Influence of lime and cement in strength characteristics of soil

Rinu Jose[1], N P Rajamane[2]

Abstract— *A structure to be strong, the soil beneath the structure plays a very critical role. The clayey soils are found to be the weakest soils which are susceptible to settlement. Such soils are to be stabilised. The present study deals with the comparison of stabilisation of clayey soils (CH and CL) with cement and lime. This study is focussed on the shear strength variation of lime and cement mixed clayey soils having high and low plasticity (CH and CL). The optimum lime content obtained in high plasticity clayey soil (CH) was found to be 4 % and that of low plasticity clayey soil (CL) was 2 %. Up to the optimum lime content the shear strength was increased and after that a slight decrease was found. The optimum cement content in CH and CL was found to be 4 %. The unconfined compressive strength was determined for all the prepared samples with lime and cement after a curing period of 7, 14, 21 and 28 days. From the UCC test results it was observed that the UCC value increases with the curing period and with the increase in the percentage of lime and cement added. The increase of unconfined compressive strength was due to the stabilisation effect of higher lime or cement concentration. The lime/cement – column technique has been applied successfully in recent years improve the physical and mechanical properties of soils. This technique would increase the soil bearing capacity and reduces sol settlement owing to improve soil strength and stiffness. This paper also presents the preliminary results of the small laboratory model test of lime – column technique on clay soil to investigate load – settlement characteristics in laboratory. The lime – column was designed as single column with 25 mm in diameter and the depth was 200 mm. The laboratory tests carried out was a small plate loading test. The results shows that before installation of lime – column, based on the load – settlement curve, the mode of failure was likely defined as general shear failure. The bearing capacity of the soil increases after the lime – column was installed. The bearing capacity of the soil again increases when the lime – column was tested after a curing period of 7, 14, and 21 days. Whole result indicated that lime – column technique is a valuable method to enhance soil bearing capacity and reduces soil settlement..*

Index Terms— Minimum Soil stabilisation, Lime, Cement, Compressive Strength, Shear strength.

1. INTRODUCTION

Soil is the basic foundation for any civil engineering structures. Most important problem encountered by the geotechnical engineers at construction site is that the properties of soil are unable to reach the required specification. This problem is normally faced by clayey soils which are susceptible to differential settlements and high compressibility. Such soils are needed to be stabilised.

Chemical stabilisation with binders can be undertaken rapidly and often at low cost, and therefore this stabilisation s becoming an important alternative. Chemical stabilisation of clayey soils involves blending a binder into the soil to increase its strength through chemical reactions. The binders are generally as dry solids. Common binders include cement, lime, fly ash, bituminous materials etc. Lime is an excellent choice for modification of soil properties. Lime stabilisation is one of the oldest forms of stabilisation. With proper design and construction techniques lime treatment chemically transforms unstable soil into usable material.

- *Rinu Jose is currently pursuing PhD program in Civil engineering in SRM University, India, PH-9447791451. E-mail: rinujs23@gmail.com*
- *N P Rajamane is the Head in CACR, SRM University, India.*

Many researches show that the improvements in engineering properties of a soil can be enhanced by lime which attributes to two basic reactions:

a) Immediate reduction in plasticity and changes in the workability and swell properties

b) The second phase is a time-dependent gain in strength through inter-particle cementation. There is pozzolanic reaction between the lime and reactive alumina or silica in the soil.

The two basic reactions above, (a) and (b), are referred to as soil modification and soil cementation respectively. These two processes are very important in soil stabilisation, since, for wet plastic soil, it is the modification that yields proper soil conditions; during compaction and mixing, it is the cementation which plays the major role in soil stabilisation.

Cement blends are effective stabilising binders applicable to a wide range of soils. Cement has two important effects on soil behaviour: It greatly reduces the moisture susceptibility of some soils, giving enhanced volume and strength stability under variable moisture conditions. It can cause the development of interparticle bonds in granular materials, endowing the stabilised material with tensile strength and high elastic modulus. Cements are produced from a mixture of calcium carbonate, aluminia, silica and iron oxide which, when calcined and sintered at high temperatures gives a new group of chemical compounds capable of reacting with water. The composition of individual cements can vary depending on the nature and composition of the raw materials being used.

Strength gain in soils using cement stabilization occurs through the same type of pozzolanic reactions found using lime stabilization. Both lime and cement contain the calcium required for the pozzolanic reactions to occur; however, the origin of the silica required for the pozzolanic reactions to occur differs. With lime stabilization silica is provided when the clay particle is broken down. With cement stabilization, the cement already contains the silica without needing to break down the clay mineral. Thus, unlike lime stabilization, cement stabilization is fairly independent of the soil properties; the only requirement is that the soil contains some water for the hydration process to begin.

2. MATERIALS AND METHODOLOGY

2.1 Material Used

1) Soil: Two types of soils are used in this study. First one is the soil collected from Thonnackal region, (naturally occurring kaolin clay) obtained through quarrying and the second is the processed kaolinite clay of white colour from English Indian Clay ltd. Table I shows the properties of Thonnackal clay and table II shows the properties of Kaolinite clay. As per the results of initial tests the Thonnackal clay was classified as CH and Kaolinite clay was classified as CL. Chart 1 shows the grain size distribution of Thonnackal clay.

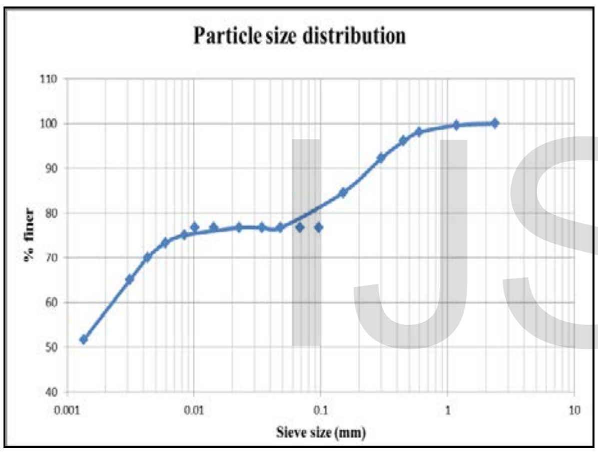

Chart 1: Grain size distribution curve of Thonnackal clay.

Table 1: Properties of Thonnackal Clay

Properties	Values
Natural water content (%)	22.5
Liquid limit (%)	56.5
Plastic limit (%)	28.89
Shrinkage limit (%)	27.8
Plasticity index (%)	27.11
Specific gravity	2.496
Optimum moisture content (%)	31.1
Maximum dry density (kN/m^3)	14.1
Unconfined compressive strength (kN/m^2)	103
Percentage sand (%)	21.5
Percentage silt (%)	20.5
Percentage clay (%)	58
Unified Soil Classification	CH

Table 2: Properties of Kaolinite Clay

Properties	Values
Liquid limit (%)	34..9
Plastic limit (%)	23.75
Shrinkage limit (%)	21.94
Plasticity index (%)	11.15
Specific gravity	2.6
Optimum moisture content (%)	30.2
Maximum dry density (kN/m^3)	14.2
Unconfined compressive strength (kN/m^2)	49.2
Percentage sand (%)	4.2
Percentage silt (%)	35.8
Percentage clay (%)	60
Unified Soil Classification	CL

2) Lime: The lime used for the study is locally available hydrated lime or slaked lime. It is calcium hydroxide Ca(OH)2 in the form of fine powder. Hydrated lime can be prepared by hydration process by adding water to quicklime as the equation below. The hydration process releases a significant amount of heat. It has lower available lime content than quicklime and so it is more suited to dry soils.

$$CaO + H_2O \longrightarrow Ca\,(OH)_2 + Heat$$

Figure 1: Lime

3) Cement: The cement used is RAMCO Pozzolanic Portland cement manufactured as per IS 1489 (Part 1) 1991. Portland cement is hydraulic cement made by heating a limestone and clay mixture in a kiln and pulverizing the resulting material. The same type of pozzolanic reaction is found in cement and lime stabilization. Both contain the calcium required for the pozzolanic reactions to occur.

2.2 Preparation of Samples

Control specimen involves Thonnackal clay (CH) and Kaolinite clay (CL). The lime and cement were added in varying percentages to CH and CL. Each sample was cured for curing period of 7, 14, 21 and 28 days. Curing was done by preparing

ISSN 2229-5518

unconfined compressive strength samples and the wrapping it neatly with aluminium foil and then placing the sample in air tight polythene bags and dipping in water for the specified period of curing. Figure 2 shows the wrapping and curing of specimen for unconfined compression test.

Figure 2: Wrapping and curing of specimen for unconfined compression test.

2.3Experimental Programme

1) Compaction tests: Compaction tests were carried out adopting the IS light compaction method as specified in IS 2720 (Part 7). Each soil sample was prepared by mixing of air dried soil and corresponding quantity of lime or cement. Then water was added and mixed again until the water spreads all over the soil. The dry and wet mixing of soil - lime/cement - water was carried out in a non – porous metal tray in order to avoid water loss. All the test samples were subjected to this test and respective Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) was determined. Determination of water content was carried out by the oven drying method.

2) Unconfined Compression Test: The conventional unconfined compression test was performed in accordance to IS 2720 (Part 10) 1973. The remoulded soil specimens with or without stabilizer were prepared in standard mould at constant optimum moisture content and maximum dry density. The cylindrical shaped specimens of 38 mm diameter and 76 mm length were used. The specimens were tested in unconfined compression machine. The samples were tested till the failure surface developed.

3) Load- settlement characteristics: The bearing capacity of soils and foundation settlement under different loads were estimated by load test in the laboratory. The model load test for the present study was conducted in a mould of 200 mm diameter and 200 mm depth. Clay was filled in the tank at constant water content. Care was taken to ensure that no significant air voids were left out in the test bed. Moist soil was placed in the tank and is compacted till the desired height is reached. Soil was gently levelled. Thin PVC pipe of 10 mm diameter were embedded in the clay bed. Required amount of lime to form the column was placed inside the pipe and the pipe was taken out. The column was then compacted using a tamper. Dial gauge were fixed. The first test was carried out on clay bed without any improvement technique and the load – settlement behaviour was investigated. Thereafter other tests were carried out on soft soil improved by lime column. The lime column was cured for a period of 1 day, 3days and 7 days for determining the improvement in the bearing capacity of the soil. The test set up for the load- settlement characteristic is shown in figure 3.

Figure 3: Test set up for Load – Settlement.

3. RESULTS AND DISCUSSION

Experimental investigations were carried out on the CH and CL soils with and without stabilisation. The results of the test are discussed here.

1) Compaction tests: The compaction characteristics of soil added with 2%, 4% and 6% of lime were determined. The dry density increases with decrease in moisture content. The values of maximum dry density and optimum moisture content for lime stabilised soil are given in table III. The compaction curves of lime stabilised soil are shown in Chart 2.

Table 3: Maximum dry density and Optimum moisture content of lime stabilised soil

Lime content (%)	Optimum moisture content(%)	Maximum dry density (g/cc)
Soil + 2% Lime	**28.897**	**1.37**
Soil + 4% Lime	**27.155**	**1.388**
Soil + 6% Lime	**24.23**	**1.413**

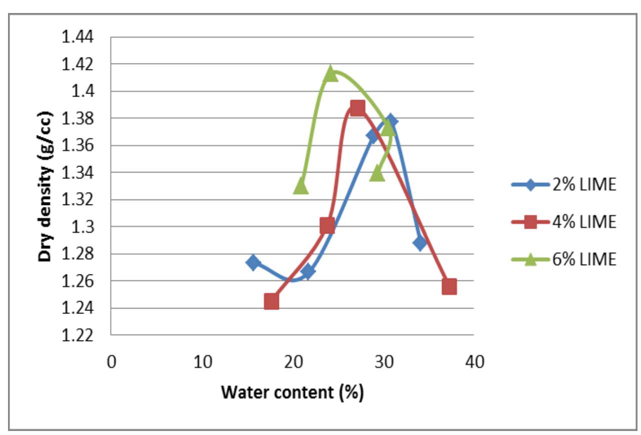

Chart 2: Compaction curves for lime stabilised soil

The compaction characteristics of soil added with 2%, 4% and 6% of cement were also determined. The values of maximum dry density and optimum moisture content for cement stabilised soil are given in table 4. The compaction curve of cement stabilised soil are shown in Chart 3.

Table 4: Maximum dry density and Optimum moisture content of cement stabilised soil

Cement content (%)	**Optimum moisture content (%)**	**Maximum dry density (g/cc)**
Soil + 2% Cement	25	1.44
Soil + 4% Cement	21.71	1.54
Soil + 6% Cement	23.07	1.53

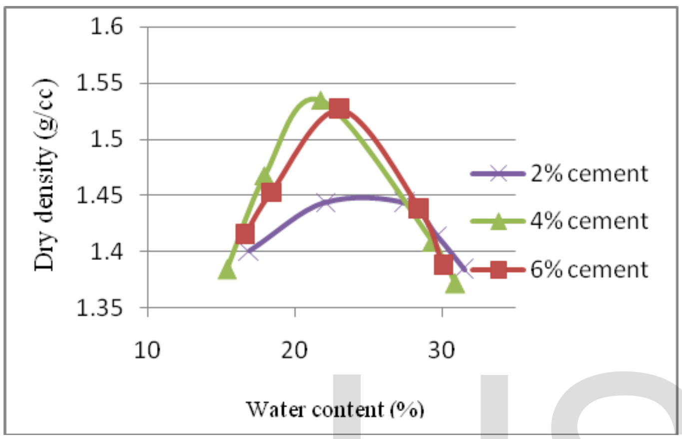

Chart 3: Compaction curves for cement stabilised soil

2) Unconfined Compression Test: Unconfined compression strength is the most common and adaptable method for calculating the strength of stabilised soil. The unconfined compressive strength of CH and CL soil samples with 2%, 4% and 6% of lime were calculated from the load settlement curve and is shown in table 5 and 6. The variation of UCC against lime content for the soil stabilised with lime is shown in Chart 5 and 6.

Table 5: UCS of Lime stabilised CH

Lime content (%)	**UCC (kN/m^2)**	**Shear Strength (kN/m^2)**
Soil + 0% Lime	103	51.5
Soil + 2% Lime	185	92.5
Soil + 4% Lime	268.3	134.15
Soil + 6% Lime	191.56	95.78

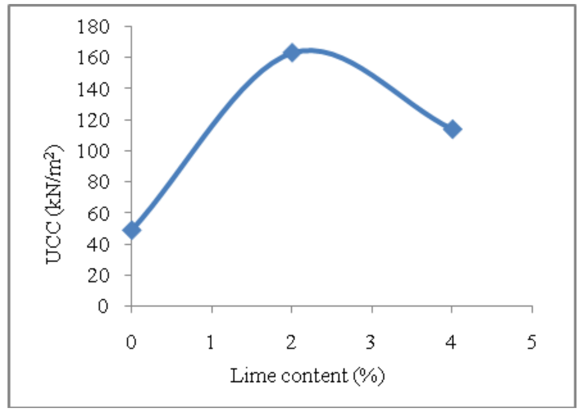

Chart 4: Variation of UCC value in CH with lime content.

Table 6: UCS of Lime stabilised CL

Lime content (%)	**UCC (kN/m^2)**	**Shear Strength (kN/m^2)**
Soil + 0% Lime	49.2	24.6
Soil + 2% Lime	163.17	81.585
Soil + 4% Lime	114.014	57.007

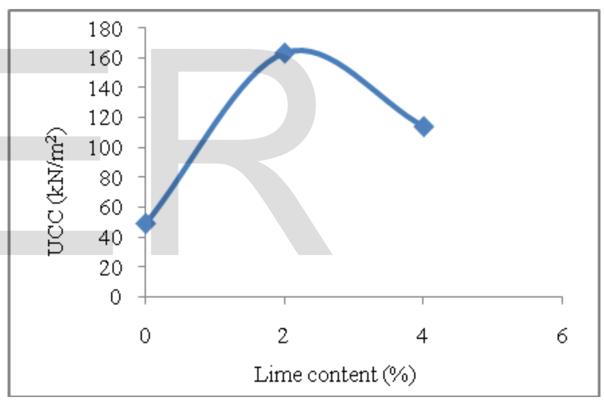

Chart 5: Variation of UCC value in CL with lime content.

The unconfined compressive strength of CH soil and CL soil samples with 2%, 4% and 6% of cement were also calculated from the load settlement curve and are shown in table 7 and 8. The variation of UCC against cement content for the soil stabilised with lime is shown in chart 6 and 7.

Table 7: UCS of Cement stabilised CH

Cement content (%)	**UCC (kN/m^2)**	**Shear Strength (kN/m^2)**
Soil + 0% Cement	103	51.5
Soil + 2% Cement	122.38	61.19
Soil + 4% Cement	169.37	84.685
Soil + 6% Cement	145.99	72.995

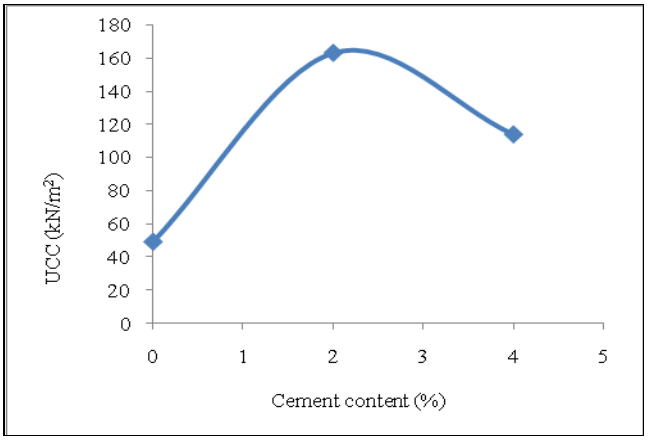

Chart 6: Variation of UCC value in CH with cement content.

Table 8: UCS of Cement stabilised CL

Cement content (%)	**UCC (kN/m^2)**	**Shear Strength (kN/m^2)**
Soil + 0% Cement	49.2	24.6
Soil + 2% Cement	121.37	60.685
Soil + 4% Cement	139.02	69.51
Soil + 6% Cement	71.56	35.78

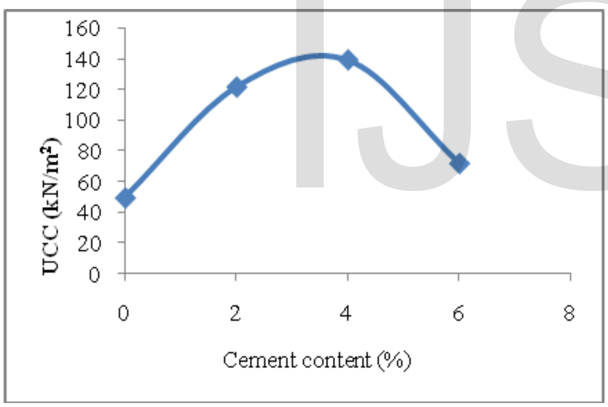

Chart 7: Variation of UCC value in CL with cement content.

Chart 8 shows the comparison of the lime content in both the Thonnackal clay (CH) and Kaolinite clay (CL) and the corresponding values are given in the table 8.

Table 8: Comparison of UCC values with lime in CH and CL

Lime content	UCC Value (kN/m^2)	
	CH	CL
Soil + 0% Lime	103	49.2
Soil + 2% Lime	185	163.17
Soil + 4% Lime	268.3	114.014
Soil + 6% Lime	191.56	-

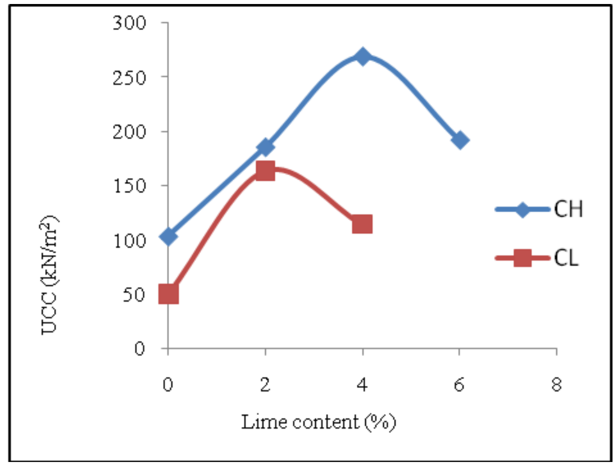

Chart 8: Comparison of UCC value in CH and CL with lime content.

Chart 9 shows the comparison of the cement content in both the Thonnackal clay (CH) and Kaolinite clay (CL) and the corresponding values are given in the table 9.

Table 9: Comparison of UCC values with cement in CH and CL

Lime content	UCC Value (kN/m^2)	
	CH	CL
Soil + 2% Cement	122.38	121.37
Soil + 4% Cement	169.37	139.02
Soil + 6% Cement	145.99	71.56

.

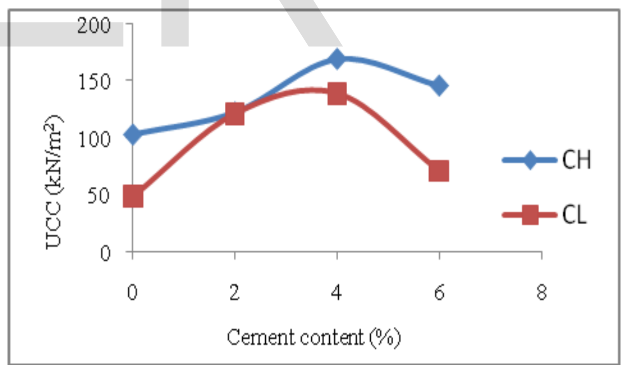

Chart 9: Comparison of UCC value in CH and CL with cement content.

3) Load – settlement Characteristics: The load – settlement responses observed from load test on unreinforced clay bed, lime column of diameter 10 mm with a curing period of 1 and 3 days are shown in chart 10.

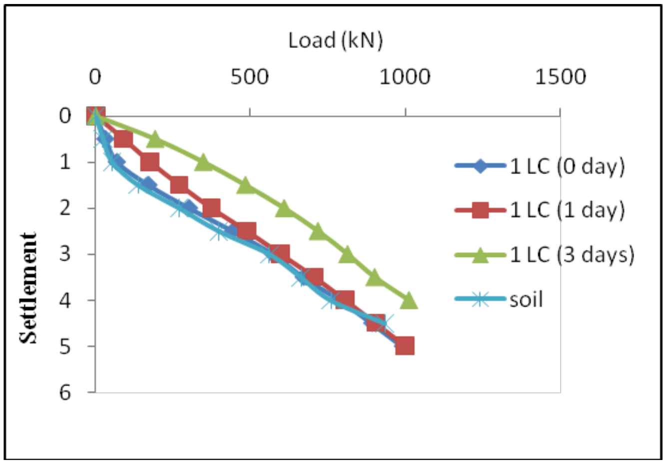

Chart 10: Load – settlement curve with and without Lime column.

4. CONCLUSIONS

The unconfined compressive strength is observed to increase with increase in lime content up to 4% in CH and 2% in CL. The increase in cement content contributes to an initial increase up to 4% followed by slight decrease in unconfined compressive strength in both CH and CL. The soil of high plasticity (CH) shows greater compressive strength when treated with lime and cement. The strength of soil increases with increase in the duration of curing for a period of 7, 14 and 21 days with both lime and cement. So it can be concluded that gain in strength is influenced by the amount of additive added and the duration of curing. The result of load testing programme shows an improvement in the performance of soil with lime column. The load required for a given settlement in lime column reinforced clay bed was higher than that required for the same settlement in unreinforced clay bed.

REFERENCES

[1] Ankit Singh Negi, Mohammed Faizan, Devashish Pandey Siddharth and Rehanjot Singh (2013) “Soil Stabilization using Lime”, *IJIRSET*., 2(2), 448-453, ISSN: 2319-8753

[2] Azhani Zukri (2012) “Peakan Soft Clay Treated with Hydrated Lime as a method of Soil Stabilizer”, *Elsevier* (53), pp 37-41.

[3] Douglas O.A. Osula (1989) “Evaluation of Admixture Stabilization for Problem Laterite”, *J.Trans, ASCE*; Vol.115 (6), 674-686, ISSN: 0733-947X.

[4] J B Oza and P J Gundaliya (2013) “Study of Black Cotton Soil Characteristics with Cement Waste Dust and Lime”, *Elsevier* (51), pp 110-118.

[5] S A A Khattab, M Al-Mukhtar and J M Fleureau (2007) “Long - Term Stability Characteristics of a Lime Treated Plastic Soil”, *J.Mater, ASCE*; Vol.19 (4), 358 – 366, ISSN: 0899 – 1561.

[6] Monica Malhotra and Sanjeev Naval (2013), “Stabilization of expansive soils using low cost materials”, *IJEIT*, Vol.2 (11), 181-184, ISSN: 2277-3754.

[7] Parampreet Kaur and Gurdeep Singh (2012), “Soil improvement with lime”, *ISORJMCE,* Vol.1 (1), 51-53, ISSN: 2278-1684.

[8] Kolawole Juwunlo Osinubi (2006), “Influence of Compactive Efforts on Lime - Slag Treated Tropical Black Clay”, *ASCE*; Vol. 18 (2), 175-181, ISSN: 0899-1561.

[9] S Boobathiraja, P. Balamurugan, M Dhansheer and Anuj Adhikari (2014), “Study of strength of peat soil stabilised with cement and other pozzolanic materials”, *IJCER*, Vol. 5 (4), 431-438, ISSN: 2278 – 3652.

[10] Manuela Cecconi and Giacomo Russo (2012),”Geotechnical properties of lime stabilized pyroclastic soils”, *EJGE*, Vol.17, pp 2581-2597.

[11] Sujit Kumar Dash and Monowar Hussain (2012) “Lime Stabilization – Reappraisal”, *J.Mater*, ASCE, Vol. 24 (6), 707 – 714, ISSN: 0899 – 1561.

[12] Manuela Cecconi and Giacomo Russo (2012),”Geotechnical properties of lime stabilized pyroclastic soils”, *EJGE*, Vol.17, pp 2581-2597.