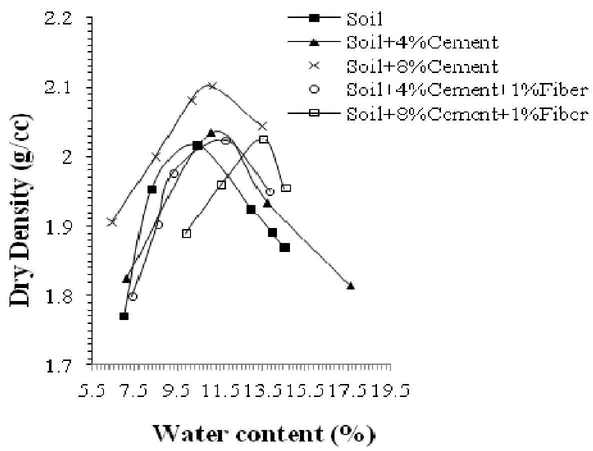

Fig. 3. Compaction curves for Soil, Soil-Cement mixes and fiber reinforced Soil-Cement mixes

The addition of cement to red earth led to increase in the MDD and OMC. The increase of the MDD may be attributed to more densely packing. Another explanation could be that since cement with a specific gravity of 3.15 was added to the red earth of specific gravity of 2.58, a resulting mixture with a higher specific gravity emerged, which in turn gave rise to an increase of the MDD of the entire mixture. The increase of the OMC with the increase of the quantity of cement could possibly be due to the increase of the surface needing to be coated as the quantity of cement increases, which makes the mix require more water for the hydration of cement.

Table 2: Compaction Characteristics

Mix	Maximum Dry Density (MDD), g/cc	Optimum Moisture Content (OMC), %
Soil+0% Cement	2.015	10.39
Soil + 4% Cement	2.035	11.07
Soil + 8% Cement	2.102	11.10
Soil+4% Cement+1% Fiber	2.024	11.71
Soil+8% Cement+1% Fiber	2.022	13.52

Compaction tests were also conducted on cement stabilized soils reinforced with 1% fiber. The addition of 1% fiber reduced MDD and increases OMC of soil-cement mixes.

4.2. Compressive Strength Tests

The soil samples were sieved through the 20 mm sieve and mixed with cement 4% and 8%, respectively, using OMC previously determined. The mixture was placed into the block mould of size 150 mm × 150 mm × 150 mm and compacted with 62 blows, with 3 layers each, to ensure the desired MDD. One sample was made for conducting each test. The stabilized red earth blocks were placed in moist gunny bags for curing (Fig. 4). The curing time considered was of seven days. After seven days of curing, the blocks were tested in the universal testing machine (Fig. 5), to evaluate compressive strength. Compressive Strength values of cement treated red earth cured for seven days are presented in Table 3 and plotted in Figure 6.

Curing enhances the strength of cement stabilized soil due to pozzolanic reaction, resulting in formation of C-S-H gel. According to Indian Standard IS:1077 [20], the strength of First Class Bricks is 10.7 MPa, the strength of Second Class Bricks is 7 MPa and the Strength of Third Class Bricks is greater than or equal to 2 MPa.

The compressive strength of soil enhanced with 8% Cement and cured for seven days was 4.5 MPa. From this it was worth mentioning that 8% cement stabilized red earth, cured for seven days, can be used as structural building block for construction of two story building. Block made of soil added with 8% Cement cured for seven days has shown water absorption of 2.66% and it was less than allowable water absorption of 20% prescribed by Indian Standard IS:1077 [20]. Water absorption tests were conducted in accordance with the procedure specified by ASTM C67-02c [21].

Fig. 4. Curing of cement stabilized Soil Blocks

Fig. 5. Compressive strength test on cement stabilized Soil Blocks

Table 3. Compressive Strength values

Mix	Seven day Compressive Strength (MPa)
Soil	0.072
Soil + 4% Cement	3.2
Soil + 8% Cement	4.5

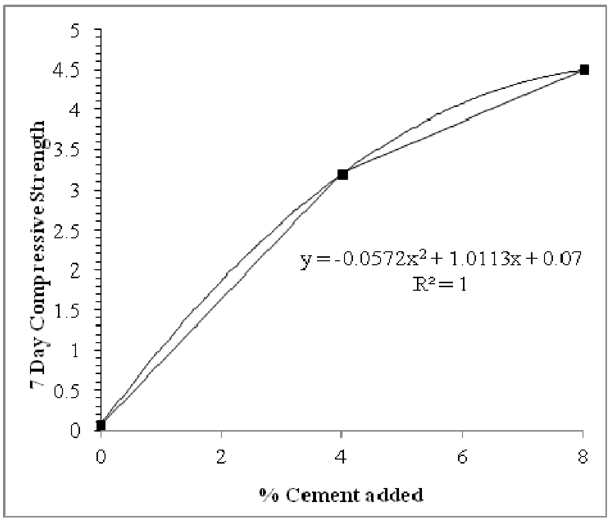

Fig. 6. Compressive strength of Red Earth with addition of Cement

A Regression Model was developed to assess the seven-day compressive strength (*f*) of cement stabilized red earth, in terms of %Cement (*C*) (Eq. 1).

$$f = -0.0572C^2 + 1.0113C + 0.07 \quad (1)$$

Coefficient of determination, $R^2 = 1$.

4.3. Soaked CBR Tests

Soaked CBR tests were conducted on Red Earth and Red Earth added with 4 and 8% cement. Soaked CBR values are presented in Table 4. CBR tests were conducted according to the procedure laid in ASTM D1883-07e2 [22]. Cement-modified soil mixes should be designed on the basis of their soaked CBR value. For design purposes, the CBR field should be regarded only as 45% to 60% of that obtained in the laboratory, depending upon the efficiency of mixing, placing, curing and other related factors [23]. The variation of soaked CBR value, with addition of cement, is shown in Figure 7.

A Regression Model was developed to estimate the soaked CBR value (CBR_S) of cement stabilized red earth in terms of %Cement (C) (Eq. 2).

$$CBR_S = 4.625C^2 - 4.25C + 7 \quad (2)$$

Coefficient of determination, $R^2 = 1$.

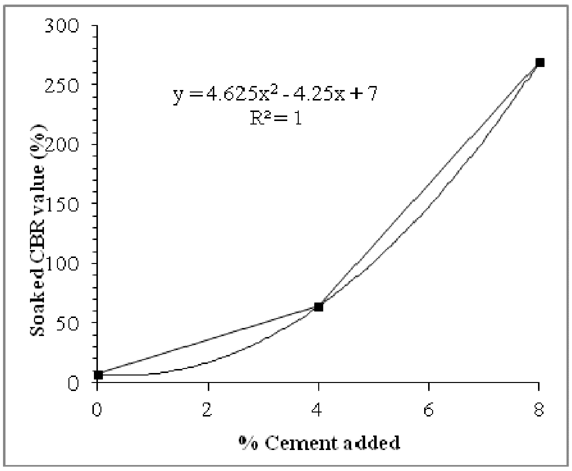

Fig. 7. Soaked CBR value of Red Earth with addition of Cement

In order to study the effect of waste plastic fiber on soil-cement mixes, 1% of waste plastic fiber was added to red earth-cement mixes. The addition of 1% waste plastic fiber strips to soil + 4% cement mix resulted in a soaked CBR value of 127%. The addition of 1% waste plastic fiber strips to soil + 8% cement mix gave a soaked CBR value of 344%. It was observed that the high degree of enhancement in the soaked CBR value was achieved with addition of waste plastic fiber. The soaked CBR value of fiber reinforced cement stabilized soils was about 1.3 to 1.5 times that of unreinforced cement stabilized soils. From this, it can be concluded that the 1% fiber reinforced cement stabilized red earth can be used as structural pavement layers such as sub-base and base. cement stabilized red earth is a more economical material as compared to graded aggregates for construction of sub-base and base of low volume rural roads.

4.4. Splitting Tensile Strength Tests

The tensile strength of materials determined by tests other than the straight pull test is designated as the “indirect” tensile strength [24]. The splitting tensile strength tests were conducted by using Universal Testing Machine (UTM), as shown in Figure 8. The Splitting Tensile Strength values for Soil + 8% cement with and without addition of 1% fiber were 48 kPa and 75 kPa, respectively. With the addition of 1% fiber, the tensile strength of the 8% cement stabilized red earth was enhanced with about 46%, due to the "bridge" effect of fiber reinforcement (Fig. 9).

Fig. 8. Splitting Tensile Strength test

Fig. 9. The 'bridge' effect of fiber reinforcement

5. CONCLUSIONS

The following conclusions were drawn based on the present study:

1. Blocks made of Red earth mixed with 8% Cement cured for seven days can be used as building blocks for two story structures. The block made of Red Earth added with 8% Cement has shown water absorption of 2.66%.
2. The soaked CBR strength of Red earth increased from 7% to 64% with the addition of 4% cement and to 269% with the addition of 8% cement. Thus, the stabilized Red earth can be promoted not only from subgrade to subbase, but also to base course in pavements.
3. The soaked CBR value of 1% fiber reinforced cement stabilized soils was about 1.3 to 1.5 times that of unreinforced cement stabilized soils. The addition of waste plastic fiber phenomenally increases CBR value.
4. With the addition of 1% fiber, the tensile strength of the 8% cement stabilized red earth was enhanced about 46% due to 'bridge' effect of fiber reinforcement.

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REFERENCES

1. Lemounga, P.N., Chinje Melo, U.F., Kamseu, E. and Tchamba, A.B., Laterite Based Stabilized Products for Sustainable Building Applications in Tropical Countries: Review and Prospects for the Case of Cameroon, Sustainability, 3, 2011, pp. 293-305.
2. Ransinchung, G.D., Kumar, P., Kumar, B., Anupam, A.K., Chauhan, A.K., Laboratory Evaluation for the use of Moorum and Ganaga Sand in the Wet Mix Macadam unbound base course, Indian Highways, The Indian Roads Congress, April, 2014, pp. 39-45.
3. Bhavanna Rao, Use of Red Earth in the name of Gravel in Poor Conditions of Roads, Proc. of National Conference on Corrective Engineering Practices in Troublesome Soils (CONCEPTS), JNTU College of Engineering, Kakinada, India, 2006, pp. 27–29.
4. Ramana Murthy, V. and Ramesh, V., Admixture Stabilisation of Murrum Soils and Development of a CBR Chart, Proc. of Indian Geotechnical Conference-2006, Chennai, India, 2006, pp. 721-724.

5. Agbede, I.O. and Joel, M., Use of Cement-Sand Admixture in Laterite Brick Production for Low Cost Housing, Leonardo Electronic Journal of Practices and Technologies, 12, 2008, pp. 163-174.
6. Aguwa, J.I., Study of Compressive Strengths of Laterite-Cement Mixes as a Building Material, AU J.T., 13(2), 2009, pp. 114-120.
7. Eze-Uzomaka, Johnson, O. and Agbo, D., Suitability of Quarry Dust as Improvement to cement stabilized -Laterite for Road Bases, Electronic Journal of Geotechnical Engineering, 15(Bund. K), 2010, pp. 1053-1066.
8. Prasad, A.C.S.V and Reddy, C.N.V.S, The Potential of cement stabilized Gravelly Soils as Construction Material, Proc. of Indian Geotechnical Conference-2011, Kochi, India, 2011, pp. 493-496.
9. Okeke, O.C. and Ekere, J.T., Effects of Variation of Sand and Laterite Mixtures on the Compressive Strength of cement stabilized Laterite Bricks, Journal of Applied Science and the Environment, 3, 2012, pp 49-53.
10. Jaritngam, S., Prachasaree, W., Yandell, W.O., and Taneerananon, P., Microstructure and Strength Characteristics of Lateritic Soil-Cement, Electronic Journal of Geotechnical Engineering, 13(Bund. B), 2012, pp. 2393-2403.
11. Amu, O.O., Bamisaye, O.F. and Komolafe, I.A., The Suitability and Lime Stabilisation Requirement of Some Selected Lateritic Soil Samples as Pavement Construction Materials, International Journal of Pure and Applied Sciences and Technology, 2(1), 2011, pp. 29-46.
12. Laurie Baker, Mud, Center of Science and Technologies for Rural Development (COSTFORD) Publishing, Trichur, India, 1993.
13. Jagadish, K.S., Building with Stabilized Mud, I.K. International Publishing House Pvt. Ltd., New Delhi, India, 2007.
14. Krishnaiah, S. and Suryanarayana Reddy, P., Effect of Clay on Soil Cement Blocks, The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), Goa, India, 2008, pp. 4362-4368.
15. Raheem, A.A., Bello, O.A. and Makinde, O.A., A Comparative Study of Cement and Lime Stabilized Lateritic Interlocking Blocks, The Pacific Journal of Science and Technology, 11(2), 2010, pp. 27-34.
16. Jagadish, K.S., Reddy, B.V.V. and Rao, K.S.N., Alternative Building Materials and Technologies, New Age International Publishers, New Delhi, India, 2007.
17. ASTM D4318-10, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM, 2010.
18. ASTM D2487-10, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM, 2010.
19. ASTM D1557-12, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort, ASTM, 2012.
20. IS:1077, Indian Standard Common Burnt Clay Building Bricks- Specification, Bureau of Indian Standards, New Delhi, India, 1992.
21. ASTM C67–02c, Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile, ASTM, 2002.
22. ASTM D1883-07e2, Standard Test Methods for CBR (California Bearing Ratio) of Laboratory Compacted Soils, ASTM, 2007.
23. IRC:50, Recommended Design Criteria for the Use of Cement-modified Soil in Road Construction, The Indian Roads Congress, New Delhi, India, 1973.
24. ASTM C496M-11, Standard Test method for Splitting Tensile Strength of Cylindrical Concrete Specimens, ASTM, 2011.