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Modification in the Properties of Sub-Grade Soil by Using Hydrated Lime

Aman Thakur[1*], Dhiraj Kumar[2], Arnaw Pandey[3], Ismit Pal Singh[4]

[1,3]Dept. of Civil Engg., "Guru Nanak Dev Engineering College", Punjab Technical University, Ludhiana, India.
[2]Dept. of Civil Engg., "North Eastern Regional Institute of Science and Technology", Itanagar, Arunachal Pradesh, India
[3]Dept. of Civil Engg., "Guru Nanak Dev Polytechnic College", PSBTE, Ludhiana, India

[*]Corresponding Author: amanthakur0220@gmail.com, Tel.: +91-95179-58181

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Abstract— Demand for the up-gradation in the road sub-grade generally needed a specific additive to work significantly in actual field circumstances. The soil interfaces weaker and makes a loophole for the shear failure, to overtake the failure of soft in-situ soil, the inclusion of chemical reflect in favor to strengthen the soil sub-grade. In earlier days the weak in-situ soil was replaced by the hard strata; despite doing so, the soil improvement technique is much more suitable and sustainable. Soil stabilization means the act of making the soil more stable and making it less likely to demolish. This present study present asynchronous of the test are done on in-situ soil and with varying the percentage of additive to evaluate various geotechnical parameters. In this present investigation, the soil was stabilized with a lime concentration of 3%, 6%, 9%, and 12%. The successive test admits the Liquid limit, plastic limit, standard proctor, and the California bearing ratio test. The optimum results were found with 6% of additive with in-situ soil. The California Bearing Ratio value is resolved at 6% lime additive is 14.59 and the maximum dry density is coming out to be 1.856kN/m^3 at 15.38% Optimum moisture content.

Keywords— *Hydrated lime, Expensive soil, compaction characteristics, Index property, Standardization.*

I. INTRODUCTION

Development of road is on the rise due to the rapid demand of road for the urge of better transportation. In recent years the work on soil stabilization has significantly increased. Soil structures have a great impact on overall structure hence the soil stabilization is an important task to operate soil in a significant way [1]. It goes under deformation due to the effect of load. So, it is very important to overcome this property of clayey soil before commencing the construction of any structure over the clayey soil [2], treated or stronger soil might resulting in significant cost advantages[[3],[4]]. Clayey soil always experiences volumetric change whenever it is loaded in the presence of moisture. Incompatible strategies are accessible to improve the designing properties of elusive soils like densification, compound adjustment, support, and procedure to decrease the pore water pressure. In this way, we can get rid of unbearable soil strata through standardization [5]. Soil improvement proficiency is a method presented numerous years prior with the reason to render the dirt skilled to meet the prerequisite of explicit designing properties.

The soil obtained from the shores of the river containing a significant percentage of fine-grained particles such as clay and silt that cause changing geotechnical characteristics [[6], [7]]. An excellent candidate for soil stabilisation is fine-grained clayey soil (size within 25% passing through #200 sieve (75mm) and having a plasticity index more than 10) with a plasticity index greater than 10.

The characteristics of the locally accessible (soil accessible at the site) may be enhanced with the application of the soil adjustment technique, and it can be used effectively as a subgrade material without being supplanted.

The expense of setting up the subgrade by supplanting the frail layers with a decent quality soil is higher than that of setting up the subgrade by modification in synthetic synthesis strategy [8]

Quick lime reacts with soil very quickly and holds the tendency to evaporate even additional moisture of clay. While the hydrated lime reacts comparatively slow and offers enough time to produce an acceptable compound to increase the strength by decreasing the moisture-holding capacity.

One of the most prevalent procedures [9] for updating the dirt of helpless properties to provide a functioning stage to development initiatives is the synthetic adjustment of clay using lime. A significant percentage of the Indian thruway framework is made up of adaptable asphalt. The California Bearing Ratio (CBR) test is an empirical method for determining the surface plan of an asphalt pavement [10].

Clay soil reflects the action of lime in two phases, the first of which (modification) unequivocally reduces the effect of moisture on soil caused by ion exchange between the soil and the addition. And “the second face (pozzolanic reaction) completely delivered for the strength accomplishment by creating a cementing product [12] occurred due to the formation of hydrated calcium aluminates (CAH) and calcium silicates hydrate (CSH)” [[11], [12] [[8], [13], [14], [15], [16]] studies the Quick lime (CaO), ingest water from the encompassing ground, making the lime swell and structures slaked lime, [$Ca(OH)_2$] according to the accompanying substance response.

$$Cao + H_2O \rightarrow Ca(OH)_2 + Energy$$
$$Ca_2 + 2(OH^-) + SiO_2 \rightarrow CSH$$
$$Ca_2 + 2(OH^-) + Al_2O_3 \rightarrow CAH$$

Clay composition in soil has limited to 80% for successful completion of soil stabilization with lime [17]. Further, expanding natural substance has been accounted for to impact the strength of the untreated clay by impeding the hydration cycle [18]. As to restoring, relieving is, significant for lime-treated dirt because the responses among lime and earth particles are time and temperature subordinate [19].

[20] with the increase in water amount in composite mix averts the bonding of lime and clay, as the rise in moisture content offers decrement in the permissible stress by accounting the shear scenario. Above the limited allowance of clay into the mixture might create the disappearance of clay particles. An increase in curing duration helps clay to attain sufficient cementing bond Particles were covered and consolidated by pozzolanic reactions, making voids in the dirt less noticeable. [21] Any moisture that gets into the soil has a tendency to increase the overall volume of the base, making construction more difficult. [8] Clayey soil trembled and lost its stiffness with a small amount of water, resulting in saturation.[22] the clayey soil response in a better way when the soil is blended and mix with slurry although the powdered lime also possesses the ability to enhance the properties. [15] study the combination of lime and volcanic ash and reported the use of lime is limited but appreciated [5] when used with some other additive.

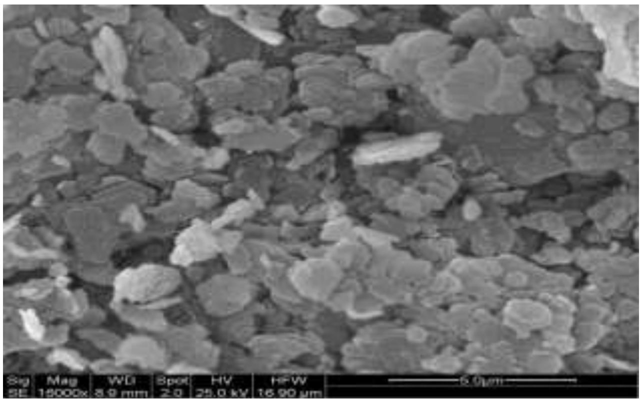

Figure 1. Scanning Electron Microscope of untreated clay [8]

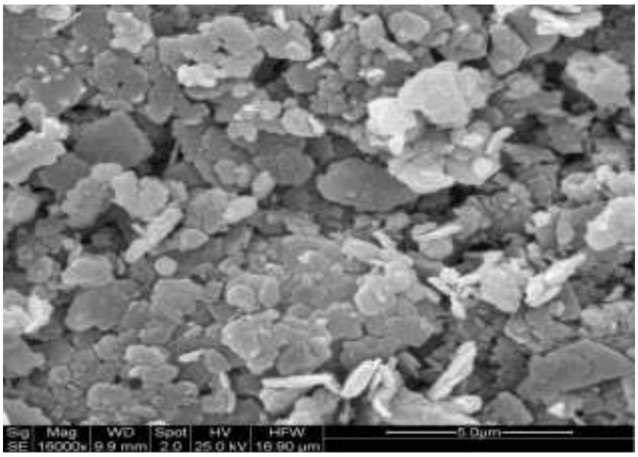

Figure 2. Scanning Electron Microscope of treated clay @ 28 days of curing [8]

II. RELATED WORK

The soil sample used in this study was collected from Basti Jodhewal in Ludhiana of India. And the lime is used in the present investigation is fine-grained hydrated lime (Ca $[OH]_2$) commercially used for the construction work. The hydrated lime used as slurry to stabilize; slurry is prepared with distilled water aftermath mixed with in-situ soil to go further treatment. The Atterberg limit was resolve without any curing of soil but the California bearing ratio and Standard proctor test were conducted in-situ as well with the curing of 48 hours of solidification. The soil sample for compaction test must pass through 4.75mm sieve and compact this soil sample in the 1000cc mould with 2.5kg rammer whereas the soil sample for CBR test must pass through 20mm sieve and retain at 10mm sieve, aftermath this obtained soil is compacted in 1500c.c mould with optimum moisture content. The series of soil samples with or without additives are prepared for conducting tests are well shown in table 1.

Study of the effect of lime on Atterberg’s limits was studied immediately after mixing whereas strength studies were carried out after 48 hours of curing. Following combinations of the soil samples, lime mixtures and hours of curing have been prepared for conducting various tests to study the effect of lime stabilization and days of curing on a soil sample. Curing of “0” Days attributes to the immediate tests.

The Index property and compaction tests are done on untreated as well on the lime-treated soil. The liquid limit and plastic limit are done under the Atterberg limit which gives evidence of enhancement in the stability of the soil. The Standard proctor and California bearing ratio tests are incurred under compaction characteristics. The liquid limit test is determined by a mechanical method using Casagrande’s apparatus or the standard liquid limit test apparatus. The liquid limit is incurring corresponding to the 25 blows. The compaction test is done with the standard proctor apparatus with the standard hammer of 2.5kg.

Table 1. Designation of various Mix Proportion

S. No.	Designation	Curing period (Hours)	Sample Mixture	
			Soil %	Lime %
1.	L0C0	0	100	0
2.	L3C0	0	97	3
3.	L6C0	0	94	6
4.	L9C0	0	91	9
5.	L12C0	0	88	12
6.	L3C48	48	97	3
7.	L6C48	48	94	6
8.	L9C48	48	91	9
9.	L12C48	48	88	12

***L0 stands for LIME PERCENTAGE and C0 stands for CURING PERIOD**

III. EXPERIMENT WORK/INVESTIGATION

A series of tests were done on the untreated as well on the treated soil. The treatment is done with the hydrated lime ($Ca(OH)_2$) and cure under controlled circumstances. The conditions are indicating favorable circumstances and help the soil to gain required strength by making it more workable so that the soil not gone under fluctuation any more under moving vehicle loading.

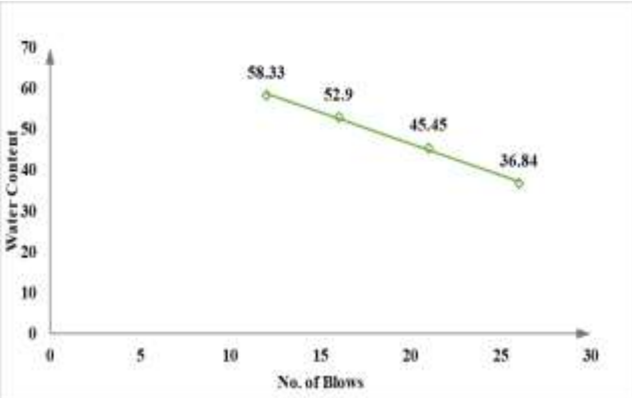

Figure 3. Flow curve for Un-treated Soil Sample

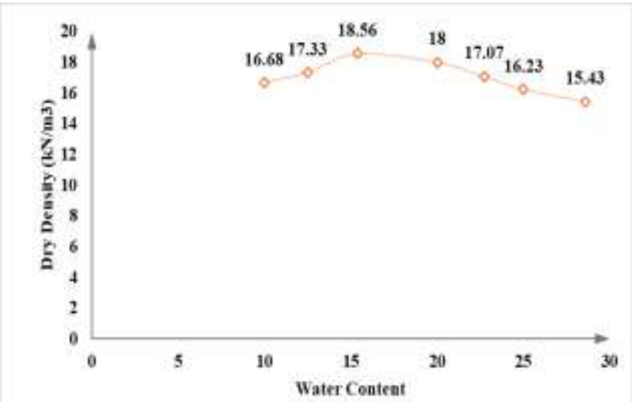

Figure 4. Compaction Curve of Un-treated soil sample

IV. RESULTS AND DISCUSSION

Effect of lime on Atterberg's limits

In geotechnical engineering, consistency limits are extremely essential in determining the physical department of soil. This covers the liquid, plastic, and shrinkage limits; however, the shrinkage limit is not discussed in this work in any way. The fact that natural moisture content exceeds the plastic limit indicates that the soil is wet and sticky, making it impossible to compact and posing a risk to moving vehicles. As a result, 3, 6, 9, and 12 percent lime by weight are added to a soil sample, which is then tested for consistency limits according to IS 2720 part-5 (1985).

The results indicated in Figure 3 clearly show that on the addition of 6% lime, LL reduced and PL significantly increased, hence reducing the plasticity index to the greatest extent. For increase of lime raised the plasticity index and hence this is the optimum quantity of lime required to be added for the stabilization process.

These outcomes happened as the dirt articles go through flocculation to shape totals. These total acts like particles of residue. The diminished pliancy records and the silty and friable surface of the combinations demonstrated advantageous changes in functionality. Fig. 4 saying all about the index property of the treated beside untreated soil.

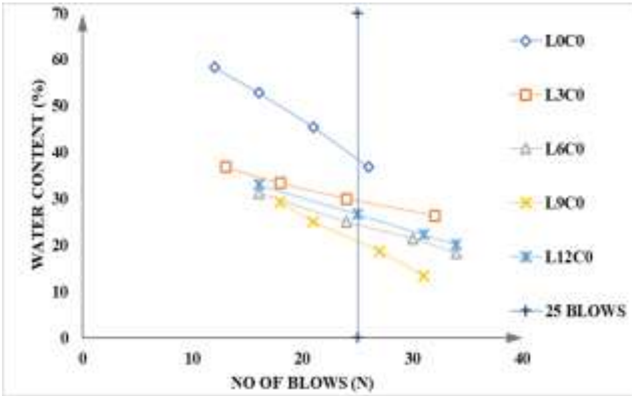

Figure 5. Flow curve of LL of in-situ soil and Various Mixes

As the clay particles flocculate to form aggregates, these outcomes occur. These aggregates act like silt particles. The decreased plasticity indices, as well as the silty and friable texture of the mixes, suggested that the workability had improved.

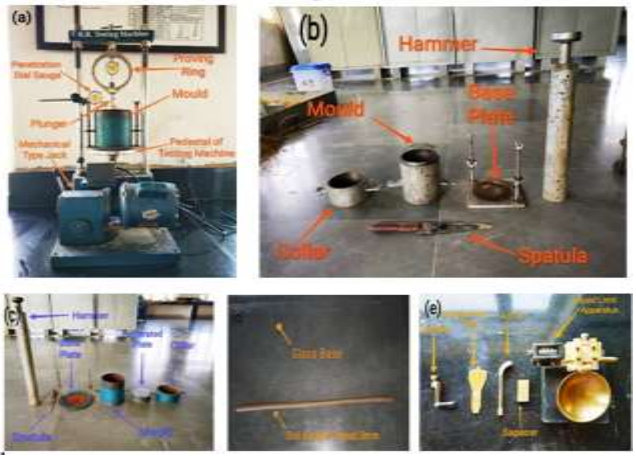

Figure 6. Apparatus used {(a) CBR test apparatus (b) Standard proctor Test for MDD and OMC (c) Modified Proctor Test for Compacting the CBR Test sample (d) Plastic Limit Test (e) Liquid Limit Test

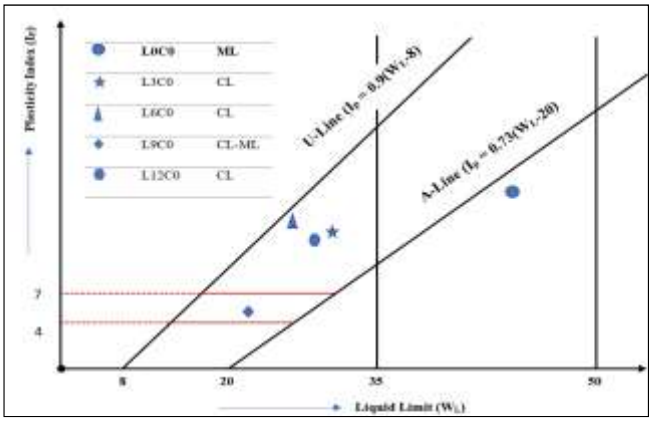

Figure 7. Classification of various soil sample

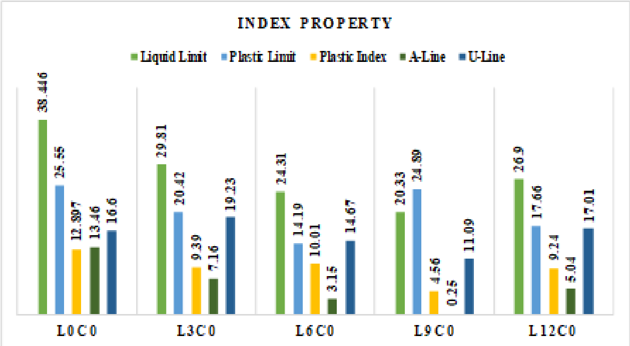

Figure 8. Plasticity Index with A-line and U-line for different soil mixes

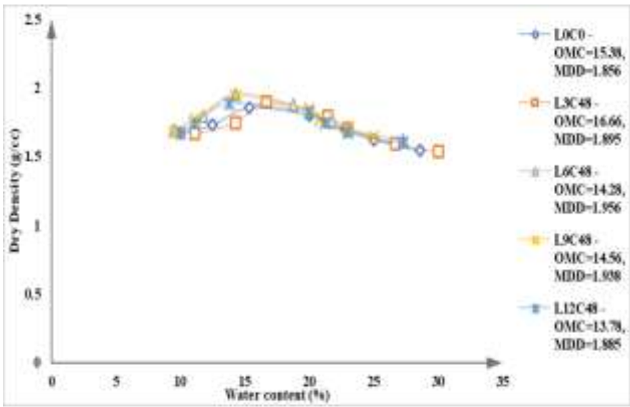

Figure 9. Flow curve of Compaction of in-situ soil and various mixes.

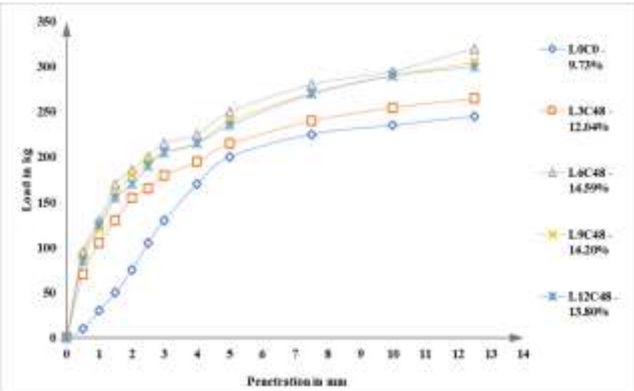

Figure 10. Flow curve of CBR test of virgin soil and various mixes

Classification of soil:

The classification of the soil was done by IS method that incorporates the use of plasticity index and liquid limit to distinguish the various category. In this present study, the classification is done for each lime concertation added while performing the strength test, the soil behaves as medium compressible (ML) when tested without the association of additive but it fluctuates between low compressible (CL) to medium-low compressible (CL-ML). After analyzing the complete classification of soil, it is crystal clear that with the use of hydrated lime the handling of clayey-soil getting easy as the compressibility lowers helps to compact sufficiently to attain maximum dry density.

Lime's effects on compaction properties include:

The addition of lime to clayey soil minerals raises their OMC while lowering their MDD. In the initial stages, the MDD is increasing and decreases with further intensifications in the lime percentage. The OMC is beginning cumulative from the initial stages and increases as the lime percentage increases. The characteristics of the soil, the amount of lime applied, the duration of curing time, and moisture content are all factors that impact the strength of cohesive soil. The load-holding capability of the sub-grade strata is directly stimulus by the additive used and the curing period of the soil. As the duration of solidifying heighten the bearing capacity increases and the soil revealing more resistance to the deformation that occurs due to the moving vehicle load.

Conclusion and Future Scope

It is seeming that all the properties of soil get enhanced but its rate of enhancement depends upon the circumstances, method of test, type of soil, and percentage of additive used. The plastic limit increases as the lime concentration increases, while the liquid limit drops, resulting in a reduction in the plasticity index. The clay minerals increase their (optimum moisture content) OMC and lower their (maximum dry density) MDD when lime is added, however when the proportion of lime is raised, the MDD increases and the OMC drops. The OMC lead off heighten from the primary phase and step-up to the concluding increment in the content of additive. The maximum dry density of 19.56 kN/m^3 is incurred at 15.04% optimum moisture content. The increase in duration length of the lime curing period increases the load-bearing capacity. The maximum California bearing ratio is incurred when the in-situ soil is treated with 6% of lime additive of a great extent. The stability of soil enhanced by the lime treatment is found to be 34.34%. With the addition of lime, clay content reduces significantly because of flocculation. The reaction between soil and lime enhances the properties and make soil particle of size greater than 2 microns. That’s why the use of lime is limited up to certain content**.**

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AUTHORS PROFILE

Aman Thakur graduated from Guru Nanak Dev Polytechnic College in Ludhiana with a diploma in civil engineering and is currently pursuing B. Tech. in civil engineering at GNDEC in Ludhiana, India. He is a student member of the “Universal Association of Civil, Structural, and Environmental Engineers”, USA;, “American Society of Civil Engineers”, USA; “Instituion of Civil Engineering”, U.K, Scientific member of "ScienceOpen" in Burlington, Massachusetts, and a Life Time member of "Eurasia Research" in India. He has “two” papers published in foreign journals. Soil standardisation, material science, and the utilisation of industrial waste in building are among his primary research interests.

Dhiraj Kumar graduated from Guru Nanak Dev Polytechnic College, Ludhiana with a diploma in civil engineering and is currently pursuing B. Tech. in Civil Engineering at the “North Eastern Regional Institute of Science and Technology” in Itanagar, Arunanchal Pradesh, India. He is a member of the “American Society of Civil Engineers” as a student.

Arnaw Pandey pursuing his B. Tech. in Civil Engineering from GNDEC, Ludhiana. He is a Scientific member of “ScienceOpen”, Burlington, MA, US. He has published “1” paper in an international journal. His main research works focus on IoT and Smart construction.

Ismit Pal Singh completed his B. Tech., and pursuing M. Tech, in Soil Mechanics & Foundation Engineering from GNDEC, Ludhiana, India. He belongs to the “Indian Society of Geotechnical Engineers” (Ludhiana Chapter). He is presently employed as a lecturer in Guru Nanak Dev Polytechnic College's Department of Civil Engineering. He has four research articles published in foreign publications and one conference paper. He has 1 year of industry experience and more than 7 years of teaching experience in civil engineering basic topics. Improvement of soil characteristics, shallow foundations, and waste material recycling are among his research interests.

