Indian Journal of Science and Technology, *Vol 9(2), DOI: 10.17485/ijst/2016/v9i2/86368, January 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Utilization of Hypo Sludge for the Stabilization of Red Soils along with Cement and Molasses

K. Mahendran and N. P. Vignesh*

Rural Technology Centre, Gandhigram Rural Institute, Dindigul - 624302, Tamil Nadu, India;
mahendran_gri@rediffmail.com, np.vignesh@gmail.com

Abstract

Background/Objectives: The present study investigates the use of hypo sludge with cement and molasses for the preparation of stabilized red mud blocks. **Methods/Statistical Analysis**: The Laboratory test results show that the physical and the mechanical properties of the red soil were assessed. The unconfined compressive strength, modulus of rupture, Ultrasonic Pulse Velocity (UPV) and water absorption tests were performed for this soil with and without hypo sludge, cement and molasses. **Findings:** It has been identified that 15% of Hypo Sludge with Cement and Molasses as additives provides optimum stabilization to the soil and it is proven with the help of unconfined compression test. **Applications/ Improvements:** The results show that the hypo sludge can be effectively used in red soil for the preparation of mud blocks.

Keywords: Cement Stabilization, Hypo Sludge, Molasses Stabilization, Paper Waste Ash, Red Soil, Ultrasonic Pulse Velocity (UPV)

1. Introduction

In India about 300 million tons of industrial wastes are being produced per year due to chemical and agricultural process. These materials create disposal, health hazards and also aesthetic problems to the environment. Around 300 kg of sludge is produced form each tone of recycled paper. This large volume of sludge produced makes the landfill uneconomical[1]. The world contributes about 7% of greenhouse gas emission to the atmosphere through cement industry. In order to create awareness on environmental effects associated with cement manufacturing and constantly using natural resources, there is a need to develop alternative binders to make concrete industry sustainable. Further waste paper sludge has very high calorific value and could be used as partial replacement for cement[2].

The Preliminary investigations on WSA have revealed that it is a pozzolanic material and its heavy metals content is below the limits stipulated by the World Health Organization (WHO), the United Nations Environmental Programme (UNEP) and the US Environmental Protection Agency (USEPA) for land applications of recycled materials[3]. WPSA classified as Class-C fly ash because WPSA rich in calcium which possesses cementitous and pozzolanic properties that results in the self-cementing characteristics. The clay soil which has been stabilized using WPSA can be considered effective to enhance clay soil strength for long periods. Also the addition of 10% WPSA shows better result on the compressive strength of the clay soil in 28 days and this strength had further been increased beyond 28 days with increase in CBR value about 1.5 times compared to control sample for un-soaked condition and 3.6 times compared to control sample for soaked condition[4]. With reference to the above study it is decided to use Hypo Sludge as a stabilizer along with cement and Molasses to enhance the stabilization property of red soil. It may be suitable to use Hypo Sludge as a binder from which a new alternative cost effective building material will be explored.

*Author for correspondence

2. Materials and Methods

2.1 Red Soil

Red soil is the main material used in this study and the sample shown in Figure 1 was collected from Athoor block of Dindigul District, Tamilnadu, India at an approximate depth of 2 m from ground level. The sample was collected in large quantity and the sample was in red color. The soil was covered as to maintain its moisture contents till it tested in the laboratory. Physical and chemical properties were found out. The physical properties were found based on IS codal provisions. The results were tabulated in Table 1 and the chemical properties were found with the help of Energy Dispersive X-ray Analysis (EDAX) Table 2.

2.2 Hypo Sludge (Paper Waste)

Hypo Sludge is also called as Paper waste shown in Figure 2 which is produced from pulp and paper industries and belongs to the group of organic wastes. They fall into two general classes with regard to their physical state, viz. suspended and dissolved. Most effluent pollution difficulties arise from this waste result in the discharge of fairly coarse suspended matter composed largely of fibre and other organic debris. The specific gravity of the collected paper waste is 2.39 and its chemical composition was given in the Table 3.

Figure 1. Collected sample of red soil.

Table 1. Physical properties of red soil

Properties	Value
Depth (m)	02.00
Specific Gravity, (G.S)	02.41
Liquid Limit, LL (%)	51.84
Plastic Limit, PL (%)	33.33
Plasticity Index, PI (%)	18.51
Shrinkage Ratio (%)	18.93
Optimum Moisture Content, OMC (%)	11.75

Table 2. Chemical composition of red soil

Chemicals	Percentage Existing
Ca	0.14
Mg	0.07
S	0.07
Fe	0.94
Al	0.11
Cu	0.06
Zi	0.05
Si	8.20

Figure 2. Sample of Hypo Sludge (paper waste) in pan.

Table 3. Chemical composition of Hypo Sludge (paper waste)

Chemicals	Percentage Existing
Ca	55.72
O	28.92
C	10.24
Si	02.76
Mg	00.88
Al	00.77
S	00.71

2.3 Cement

Ordinary Portland cement of grade 53 having specific gravity of 3.2 was used as Additives along with the Hypo Sludge. Since cement is a pozzolanic material, it had been mixed with the soil to enhance the process of stabilization.

2.4 Molasses

Molasses is a viscous by product of refined sugarcane or sugar beet in the process of extracting sugar shown in Figure 3. Molasses is the most valuable by-product from the Sugar Industry[5]. The molasses referred to in this article is blackstrap molasses, which is the molasses from the production of raw sugar from sugar cane[6]. The elemental composition of molasses is given in the Table 4.

2.5 Water

Portable water is used for the soil preparation of mud blocks. The pH of water should be between 6 and 8 and it is also free from organic matter which satisfies I.S.3025 (pt. 18).

3. Sample Preparation and Testing

3.1 Properties of Soil

To find out the properties of soil and the effective use of stabilizer, various laboratory test where carried out and its Atturberg limits were found. In the present work the soil is improved by adding industrial wastes in different percentage. The effect of addition of industrial wastes on the strength behavior of the soil is studied by varying percentage of industrial waste by weight of sample[7].

Figure 3. Sample of molasses in a container.

Table 4. Chemical compositions of molasses

Chemicals	Percentage Existing
C	50.34
Ca	13.00
K	05.80
Na	02.40
Mg	04.00
Fe	05.62
Z	10.09
Cu	06.00
Si	02.75

3.2 Casting of Stabilized Mud Blocks

The soil samples were prepared as two sets of six different mix proportions by varying the percentage of hypo sludge along with 5% of cement and molasses as constant. The mix proportions are designated and are given in the Table 5 and the casted mud blocks are shown in Figure 4.

It is to determine the optimum percentage of hypo sludge is required with cement and molasses for the manufacture of stabilized mud blocks. Initially, soil samples were thoroughly mixed with hypo-sludge at dry state.

Table 5. Designation of soil at different mix proportions

	SNo.	Designation of Mix	Soil (%)	Hypo Sludge (%)	Cement (%)
Hypo Sludge with Cement (HSC)	1	M1	100	0	0
	2	M2	95	0	5
	3	M3	90	5	5
	4	M4	85	10	5
	5	M5	80	15	5
	6	M6	75	20	5
	SNo.	Designation of Mix	Soil (%)	Hypo Sludge (%)	Molasses (%)
Hypo Sludge with Molasses (HSM)	1	M7	95	0	5
	2	M8	90	5	5
	3	M9	85	10	5
	4	M10	80	15	5
	5	M11	75	20	5
	6	M12	95	5	0

Figure 4. Casted mud blocks.

Then it was again mixed with water at optimum content, cement and molasses. The mixing should be thorough and formations of lumps have to be avoided so as to prevent the blocks from the formation of voids during cast. AURAM as one of the manual pressing equipment to cast stabilized mud blocks. Casting of blocks was carried out through compression of mud. The author was used for casting of mud blocks which can cast two blocks at a time. The required proportion is mixed and the mud is loaded in the mould and was pressed to stabilized mud blocks. The size of the bricks casted is 230 mm length, 230 mm width, 90 mm thick.

3.3 Unconfined Compressive Strength Test

It is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test. It has been done based on IS 2720 (Part 10): 1991 Indian Standard. This is a quick and simple testing to determine the compressive strength. The sample specimens were prepared at its maximum dry density and optimum moisture content. The specimen for the test shall have a minimum diameter of 38 mm and the height to diameter ratio shall be within 2 and 2.5 as per IS Codal provision. The Measurements of height and diameter shall be made with Vernier calipers or any other suitable measuring device to the nearest 0.1 mm[8].

3.4 Compression Strength Test

The blocks are prepared and cured for 28 days by covering it with a polythene sheet and water was sprinkled to maintain the humidity. The blocks were then taken and dried about one hour before testing. The blocks made with HSC and HSM mix proportions were tested at 7th, 14th, 21st and 28th day of curing. The blocks were tested in Compression Testing machine. The test was conducted and the following are the average compressive strength obtained on the testing which is shown in the Figure 6a and 6b.

3.5 Ultrasonic Pulse Velocity Test (UPV)

This test was done based on IS 13311 (Part 1): 1992. The Ultrasonic Pulse Velocity is one of the widely used common non-destructive testing techniques in research and construction industry. The pulse or stress wave velocity in a material is related to Young's modulus of elasticity, density and Poisson's ratio[9].The ultrasonic pulse is generated by an electro acoustical transducer which is less than 20 kHz. When the pulse is induced on an object from a transducer, a complex system of stress waves is developed which includes longitudinal (compression), shear (transverse) and surface (Rayleigh) waves. The quality of object will be assessed based on the velocities of waves obtained. Higher the velocity the object is good in homogeneity and uniformity, lower the velocity there may be presence of cracks, voids or flaws inside the object which make the path length longer[10].

3.6 Modulus of Rupture (Flexural Strength)

This test was conducted based on IS 4332 (Part VI): 1972. Flexural strength also known as Modulus of rupture is the limit at which a material can withstand flexural stress. When an object is subjected to flexural stress, it undergoes both tension and compression because of bending moment. Flexural strength of a material will depend on either its tensile strength or compressive strength, whichever is lesser. This standard covers the procedure for determining the flexural strength of soil cement by the use of a simple beam with third point loading[11].

3.7 Water Absorption Test

The blocks were tested in accordance with the procedure laid down in IS: 3495 (Part II) 1976, after immersion in cold water for 24 hours, as per the code the average water absorption shall not be more than 15% by its weight[12].

4. Results and Discussion

4.1 Unconfined Compressive Strength

From the laboratory test of Unconfined Compression Strength (UCS) for soil stabilized with various percentages of Hypo Sludge with Cement (HSC) and Hypo Sludge with Molasses (HSM), the optimum percentage of stabilizer for both HSC and HSM were obtained. The test results are plotted as graph and are shown in the Figure 5a and 5b. It shows that the UCS in both HSC and HSM increased with increase of stabilizer up to15%. It also shows that there is a decrease in the strength when the addition of stabilizer goes beyond 15%. From the results, it was found that the optimum percentage of Hypo Sludge with Cement and Molasses is about 15% to stabilize the soil at the maximum compressive strength were determined. Though the optimum percentage of stabilizer is same for both HSC and HSM, but there is a variation in strength attained. The strength attained by HSC is more than 20% compared to HSM. Previous study indicated

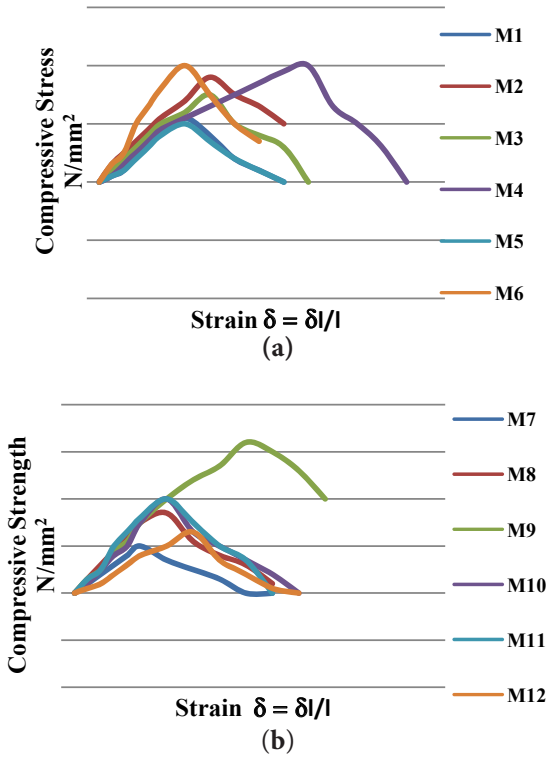

Figure 5. (**a**) Optimum percentage of Hypo Sludge and cement. (**b**) Optimum percentage of Hypo Sludge and molasses.

that addition of 10% of Waste Paper Sludge Ash (WPSA) improved the strength of clay soil[4], the particle size of WPSA and type soil may be the reason for the strength development at 10% of addition.

4.2 Compression Strength

After the experimental investigation for compression strength of the casted mud blocks, the effect of Hypo Sludge in addition to Cement and Molasses on stabilized mud blocks (HSC) and (HSM) at different proportions were plotted as graph and shown in Figure 6a and 6b. The results show that there is consecutive increase in compression strength up to 15% addition of stabilizer in both the Sets. The maximum strength attained in HSC after 28 days of curing is 15.01 MPa (M4) and the minimum strength attained is 6.1 MPa (M1).

Similarly the maximum strength attained in HSM is 8.05 MPa (M9) and least strength attained 5.7 MPa (M7). It is also noted that the addition of stabilizer beyond 15% leads to gradual decrease in compression strength. The decrease in compression strength due to increase in water absorption when, increase the Hypo Sludge beyond 15%.

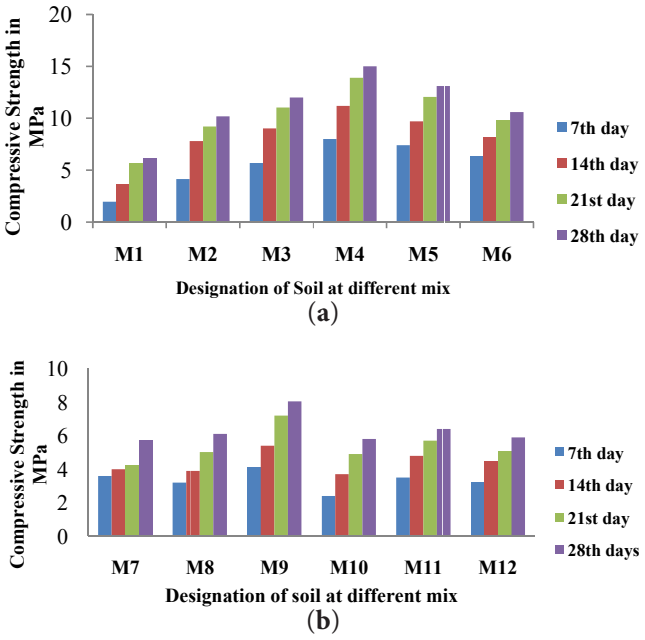

Figure 6. (**a**) Effect of HSC on compressive strength. **(b)** Effect of HSM on compressive strength.

4.3 Ultrasonic Pulse Velocity (UPV)

The stabilized mud blocks were subjected to one among many Non-Destructive testing methods called Ultrasonic Pulse Velocity (UPV) to evaluate the quality of mud blocks. The results were found and correlated with compressive strength of the mud blocks. It was observed that the compressive strength and the ultrasonic velocity were increased with the age of curing is shown in Figure 7a and 7b.

It was seen that the maximum pulse velocity reached in both HSC and HSM are almost same (i.e. 3700 m/s) at 15% addition of stabilizers. This shows that the stabilizers and additives are reactive to the soil which develops better bondage results in reduction of pores that are witnessed from Scanning Electron Microscope (SEM) shown in Figure 8a, 8b, 8c and 8d.

The SEM image shows Figure 8a that the presence of pores between the soil particles similarly the images Figure 8b and 8c shows that the reaction of Hypo Sludge with Cement and Molasses resulted in the reduction of pores. The image Figure 8d shows that the Hypo Sludge acts as a fibre which providing additional strength to the blocks.

4.4 Modulus of Rupture

Flexural strength, also known as modulus of rupture is important to value the Flexural strength of alternative

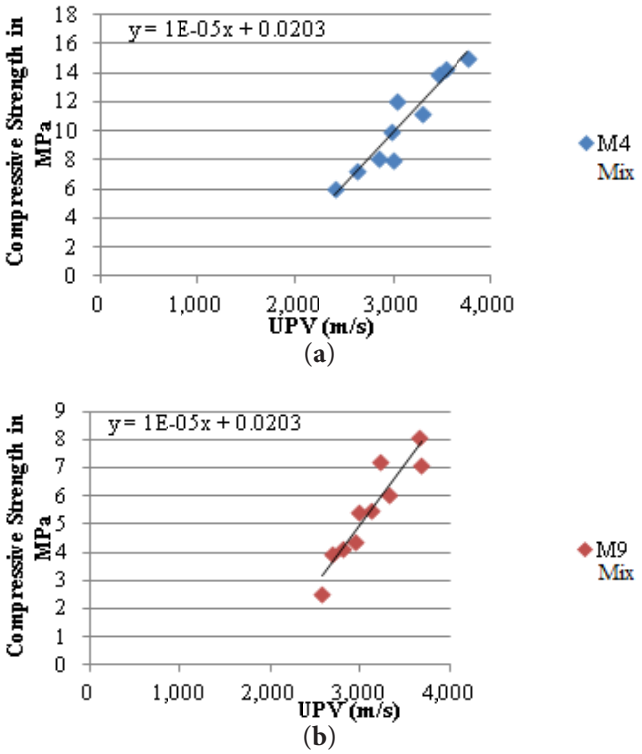

Figure 7. (**a**) UPV vs. compressive strength for HSC. (**b**) UPV vs. compressive strength for HSM.

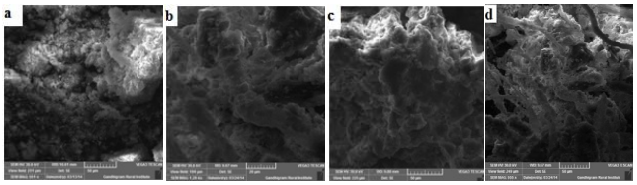

Figure 8. (**a**) Raw soil, (**b**) Soil stabilized with HSC, (**c**) Soil stabilized with HSM, (**d**) Fibre action of Hypo Sludge in soil.

building materials to determine its performance when subjected to lateral loads due to wind, floods or any other load that can cause out-of-plane bending[13]. Hence it is necessary to find the performance of the stabilized blocks during flexure.

As expected, the M4 of HSC blocks performed at maximum strength of 0.57 MPa. Likewise the M9 from HSM shows better result that it reached maximum value of 0.52 MPa. These results reveal that the Hypo Sludge with cement as additives have a dominant character than Hypo Sludge with Molasses. This may be due to presence of high Pozzolanic content in the mix shown in Figure 9a and 9b.

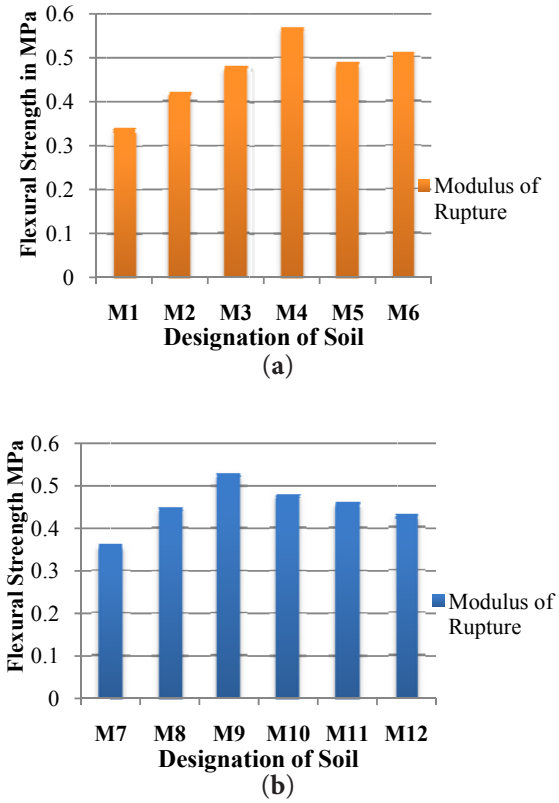

Figure 9. (**a**) Modulus of rupture for HSC. (**b**) Modulus of rupture for HSM.

4.5 Water Absorption

The water absorption test was done after 28 days of complete curing. The test results shown the maximum absorption of 21% which is attained by the block made of no stabilizer (M1). Also it can be observed that the maximum water absorption is attained by the block made of Hypo Sludge with cement as stabilizer, is 16.2% (M2) and the minimum absorption of 8.1% was attained by the block (M4). Similarly the maximum water absorption attained by block made of Hypo Sludge with Molasses as stabilizer is 11.7% (M7) and the minimum absorption seen in the block (M9) is 6.8% which are satisfying according to the IS recommendation compared to the test results are shown in the Figure 10a and 10b.

It could be noticed that the addition of stabilizer up to 15% reduces the water absorption in both Sets. Further increase in the stabilizer content increases the water absorption, because the presence of irregular pores and envelopes provides obstacle for moisture to move towards the surface[1]. While comparing the results of HSC and

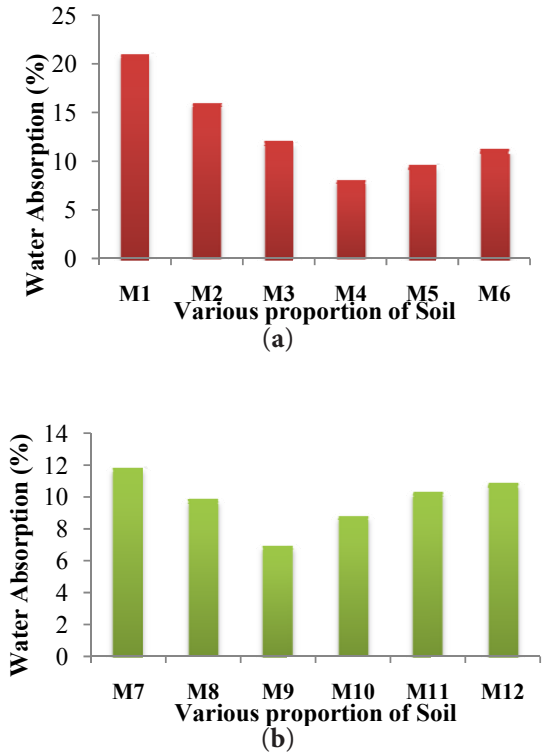

Figure 10. (**a**) Water absorption for HSC blocks. (**b**) Water absorption for HSM blocks.

HSM, HSM poses less water absorption. The addition of molasses may act as permeability reducing agent in HSM mud blocks[14].

5. Conclusion

It has been identified that 15% of Hypo Sludge with Cement and Molasses as additives provides optimum stabilization to the soil and it is proven with the help of unconfined compression test. The maximum strength reached by blocks at optimum percentage of Hypo Sludge with additives in both HSC and HSF; this may be due to better Pozzolanic reaction between soil and Hypo Sludge along with the additives. The age of curing and UPV proves that and also confirms from the micro structural study through SEM. The stabilized mud blocks validated for flexural strength and had resulted well. The durability study was done using water absorption test and found better results for the block made of HSM at optimum content of stabilizer but HSC attained satisfactory value at optimum percentage of stabilizer have been found. This Shows HSC blocks have dominant character than blocks made of HSM at optimum percentage except in water absorption which are satisfactory. The blocks made of HSM at optimum percentage of stabilizers provides satisfactory results only. Hence it was concluded that the Hypo Sludge with Cement and Molasses as additives at 15% as optimum can be effectively used in the red soils to prepare stabilize mud blocks.

6. Acknowledgement

Authors place on record the financial assistance received from UGC, New Delhi in the form of Major Research Project.

7. References

1. Balwaik SA, Raut SP. Utilization of waste paper pulp by partial replacement of cement in concrete. International Journal of Engineering Research and Applications. 2011; 1(2):300-9.
2. Ahmad S, Iqbal MM, Wani MB, Ahmad R. Study of concrete involving use of waste paper sludge ash as partial replacement of cement. International organization of Scientific Research. 2013; 3(11):06-15.
3. Bujulu PMS, Sorta AR, Priol G, Emdal AJ. Potential of wastepaper sludge ash to replace cement in deep stabilization of quick clay. Annual Conference of the Transportation Association of Canada Saskatoon; Saskatchewan. 2007. p. 1-16.
4. Khalid N, Mukri M, Kamarudin F, Arshad MF. Clay soil stabilized using Waste Paper Sludge Ash (WPSA) mixtures. Electronic Journal of Geo-Technical Engineering. 2012; 17:1215-25.
5. Jackson B, Jayanthy T. Determination of sucrose in raw sugarcane juice by microwave method. Indian Journal of Science and Technology. 2014; 7(5):566-70.
6. Shirsavkar SS, Koranne SS. Innovation in road construction using natural polymer. Electronic Journal of Geo-Technical Engineering. 2010; 15:1614-24.
7. Nigade YM, Warudkar AA. Improvement of index properties of soil using industrial waste (spent wash). International Journal for Science and Research in Technology. 2015; 1(6):25-30.
8. IS 2720 (Part 10). Determination of Unconfined Compressive Strength. Bureau of Indian Standards. New Delhi. 1991.
9. Dilek U. Ultrasonic pulse velocity in nondestructive evaluation of low quality and damaged concrete and masonry construction. Journal of Performance of Constructed Facilities. 2007; 21(5):337-44.

10. IS 13311 (Part 1). Non-Destructive Testing of Concrete - Methods of Test Part 1 Ultrasonic Pulse Velocity. Bureau of Indian Standards. New Delhi. 1992.
11. IS 4332 (Part VI). Methods of Test for Stabilized Soils. Part VI: Flexural Strength of Soil Cement Using Simple Beam with Third Point Loading. Bureau of Indian Standards. New Delhi. 1972.
12. IS: 3495 (Part II). Methods of Tests of Burnt Clay Building Bricks Part 2 Determination of Water Absorption. Bureau of Indian Standards. New Delhi. 1976.
13. Jayasinghe C, Mallawaarachchi RS. Flexural strength of compressed stabilized Earth masonry materials. Materials and Design. 2009; 30(9):3859-68.
14. Ali Bahobail M. The mud additives and their effect on thermal conductivity of adobe bricks. Journal of Engineering Sciences. 2012; 40(1):21-34.