Engineering Properties of an Expansive soil Stabilized with Rice husk ash and Lime sludge

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***Abstract*— Compaction properties, California bearing ratio, shear strength parameters, compression index, swelling pressure and durability of an expansive soil stabilized with rice husk ash and lime sludge have been discussed in this paper. The effects of 7 and 28 days of curing on these properties except the compaction properties have also been discussed.**

Keyword- Expansive soil, Rice husk ash, Lime sludge, California bearing ratio, Shear strength parameters.

I. INTRODUCTION

Expansive soil is a difficult soil for construction because of its cyclic swell - shrink behavior and low strength. These types of soils expand significantly coming in contact with water and shrink when water evaporates out, resulting severe damages to lightly loaded structures constructed on them. The damages done to civil engineering structures are so severe that, it is estimated to be $1000 million in USA and £150 in UK [1]. Stabilization using industrial wastes is one of the efficient, popular and cost effective techniques, out of several techniques of construction on expansive soils. Soil stabilization is a process by which certain materials are added to soil to improve its engineering properties. These materials may be classified as pozzolanic (fly ash, rice husk ash etc.), binder (lime, cement, cement kiln dust, lime sludge etc.) and inert (quarry dust, sand, ceramic dust etc.) are added to soil individually or combinedly.

Rice husk ash (RHA) is the ash produced by burning of rice husk.Silica is the main constituent of rice husk ash. It has been found to be pozzolanic material due to its high amorphous silica content. Another waste produced from paper manufacturing industry is lime sludge the main constituent of which is lime.RHA as a pozzolanic material and lime sludge as a binder can be utilized to stabilize expansive soil.

Stabilization of expansive soil using rice husk ash (RHA) as a pozzolanic material along with a binder has been studied by a number of researchers. Some of these works are, RHA -lime [2]-[3], RHA- cement [4],[5], RHA-calcium chloride[6],RHA- marble dust[7], RHA-lime-gypsum [8] etc. Similarly the utilization of lime sludge as a binder along with a pozzolanic material has also been studied by a number of researchers. Some these research works are bagasse ash –lime sludge [9], fly ash –lime sludge [10]) etc. Chandra et al. [11] had stabilized a non-expansive clayey soil with RHA and lime sludge. RHA added to soil was from 5 to 20% in steps of 5% and lime sludge from 4 to 16% in steps of 4%. Properties of the stabilized soil studied were, Atterberg's limits, maximum dry density (MDD), optimum moisture content (OMC), unconfined compressive strength (UCS) and soaked California bearing ratio (CBR) of soil. The optimum percentage of RHA and lime sludge for stabilization of soil was found to be 10% and 16% respectively.

Sabat [9] had studied the stabilizing effects of bagasse ash and lime sludge on compaction (standard Proctor) properties, UCS, CBR and swelling pressure of an expansive soil. All properties were tested after 7 days of curing. The effects of compaction delay, molding water content on CBR of the stabilized soil were studied. The economy of the stabilization was also studied. He had not studied, other engineering properties including durability of the stabilized soil along with the effects of curing period on the properties for which tests were conducted.

From the review of the literature, the stabilizing effects of RHA and lime sludge on engineering properties of expansive soil were not found.

The objective of the present investigation is to study, the compaction properties, soaked CBR, swelling pressure, shear strength parameters, compression index and durability of an expansive soil stabilized with RHA and lime sludge, along with the economy of, RHA and lime sludge stabilization.

II. MATERIALS AND METHODS

The materials used in the experimental programme are expansive soil, rice husk ash and lime sludge.

Expansive soil

The geotechnical properties of a local expansive soil used in the laboratory tests are:

Grain size analysis:-Gravel size -0%, Sand size- 12%, , Silt size- 28%, Clay size- 60%, Atterberg's limit:-Liquid limit- 61% , Plastic limit- 31%,Plasticity Index- 30%,Specific Gravity-2.67,OMC-20.7%,MDD-16.1kN/m^3,UCS-58kN/m^2,CBR-1.92%,Cohesion-17 kN/m^2, Angle of internal friction-13^0, Coefficient of compression -0.218

Rice husk ash

The RHA used in the laboratory tests is a processed RHA, collected from a plant. The chemical compositions of RHA are:- SiO_2 -91.6%, Al_2O_3 -3.52%, Fe_2O_3-0.64 %, CaO -1.34 % etc. The specific gravity of the RHA is 2.3.

Lime sludge

Lime sludge used was collected from a paper manufacturing industry. The chemical compositions of the lime sludge are: CaO-48%, SiO_2 -6.54%, Al_2O_3 -1.15%, Fe_2O_3-1.2% etc.

Testing Procedures

The optimum percentage of RHA was found out by conducting UCS tests on soil-RHA mixes. RHA was added to soil from 5 to 20% at an increment of 5% by preparing the samples at OMC and MDD of unstabilized soil. Lime sludge was added to soil stabilized with optimum percentage of RHA was from 0 to 15% at an increment of 5%. Standard Proctor compaction tests were conducted on lime sludge stabilized soil-RHA mixes to find OMC and MDD to prepare samples for UCS(durability tests),CBR, consolidated undrained triaxial compression tests, swelling pressure tests and consolidation tests.UCS, CBR, consolidated undrained triaxial compression tests, swelling pressure tests and consolidation tests were conducted at 0,7 and 28 days of curing. Tests were conducted according to the procedures given in relevant Indian standard codes. Durability tests were conducted on lime sludge stabilized RHA-soil mixes according to the procedure laid in ASTM-559-2003(without use of scratch brush). Each wet-dry (W-D) cycle consisted of submerging the samples in water for 5 hours and then placing them in oven for 42 hours at 71^0C. After each W-D cycles the volumetric changes were measured. Samples those had volumetric strain more than 10% were rejected. The test continued for 6 W-D cycles. The UCS tests were conducted again on the samples those survived the 6 W-D cycles and had volumetric strain less than 10%.

III. ANALYSIS OF TEST RESULTS

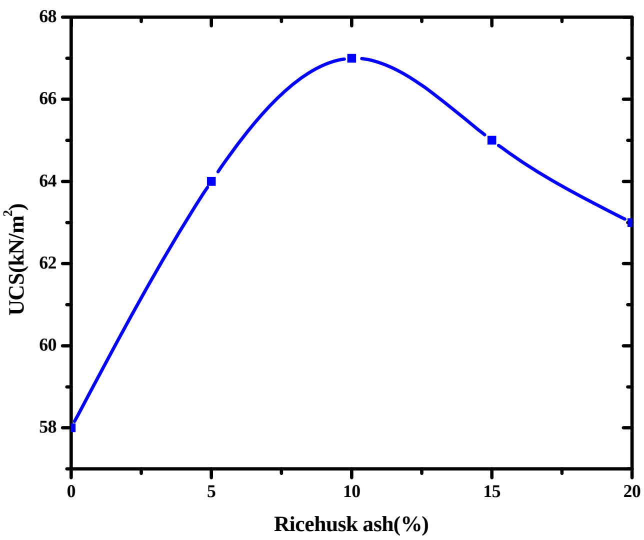

Fig.1 Variation UCS of Soil with Rice husk ash

Fig.1 shows the variation UCS of soil stabilized with different percentage of RHA.From the figure it can be seen that with increase in percentage of RHA the UCS of the soil goes on increasing up to 10% addition of RHA, there after it decreases. The UCS increases to 67 kN/m^2 from 58 kN/m^2 when the percentage of RHA is 10%.The optimum percentage of RHA for stabilization of expansive soil is found to be 10%.

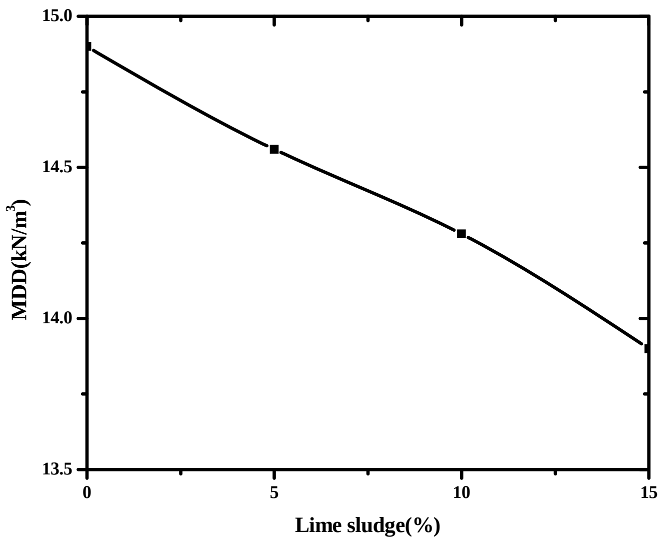

Fig.2 Variation of MDD of RHA stabilized soil with lime sludge

Fig.2 shows the variation of MDD of RHA stabilized soil with different percentage of lime sludge. From the figure it is found that with increase in percentage of lime sludge the MDD of the RHA stabilized soil goes on decreasing up to 15% addition of lime sludge. The MDD of soil reduces to 14.9 kN/m^3 from16.1 kN/m^3 when 10% RHA is added, and decreased to 13.9 kN/m^3 when the percentage of lime sludge is 15%.

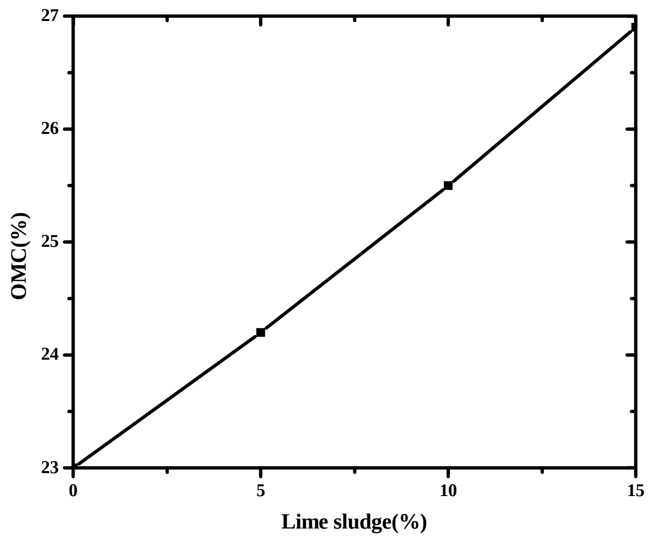

Fig.3 Variation of OMC of RHA stabilized soil with lime sludge

Fig.3 shows the variation of OMC of RHA stabilized soil with different percentage of lime sludge. From the figure it is found that with increase in percentage of lime sludge the OMC of RHA stabilized soil goes on increasing up to 15% addition of lime sludge. The OMC of soil increases to 23% from 20.7% when 10% RHA was added, and increased to 26.9% when the percentage of lime sludge is 15%.

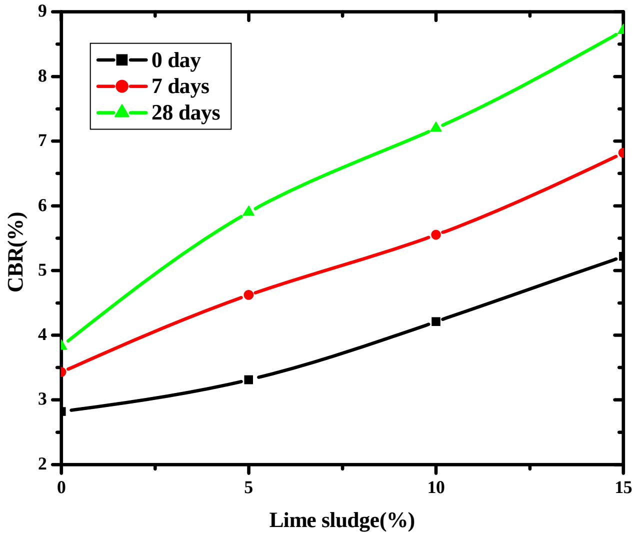

Fig.4 Variation of CBR of RHA stabilized soil with lime sludge and Curing period

Fig.4 shows the variation of CBR of RHA stabilized soil with different percentage of lime sludge and curing period. The CBR of soil increases to 2.82% from 1.92% when 10% RHA was added to soil. With addition of different percentage of lime sludge the CBR of RHA stabilized soil goes on increasing up to 15% of lime sludge. Increase in curing period further increases the CBR irrespective of the percentage addition of lime sludge. The CBR increases to 8.71% at 28 days of curing, for the mix having soil:RHA:lime sludge: :75:10:15.

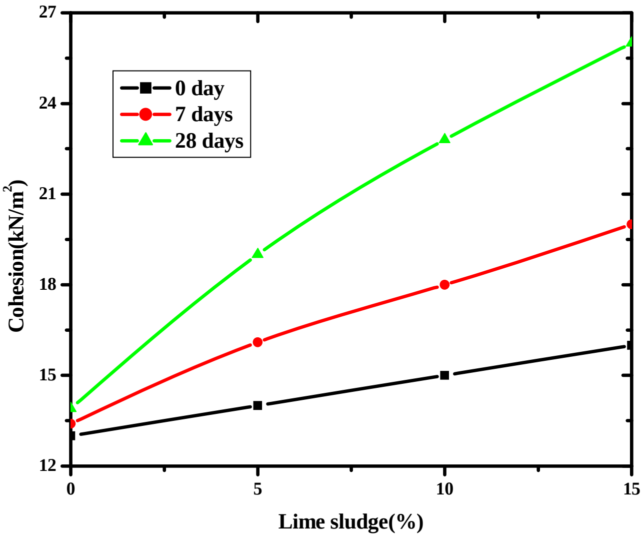

Fig. 5 Variation of Cohesion of RHA stabilized soil with lime sludge and Curing period

Fig.5 shows the variation of cohesion of RHA stabilized soil with different percentage of lime sludge and curing period. The cohesion of soil decreased when 10% RHA was added to soil. With increase in percentage addition of lime sludge the cohesion of RHA stabilized soil goes on increasing up to 15% addition of lime sludge. Increase in curing period further increases the cohesion irrespective of the percentage addition of lime sludge. The cohesion increases to 26 kN/m^2 at 28 days of curing for the mix having soil: RHA: lime sludge: :75:10:15.

Fig.6 shows the variation of angle of internal friction of RHA stabilized soil with different percentage of lime sludge and curing period. The angle of internal friction of soil increases when 10% RHA was added to soil. With increase in percentage addition of lime sludge the angle of internal friction of RHA stabilized soil goes on increasing up to 15% of lime sludge. Increase in curing period further increases the angle of internal friction irrespective of the percentage addition of lime sludge. The angle of internal friction increases to 21^0 at 28 days of curing for the mix having soil: RHA:lime sludge: :75:10:15.

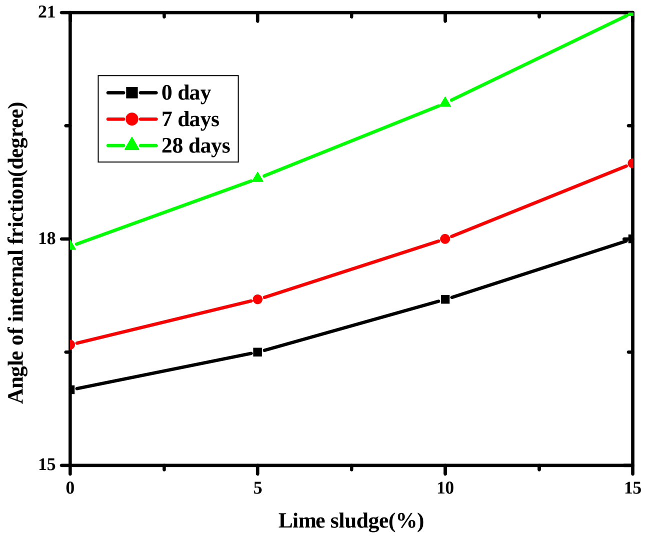

Fig.6 Variation of Angle of Internal friction of RHA stabilized soil with lime sludge and Curing period

Fig.7 shows the variation of compression index of RHA stabilized soil with different percentage of lime sludge and curing period. The compression index of soil decreases to 0.167 from 0.218 when 10% RHA was added to soil. With increase in percentage addition of lime sludge the compression index of RHA stabilized soil goes on decreasing up to 15% of lime sludge. Increase in curing period further decreases the compression index irrespective of the addition of lime sludge. The compression index decreases to 0.1 at 28 days of curing for the mix having soil:RHA:lime sludge: :75:10:15.

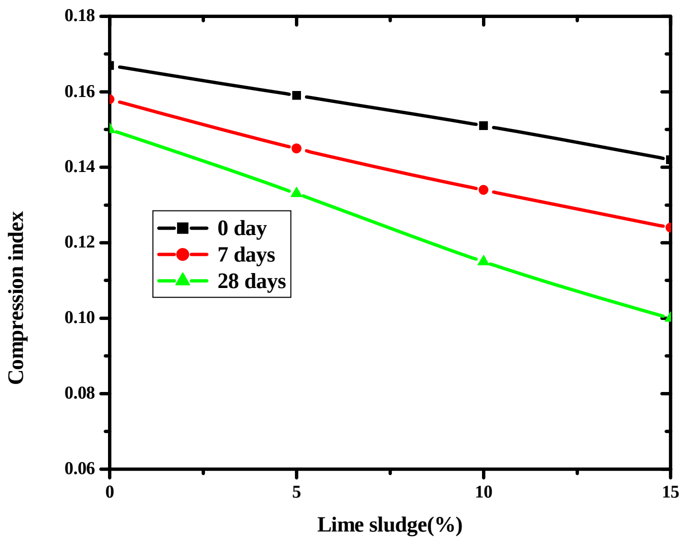

Fig.7 Variation of Compression index of RHA stabilized soil with lime sludge and Curing period

Fig.8 shows the variation of swelling pressure of RHA stabilized soil with different percentage of lime sludge and curing period. The swelling pressure of soil decreases to 104 kN/m^2 from 130 kN/m^2 of virgin soil when 10% RHA is added to soil. With increase in percentage addition of lime sludge the swelling pressure of RHA stabilized soil goes on decreasing up to 15% of lime sludge. Increase in curing period further decreases the swelling pressure irrespective of the addition of lime sludge. The swelling pressure decreases to 4 kN/m^2 at 28 days of curing for the mix having soil: RHA: lime sludge: :75:10:15.

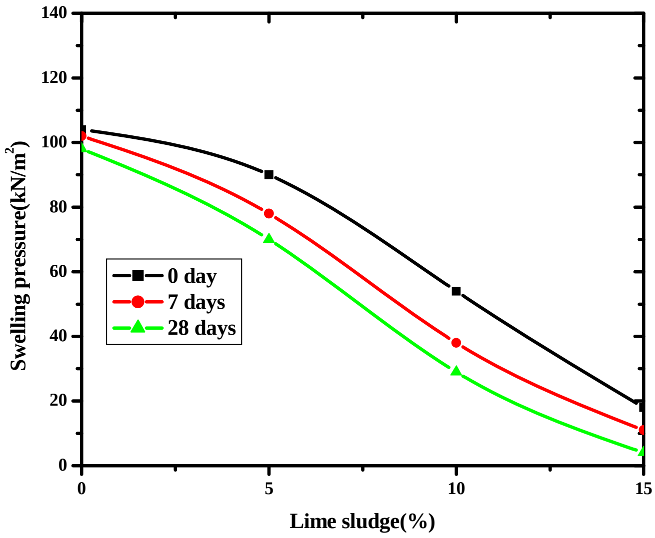

Fig.8 Variation of Swelling pressure of RHA stabilized soil with lime sludge and Curing period

Fig.9 shows the durability test results in terms of loss of UCS values of the stabilized soil at 7 and 28 days of curing after subjecting them to 6 W-D cycles. The soil stabilized with 10% RHA and RHA-soil stabilized with different percentage of lime sludge with 0 day curing were not able to survive any W-D cycles, hence these values have not been shown in the figure. However addition of different percentage of lime sludge to RHA stabilized soil cured for 7 and 28 days survived the 6 W-D cycles. Increase in percentage addition of lime sludge and curing period decreases the loss of UCS. The losses in UCS is more than 20% in all samples except for the samples stabilized with 10% RHA and 15% lime sludge cured at 7 and 28 days for which the percentage losses are 18% and 9% respectively.

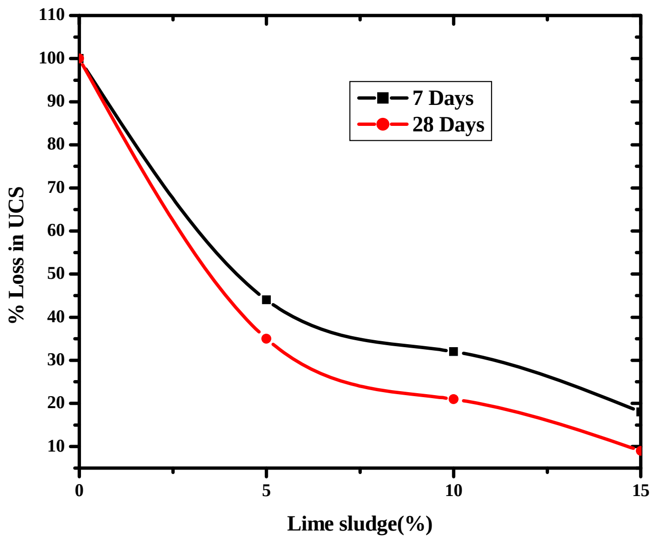

Fig.9 Variation in Percentage reduction in UCS with lime sludge after 6 W-D cycles

From the analysis of test results it is found that the optimum percentages of RHA and lime sludge for stabilization of expansive soil are 10% and 15% respectively.

Economy of Using Rice husk ash and Lime sludge in Construction of Flexible Pavements over Expansive Soil Sub-grade

To study the economy of RHA-lime sludge stabilization the thickness of a flexible pavement was calculated for traffic intensity of 1,5 and 10 MSA based on the guidelines provided in IRC 37:2001[12]. Fig.10 shows the variation of pavement thickness with cumulative traffic. The pavement thickness for stabilized soil has been found out for the mix having optimum percentage of RHA (10%) and lime sludge (15%).The thickness of the pavement based on CBR value of unstabilized soil has been found out by taking its CBR value as 2%.It can be seen from the figure that, for same traffic intensity, the pavement thickness goes on decreasing with increase in CBR values and the pavement thickness of the unstabilized soil is more than the pavement thickness of stabilized soil for all traffic intensity considered.

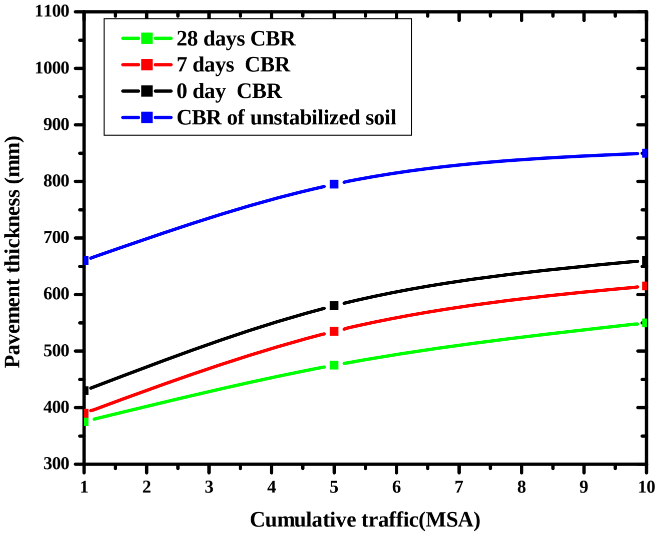

Fig .10 Variation of pavement thickness with cumulative traffic

Fig.11shows the percentage reduction in pavement thickness with cumulative traffic based on CBR values of stabilized soil (stabilized with optimum percentage of RHA and lime sludge) at different curing period in comparison to unstabilized soil. From the figure it can be seen that, with increase in curing period the reduction in pavement thickness (%) goes on increasing and decreases with increase in traffic intensity. This shows the economy of construction of flexible pavement using stabilized soil in place of unstabilized soil as well as the effect of curing on the economy of construction.

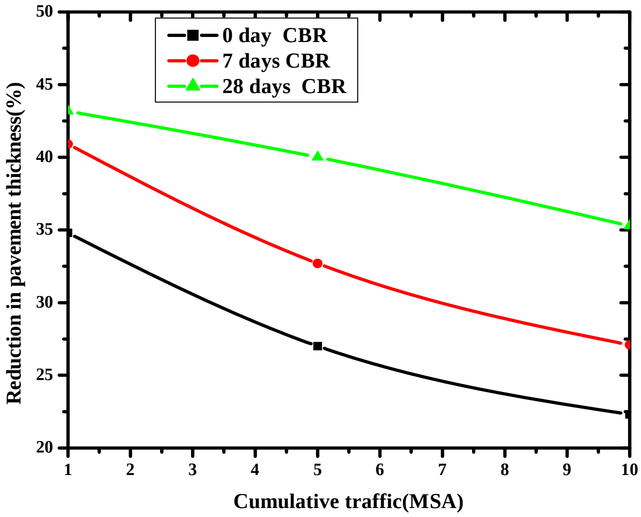

Fig.11 Reduction in Pavement thickness (%) with cumulative traffic

IV. CONCLUSION

Based on compaction, CBR, shear strength, consolidation and durability test results the following conclusions are drawn from this study.

1) The optimum percentages of RHA and lime sludge for stabilization of expansive soil are 10% and 15% respectively.
2) The OMC, CBR, cohesion and angle of internal friction increases at the optimum percentages of the stabilizers. The CBR, cohesion and angle of internal friction further increases with increase in curing period.
3) The MDD, coefficient of compression and swelling pressure decreases at the optimum percentages of the stabilizers. The coefficient of compression and swelling pressure further decreases with increase in curing period.
4) Soil stabilized at the optimum percentages of the stabilizers, cured for 7 and 28 days are found to be durable. In these cases, the percentage losses in strength are 18% and 9% respectively.
5) From the study of the economy of stabilization, it is found that there can be substantial save in cost of construction of pavement if RHA and lime sludge is utilized in strengthening the sub-grade of flexible pavement. However, the benefits of economy and durability can be achieved if the sub-grade soil is stabilized at optimum percentage of RHA and lime sludge and cured for a minimum period of 7 days.

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