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An Experimental Study on the Geotechnical Properties on Cement and Lime Treated Sandy Soil

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Abstract—*Ground improvement is necessary when the soil beneath the foundation of the construction site is unsuitable for supporting the structural load. Soil stabilization techniques are a corrective action that lowers the permeability and compressibility of soil in earthen structures, increases its shear strength, and aids in preventing the settlement of buildings. To increase the geotechnical attributes of poor soils, stabilizing agents are used. Adding cement and lime to the soil is a common method of enhancing soil quality. Nowadays, this method is employed all over the world in a variety of applications, including foundations and embankments. Thus, it becomes necessary to thoroughly investigate the behaviours of the soil-cement and soil-lime mixtures. In this research soil-cement and soil-lime mixtures were formed in the proportion of 3%, 7%, 10%, 13% and 17% and 2%, 4%, 6% and 8% respectively. The soil sample is collected from the Girijananda Chowdhury University campus located in Guwahati city at a depth of 0.75 m from the ground surface. On each of these mixtures, various laboratory experiments such as sieve analysis, liquid limit test, plastic limit test, standard proctor compaction test and California Bearing Ratio (CBR) test are performed. The findings revealed that the inclusion of lime and cement significantly influenced the behaviour of the sandy soil. As the content of lime and cement increased, the soil exhibited alterations in its plasticity, compaction and load-bearing capacity. Lime and cement acted as a stabilizing agent, reducing plasticity and thus, improving the resistance of soil to compression and bearing capacity.*

1. INTRODUCTION

Enhancing the mechanical characteristics and resilience of loose, granular sandy soil, stabilization of soil is an essential engineering method. Loose granular soil because of their low bearing capacity and poor cohesiveness, is unsuitable for infrastructure and building projects unless they are well treated. Loose sandy soils may undergo liquefaction whereby, they momentarily behave like a liquid during seismic activity or heavy vibrations. Sandy soil can be stabilized using a variety of techniques, the most popular being chemical stabilization. In order to accomplish specified technical or environmental goals, chemical stabilization is a process of adding chemical admixtures to problematic soil to improve their qualities. Depending on the soil classification and intended level of improvement, these admixtures which include cement, marble dust, fly ash, lime, and stone waste etc. are added to the poor soil in a certain percentage.

Several research workers have used different admixtures to improve the quality of soil. Many studies have shown that adding a stabilizing agent will increase the effective cohesiveness of sandy soil [9]. The stabilization of soil with appropriate admixtures, such as fly ash, cement, calcium chloride, lime, and bituminous material, has been utilized more and more successfully in recent years to construct road foundations in Bangladesh, India, the United Kingdom, and the United States of America, among other places [3]. Chitosan, a biopolymer is extensively used for sandy soil stabilization [14]. This stabilization technique has also been approved by the Indian Road Congress [4] as a standard technique.

A highly popular additive used to stabilize sandy soil is cement. Cement stabilization can be accomplished with soil that contains less than 2% organic matter [1]. The internal friction angle is thought to be significantly increased by stabilization with cement [8], while for other researchers this effect is negligible [13]. Shear strength parameters are increased with increasing stabiliser concentration and curing time, according to research on the impact of cement stabilisation of sandy soils [2]. Lime is also employed as a stabilizing agent nowadays and has good outcomes when given to the soil in a specific percentage. When lime is used, a soil's properties are greatly altered to create lasting strength and stability throughout time, especially with regard to the effects of water and cold [10].

2. MATERIAL AND METHODOLOGY

In this research work two admixtures i.e. lime and cement are used for stabilizing the soil. Soil samples were collected from the Girijananda Chowdhury University campus at a depth of 0.75 m from the ground surface and were air dried for 15 days. In contrast to lime, which is blended in proportions of 2%, 4%, 6%, and 8%, cement-soil mixes were formed in the following proportions: 3%, 7%, 10%, 13%, and 17%. Several laboratory tests were performed on all cement - soil and lime - soil mixes as well as on the soil sample without any admixture in order to examine the effects of these admixtures on the soil sample. The tests include liquid limit (LL), plastic limit (PL), standard proctor test and California Bearing Ratio (CBR) test. For the soil classification grain size distribution (GSD) analysis have been performed.

3. RESULTS AND DISCUSSION

The results of the laboratory tests are discussed below

3.1 Grain Size Distribution Analysis

The percentages by dry mass of soil dispersed over predetermined particle-size ranges are referred to as particle size distribution, or gradation. [11]. A grain size distribution curve is obtained by plotting the mechanical analysis results. The diameter of the particle is represented on a logarithmic scale as the abscissa, and the ordinate represents the percentage finer (N) as shown in Fig. 1. The curve gives us an idea about the type and gradation of the soil. It is found that the soil contains 3.1 % fines passing through 75 µ sieve. From Grain Size Distribution Curve: D_{10}= 0.21 mm, D_{30}=0.72 mm and D_{60}= 2.18 mm. The coefficient of uniformity, Cu and co-efficient of the curvature, Cc were found to be 10.33 and 1.11 respectively which indicates that the soil sample is well graded sand (SW).

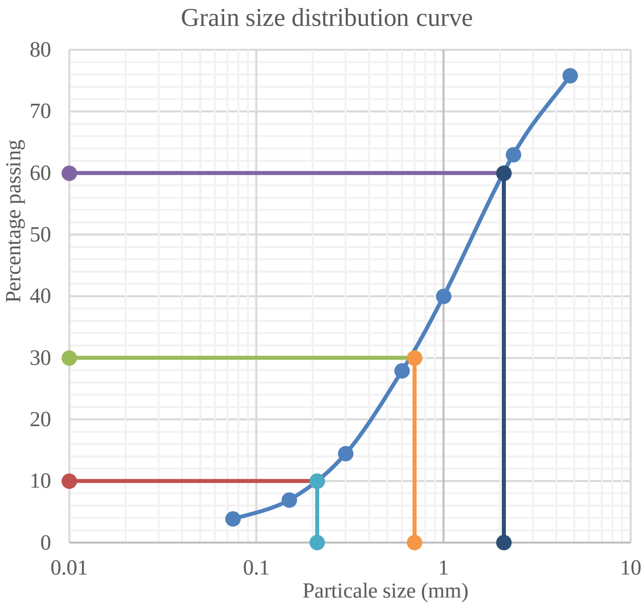

Figure 1: Grain size distribution curve

3.2 Consistency Limits

The Atterberg limit tests were carried out referring the [5] for all cement – soil (C-S) and lime – soil (L-S) mixes. Liquid limit test is determined using Casagrande's apparatus and the ASTM tool was used to tear the sides of the grooves for C-S and L-S mixes. Liquid limit values for all the mixes are presented in Table 1 which is also shown graphically in figure 2. From the plot of liquid limit (%) versus admixture content (%), it is seen that for C-S mixes, LL increases up to 7 % cement content with a value of 39.97 % and then decreases with further addition of cement whereas, for L-S mixes, with increasing lime content upto 4 %, liquid limit increases reaching a LL value of 36.3% but with further addition of lime, liquid limit decreases.

Table 1: Liquid Limit of stabilized and unstabilized soil

Sample	Admix. %	Liquid liquid, %
Soil	0	34.22
Cement-Soil	3	38.65
	7	39.97
	10	39.21
	13	38.81
	17	38.12
Lime-Soil	2	35.68
	4	36.13
	6	32.51
	8	31.18

From the LL versus admixture content graph (Figure: 2), it is observed that both the curves show similar trend with 4 % lime content and 7 % cement content for maximum LL.

Plastic test is also performed in accordance with IS: 2720 (Part 5) –1985 on the soil sample without adding any admixtures and is found to be 30%. Thus, the plasticity index (PI) of the soil sample is 4.22%. Since, PI is less than 7%, hence the soil sample can be describes as 'low plastic' [**12**]. Further, it is observed that addition of cement and lime reduces the plasticity of soil and so the plastic limit test for the C-S and L-S mixtures could not be performed for any of the proportions. As a result, the mixes become non-plastic after the admixtures are added with the soil sample.

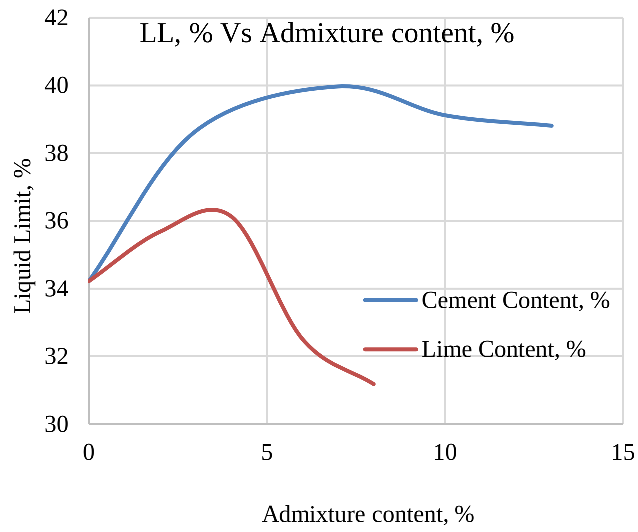

Figure 2: Liquid Limit, % Versus Admixture content, %

3.3 Standard Proctor Test

Soil sample with and without admixtures are compacted to enhance the mechanical qualities of the mixes. Compaction of the subgrade soil to a desired density is necessary during road building to guarantee that the soil can support the acting loads. The guidelines were followed as per **[6]** while performing the proctor compaction test. The results of maximum dry density (MDD) and optimum moisture content (OMC) of C-S mixes and L-S mixes along with the unstabilized soil is presented in table: 2.

Table 2: Compaction properties of stabilized and unstabilized soil

Cement-Soil mixes			Lime-Soil mixes		
Cement content, %	**MDD, g/cc**	**OMC, %**	**Lime content, %**	**MDD, g/cc**	**OMC. %**
0	1.57	21.22	0	1.57	21.22
3	1.68	19.51	2	1.74	20.51
7	1.76	19.35	4	1.78	19.72
10	1.79	17.85	6	1.81	18.65
13	1.82	17.02	8	1.83	17.34
17	1.92	16.61	-	-	-

The MDD and OMC value of soil sample without admixture is found to be 1.57 g/cc and 21.22% respectively. It has been observed that with addition of admixtures, MDD values increases gradually whereas, OMC values decreases gradually. For C-S mixes, the MDD value increases from 1.68 g/cc to 1.92 g/cc for cement content between 3% to 17%, while for L-S mixes, the increase is from 1.74 g/cc to 1.83 g/cc for lime content within a range of 2% to 8%. Again, for the aforementioned range of the corresponding admixtures, the OMC value drops from 19.51% to 16.61% for C-S mixes and from 20.51% to 17.34% for L-S mixes. A trend of gradually increasing MDD values and gradually decreasing OMC values has been noticed with the addition of admixtures which is shown in Figure: 3 and Figure: 4 respectively.

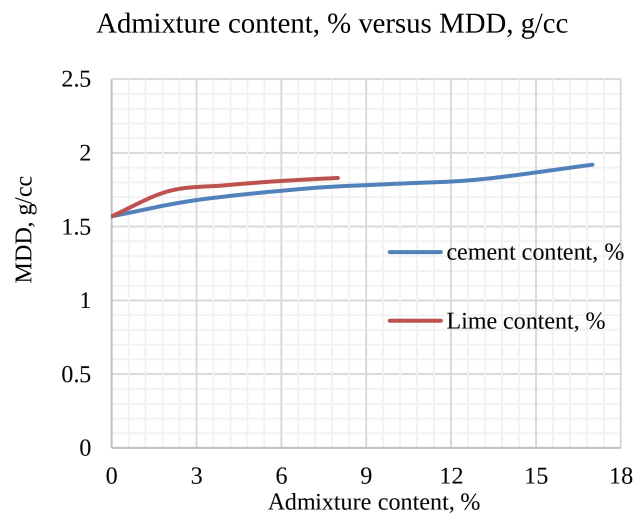

Figure: 3 Admixture content, % versus MDD, g/cc

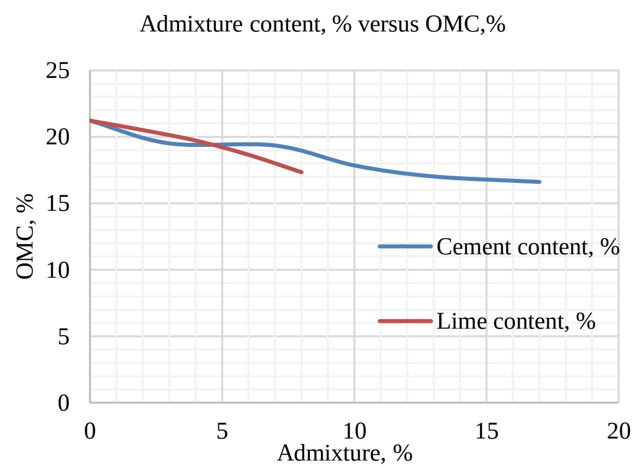

Figure 4: Admixture content, % versus OMC, %

3.4 California Bearing Ratio (CBR)

Soil sample without any admixture, C-S mixes, and L-S mixes are tested using the CBR method following the guidelinesas per **[7].** The unsoaked specimens were dynamically compacted using light compaction test. Load- penetration curves are generated for each specimen to determine the corresponding load at 2.5 mm and 5 mm penetration,. CBR values are thus determined at penetration depths of 2.5 mm and 5 mm. It has been noted that the CBR value at 2.5 mm penetration is higher than that at 5 mm penetration. Accordingly, the CBR values are shown in table: 3 for each specimen.

Table 3: CBR values of stabilized and unstabilized soil at 2.5 mm

Admixtures	% of Admixture	CBR, %
Cement	0	10.33
	3	18.23
	7	20.39
	10	21.70
	13	23.11
	17	25.09
Lime	0	10.33
	2	15.12
	4	17.21
	6	20.12
	8	21.22

The soil sample without admixture has a CBR value of 10.33%. The CBR values of C-S and L-S mixes have been shown to progressively increase with the addition of admixtures. When the cement percentage in C-S mixes ranges from 3% to 17%, the CBR value increases from 18.23% to 25.09%, and when the lime concentration in L-S mixes ranges from 2% to 8%, it increases from 15.12% to 21.22%. With the addition of admixtures, a pattern of steadily rising CBR values has been observed, as seen in Figure 5.

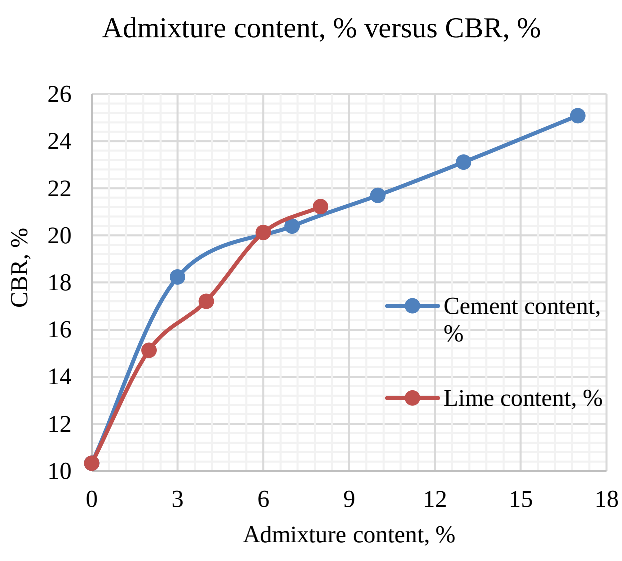

Figure: 5 Admixture content, % versus CBR, %

4. CONCLUSION

The geotechnical analysis of the sandy soil revealed several key findings. The grain size distribution indicated a well-graded sand (SW), highlighting potential challenges such as low cohesion, liquefaction, erosion and a low bearing capacity. The addition of cement and lime as stabilizing agents showed interesting results. While the liquid limit increased up to 7 % for cement, for lime the maximum LL showed at 4 %, further addition of both the admixtures led to decrease in LL. The plastic limit test could only be performed for the unstabilized soil sample whereas, for both the admixtures PL test could not be conducted due to the reduction in soil plasticity caused by the admixtures. The plasticity index initially indicated a low plastic nature of the soil, with cement and lime further reducing its plasticity. This is significant for understanding the behaviour of soil under different conditions. The standard proctor test showed that maximum dry density (MDD) increased with admixture content, suggesting improved load-bearing capacity. However, the optimum moisture content (OMC) decreases with further addition of admixtures.

The geotechnical analysis and ground improvement efforts using cement and lime revealed promising results. The soil, identified as well-graded sand, exhibited enhanced properties with the addition of both the admixtures, particularly up to a certain percentage. Due to differences in the contents of the two admixtures, a comparison between stabilized (either cement or lime) and unstabilized soil is presented through this research rather than between the two admixtures. The findings provide valuable insights for future construction or development projects in sandy soil areas, emphasizing the need for careful consideration of lime content to achieve optimal results in terms of stability and load-bearing capacity.

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