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# LABORATORY INVESTIGATION OF CLAYEY SOIL STABILIZED WITH CEMENT AND LIME

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Abstract: When the clayey soil comes in contact with water it expands and it behaves as a liquid by losing its strength. When it loses water from it, it shrinks. This property of expansive and shrinkage cause serious problems like formation of potholes, dilation problems etc in the cement constructed over this soil. This makes it unsuitable for construction of any civil structures. The soil contains mainly quartz and kaolinite which increases expansion characteristics of the soil. It does not possess any desirable engineering property and its behaviour is unpredictable, especially when the soil is fully saturated. Therefore construction on this type of soil requires special design and precautions, which leads to extra cost of construction. In this research soil is replaced with cement and lime by 3%, 6 %, 9%, and 11 %.

## **1.0 INTRODUCTION**

Soft soils show major volume changes due to change in the moisture content. This causes major damage to property constructed on it. These soils contain minerals such as montmorillonite that are capable of absorbing water. When they absorb water their volume increases. Although mechanical compaction, dewatering and earth reinforcement have been found to improve the strength of the soils, other methods like stabilization using admixtures are more advantageous. The different admixtures available are lime, cement, fly ash, blast furnace slag etc. At present cement stabilization nowadays is not preferable because of the increasing cost of cement and environmental concerns related to its production. Lime is also not suitable for a soil which contains sulphates. Presence of sulfates can increase the swelling behavior of soil due to the formation of swelling minerals such as ettringite and thaumasite

The term soil stabilization means the improvement of the stability or bearing power of soil by the use of controlled compaction, proportioning and or the addition of suitable admixture or stabilizer. Soil stabilization deals with physical, physico-chemical and chemical methods to make the stabilized soil serve its purpose as pavement component materials.

The basic principles in soil stabilization may be stated as follows:

- Evaluating the properties of given soil
- Deciding the method of supplementing the lacking property by the effective and economical method of stabilization
- Designing the stabilized soil mix for desired stability values.
- Considering the construction procedure by adequate compaction of stabilized layers. Soil stabilization may result in any one or more of the following changes:
- Increase the drain ability of the soil
- Increase stability
- Reduce volume changes
- Control the undesirable effects associated with clay.
- Reduce settlement
- Increases sharing resistance
- Increases the bearing capacity of soil.
- Improving the local soil

This can be achieved by mechanical (or) chemical methods to make the soil stabilized for fulfilling its purpose as pavement component material. Soil type is one of the key features used to determine which method and material should be used for achieving best compaction.

# **1.1 MECHANICAL STABILIZATION**

The Objective of mechanical stabilization is to blend different available soils so that when compacted, they give the desired stability. In some areas the natural soil at an existing location may have weak in nature (poor CBR). It may due to clay, silt or fine sand. Suitable soil may be selected (contains granular material) and this is to be blended with the available soils to improve the soil properties at a lesser cost in manpower and materials to achieve best results (Increase of CBR). The mechanical stability of soil-aggregate mixtures depends upon the mechanical strength of aggregate, the mineral composition of the materials, the gradation of the mixture, the plasticity characteristics of the binder soil and the compaction. With respect to mineral composition, any material which is resistance to weathering can be used.

Sodium sulphate and sodium carbonate have a detrimental effect on the stability because of their high volume changes caused by hydration and dehydration. Presence of chlorides and carbonates are beneficial.

## Factors affecting mechanical stability:

The stability of mechanical stabilized soil mixes depends on the following factors: Mechanical strength of aggregates, gradation, properties of soil, presence of salts, mica etc and compaction.

## Limitation of mechanical stabilization:

- Original soils contains fines, use of coarser fractions for blending may be expensive
- If clay has been added to "Stabilize" soils, it should be susceptible to frost action.
- Creation of dust clouds results in nuisance to traffic
- Reduction of soil cohesion (or) binding forces ultimately leads to material disintegration.

## **1.2 APPLICATIONS**

For geotechnical and environmentally purposes, the typical application of deep mixing methods can be grouped into two main categories:

- 1. Non-structural purposes
  - Ground cutoff wall
  - Dewatering wall
  - Containment of contaminants
  - Secondary containment
- 2. Structural purposes
  - Deep and shallow foundation
  - Tunnel and Retaining wall (stabilization of cuts and open excavation)

## 2.0 LITERATURE REVIEW

Marasteanu et al. Conducted resilient modulus and tri-axial tests on two soils which were stabilized with two different enzymes. Soil-I has 96% of fines (75% of clay) a SPG of 2.73 and plasticity index of 52%. Soil-II has 60% of fines (14.5% of clay) and plasticity index of 9.4%. Chemical analysis of only one enzyme (A) was conducted, as the supplier of the other enzyme (B) did not agree for this. The chemical analysis for the enzyme included pH, metals concentrations (e.g., Ca, Fe, and Al), total organic carbon concentration, and inorganic anion concentrations (e.g., Cl-, NO3- and SO4 2-). The pH of product A was 4.77 and had very high concentration of potassium (K), and moderate to high concentrations of calcium (Ca), magnesium (Mg), and sodium (Na). The metal concentration and inorganic anion concentration are given in Tables 1 and 2. The tests were conducted on a base (Base-1) as well to compare the results. The protein concentration in the undiluted product A was 9230 mg/L. The presence of protein alone does not indicate that the solution will exhibit enzymatic activity therefore enzyme activity tests were conducted and it was found that the product A exhibited no detectable enzymatic activity for the used substrates. This indicates two possibilities: Product A is a highly purified enzyme solution that contains only a single enzyme or group of enzymes that catalyze reactions not tested for in our experiments or product A may not stabilize soil via enzymatic activity but rather via some other mechanism, possibly due to their surfactant-like characteristics. Milburn & Parsons Conducted different tests (freeze-thaw, wet-dry, leach testing, Atterberg's limits and strength tests) on soils (classified as CH, CL, ML, SM, and SP) stabilized with lime, cement, Class C fly ash, and Permazyme 11-X. Compaction, Unconfined compression, stiffness, freeze-thaw, wet-dry and leaching tests were conducted on two silty soils (ML and SM) treated with Permazyme 11-X at a dosage recommended by the supplier. ML and SM soils had fines 88 and 30%, LL 30 and 20% and PI 7 and 3% respectively. Compaction test for treated soils was carried out at moisture content 1% less than the optimum. But only 4% and 1% increase in dry density was found for ML and SM soils respectively. The soil samples for two soils after 28 days of curing were tested for stiffness and no improvement was recorded. Similarly for freezethaw very modest improvement and for wet-dry and leaching tests no improvement was observed.

**J.Ranjitha et al** investigated on the improvement of subgrade characteristics of expansive soil stabilized with nailing technique. In this study an attempt is made to use the concept of ground improvement technique for stabilizing the black cotton soil Subgrade by driving nails. No fines concrete tapered nails in the form of geonails are driven into the subgrade soil at an inclination of 90q. These nails are preferred as they are corrosion resistant in comparison with reinforced steel. The diameter and height is varied to get geonails of three different dimensions. California Bearing ratio and the load settlement characteristics by miniature plate bearing test is analyzed. The number and spacing of the nails is varied to determine the effect of group efficiency on overall improvement in the strength of the subgrade.

Seyedesmaeil Mousavi et al studied on the utilization of Brown Clay and Cement for Stabilization of Clay. This paper investigates the utilization of brown clay and cement in order to stabilize soft clay. Brown clay mixed with a suitable amount of cement paste is capable to impart filler and pozzolanic effect. Therefore, the mechanical behavior of the soil would be improved. Treatment of fine grained soils with cement is not novel. While stabilization of fine grained soil with brown clay has not been completely investigated, this paper attempts to assess the mechanical behavior of treated

soil with cement and brown clay. Laboratory investigations include direct shear, vane shear, unconfined compression and CBR tests which were applied on the test specimens. In addition, laboratory compaction test was performed to supply the soil specimens with optimum moisture content and maximum dry density. The outcome of the study is an optimal mix design of stabilized clay, which can be applied to improve soft clay. For the optimal mix design, binder composition of cement 8.5%, brown clay 1.5%, and silica sand 5% was obtained. Therefore, input cement can be saved due to partial replacement of ordinary Portland cement with 1.5% brown clay.

**Mrs. Shruthi.P.J et al** studied on the behaviour of Lithomargic Clay with Various Admixtures. In this research the soil has been stabilized by adding flyash, cement and lime in varying percentages by weight of soil. Various tests have been carried out to determine the strength properties such as specific gravity, consistency limits, compaction tests and CBR tests. The addition of cement has proved the process uneconomical. The addition of lime and flyash has showed improvement in the strength.

**Rashmi Bade et al** investigated on expansive Soil Stabilized with Groundnut Shell Ash. The main objective of the soil stabilization is to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for pavements or structures. In this paper an organic waste product which is readily available and is quite effective and cost friendly is used. The material used is the shell of groundnut which is easily available waste product in every household. The tests have shown that it increases the strength of soil effectively without affecting the foundation of the structure; Atterberg's test, proctor test and its specific gravity test have shown that the material used for stabilization is highly soil friendly and effective for civil engineers who have major problems dealing with expansive soils.

**Suksun Horpibulsuk et al** analysed on the strength development in cement-stabilized silty clay from micro structural considerations. This paper analyzes the strength development in cement-stabilized silty clay based on micro structural considerations. A qualitative and quantitative study on the microstructure is carried out using a scanning electron microscope, mercury intrusion pore size distribution measurements, and thermal gravity analysis. Three influential factors in this investigation are water content, curing time, and cement content. Cement stabilization improves the soil structure by increasing inter-cluster cementation bonding and reducing the pore space. As the cement content increases for given water content, three zones of improvement are observed: active, inert and deterioration zones. The active zone is the most effective for stabilization where the cementitious products increase with cement content and fill the pore space. In the active zone, the effective mixing state is achieved when the water content is 1.2 times the optimum water content.

**Magdi M. E. Zumrawi et al** studied on the expansive Soil Stabilized with Calcium Chloride. In this study, an attempt has been made to evaluate the influence of Calcium Chloride (CaCl2) stabilizer on the engineering properties of expansive soil. A series of laboratory experiments including consistency limits, free swell, compaction, and shear strength tests were performed to investigate the effect of CaCl2 additive with various percentages 0%, 2%, 5%, 10% and 15% for improving expansive soil. The results obtained shows that the increase in the percentage of CaCl2decreased the liquid limit and plasticity index leading to significant reduction in the free swell index. This, in turn, increased the maximum dry density and decreased the optimum moisture content which results in greater strength. The unconfined compressive strength of soil stabilized with 5% CaCl2 increased approximately by 50% as compared to virgin soil. It can be concluded that CaCl2 had shown promising influence on the strength and swelling properties of expansive soil, thereby giving an advantage in improving problematic expansive soil.

#### 3.0 EXPERIMENTAL METHDOLOGY

This research details the various tests conducted in the laboratory in order to study the characteristics of sub-base material. In the present study, samples were collected to assess the suitability of cement & lime as soil stabilizer on clayey soil. Various laboratory and experimental work have been carried out in the present investigation. The work includes four different soils with different liquid limit, different quantity of clay content and one additive. Specimens were prepared at three different dosages of the additive and cured up to 7, 14 and 21 days. The tests on stabilized soil were conducted at 7 day intervals. All experiments were carried out as per the standard procedures described in the Bureau of Indian Standards. In this research soil is replaced with cement and lime by 3%, 6 %, 9%, and 11 %.

#### 4.0 RESULT & DISCUSSION

#### **GEOTECHNICAL PROPERTIES OF SOIL**

The properties discussed include Atterberg's limits, the different densities, particle size distribution, permeability, and the parameters related to consolidation and shear strength. The tests required to obtain these parameters are also discussed. The tests conducted at laboratory to know the various Geotechnical properties of clayey soil is discussed in this section. The various geotechnical properties of soil are discussed in table 4.1.

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Laboratory tests	IS code Standards –	Soil sample name					
		<b>S1</b>	S2	<b>S</b> 3	<b>S4</b>		
Sp. Gravity	IS-2720 (Part3): 1980 Sect/2	2.63	2.75	2.84	2.81		
		Grain size di	istribution				
Sand (%)		4	6	2	60.1		
Silt (%)	IS-2720 (Part4):1985	17	11	8	35.4		
Clay (%)		74	85	91	38.3		
Liquid limit (LL)		53.60	68.85	78.54	29.8		
Plastic limit (PL)	IS-2720 (Part VII): 1972	34.85	36.87	46.84	18.98		
Plastic Index (PI)		21.25	33.65	38.74	5.87		
Shrinkage limit		12.43	8.47	7.32	14.58		
IS soil classification		СН	СН	СН	ML		
Compaction Characteristics							
(MDD) kN/m3	IS-2720	15.84	14.85	14.54	17.84		
<b>OMC</b> (%)	(PartVII): 1980	18	20	18	12		

## CALIFORNIA BEARING RATIO TEST

Soaked CBR test was conducted by mixing the soils at soaked condition. Predetermined quantity of water is mixed with cement and lime was added corresponding to optimum moisture content by standard proctor's test for the mix, mixed thoroughly. These mixes were compacted in CBR mould to maximum proctor's density. Two identical specimens which were prepared as per IS code 2720- PART XVI, kept in air tight bags for testing 7, 14 and 21 days curing and was soaked in water for 96hours before testing of curing period, then tested for CBR. The following Fig. 1 and figure 2 graph of soaked CBR (%) virus soil sample represents effect of enzyme reacting on the soils at different curing period. The Table 1 provides the details of soaked CBR test results of effect for soil samples.

Table 1: CBR values of various mixes								
Soaked CBR values in %								
Dosage	3	%	6	5 %	9	%	11	[ %
Stabilizer	Lime	Cement	Lime	Cement	Lime	Cement	Lime	Cement
CBR in % at 2.5 mm Penetration	4.28	4.54	4.78	4.89	6.58	6.87	5.32	5.87
CBR in % at 5 mm Penetration	4.41	4.75	5.30	5.84	6.21	6.42	5.79	5.21



Figure 1:	Effect	of Lime	on CBR	Value
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## CONCLUSION

In this paper, various percentages of Ordinary Portland Cement (OPC) and Lime were mixed with the soil specimen and compacted at optimum moisture content. The compacted soil specimen with maximum dry density and optimum moisture content was tested under unconfined compression and CBR tests. The following conclusions are drawn from this study:

- Results of analysis reveal lime clay mixed with cemented soil influences the shear and unconfined compressive strength of the soil specimen.
- The optimal mix design of stabilized soil was determined for binder composition of OPC 11 %, Lime 11 %.
- It is observed that replacement of soil with cement is more effective than the lime.
- The optimum value for CBR is 9 % for both materials lime and cement.
- A slight decrease in CBR value is noted in 11 % replacement with lime and cement.
- Specific gravity increases with increase in percentage of additives.
- Liquid limit decreases as the percentage of replacement increases and plastic limit varies with varying percentages of replacement of lime and cement.
- Optimum moisture content is obtained at 11% replacement of additives.
- CBR is highest at 9% replacement of lime at soaked.
- With cement combination CBR has increased at 09% replacement at soaked condition.
- The replacement of cement does not show better improvement till 6% replacement and also it makes the process uneconomical.
- Lime has proved to be a very good additive to be replaced by exhibiting its increasing strength properties with soil.
- Hence it is proved that clayey soil increases its strength if stabilized with certain additives and it can be successfully used in construction field.
- It can be concluded that the by the decrease in plasticity index and increase in dry density improves the bearing capacity of clayey soil.
- As the amount of lime and cement are increased in tested (treated) soil samples, the value of plastic limits tends to increase.
- The improved PI value is due to addition of lime and cement as admixtures to the clayey soil.

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