Study on Marine Clay Replaced with Sodium Lignosulfonate and Cement

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***Abstract*— Marine clay is identified as the one with high organic content and as an expansive soil which shrinks and expands rapidly causing damage to foundations. Many stabilizers are used to improve its strength and other engineering properties. This paper presents the modification of modulus of elasticity in terms of E/q_u with strain for marine clay stabilized with sodium lignosulfonate and it is compared with cement treated clay. It was observed that for an optimum percentage of lignosulfonate (5%) there has been significant increase in unconfined compressive strength. The variation of E/q_u with strain showed that the failure strain of lignosulfonate treated soil is more than that of cement treated clay and thus makes it less brittle. Traditional admixtures such as cement and lime are found to cause brittle nature in soil and also induce toxicity to the soil to a level that vegetation on the land is affected. The usage of lignosulfonate has found to be a solution to this problem. In order to validate the above parameters of lignosulfonate treated soil, electrical conductivity test was conducted. It was observed that for lignosulfonate treated soil the value of electrical conductivity decreased over 7 days curing while cement treated soil showed increase in EC over the curing period of 7 days and remained the same even after 28 day curing. This indicated the presence of unstable compounds in cement treated soil and thus proves that lignosulfonate treated soil are non-toxic and less brittle.**

Keywords*— *Marine clay, Sodium Lignosulfonate, Unconfined Compressive Strength, Electrical Conductivity

I. INTRODUCTION

Marine clay is a type of soil found in coastal regions around the world. They are microcrystalline in nature and clay minerals like chlorite, kaolinite and illite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent. It possesses many unique physical properties such as high liquid limit, plastic limit, high swelling characteristics and high seepage loss. Due to these properties, construction on this soil has been very difficult and tedious. The infrastructure and construction industry is booming at an alarming rate and this calls for greater utilization of all the land available. Most of the construction works done on coastal areas are often slowed down due to the presence of large volumes of unwanted marine clay which are found at greater depths. As the marine clay is very susceptible to changes in moisture content, they are often observed to be unstable beneath pavements. They tend to swell when they are wetted, and shrink and become hard when they are dried. India has a large area which comes under coastal areas such as West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat. The engineers are thus now looking for various methods to stabilize the soil available and also to reuse them for various purposes such as fill materials for land reclamations. Marine clay has very low compressive strength and thus makes it unsuitable for supporting foundations of high rise buildings. With the advancement of research and technology, many stabilizers are used to improve these engineering properties of marine clay. The traditional admixtures used such as lime and cement alter the pH value of the soil which results in ground water pollution and also reduces the chances of re-vegetation on that land. Apart from these environmental issues, their usage also imparts brittle behavior to the treated soil making it vulnerable to structures subjected to cyclic loadings such as rail embankments and aircraft runways. These problems highlight a need for an ecofriendly stabilizer that improves the engineering properties of marine clay. The effectiveness of sodium lignosulfonate as a stabilizer is discussed in this paper.

A. Sodium lignosulfonate and cement as a stabilizer

Sodium lignosulfonate is a lignin based polymeric compound containing both hydrophilic groups including sulphonate, phenylic hydroxyl, and alcoholic hydroxyl, and hydrophobic groups including the carbon chain. As discussed above, it is a waste product from paper industry and its chemical properties such as molecular weight depends on the wood from which it is derived which varies from 4600 to 398000 g/mol. Studies conducted showed that these are soluble on soils with wide range of pH values. The stabilization process of lignosulfonate on soil is mainly based on the electro static reaction process which is basically attraction or repulsion between two charged ions. The lignosulfonate mainly comprises of positive ions and these reacts with the negative ions present in clay minerals to form stable aggregates by reducing the double layer thickness of clay particles.

The stabilizing action of cement is mainly due to the cementatious products from during hydration. The formation of calcium silca hydrates and calcium alumina silca hydrates imparts long trem strength to the treated soil by altering its physico-chemical properties. The addition of cement on soil imparts brittle behaviour of soil and also pollutes the ground water.

B. Literature review

Lignosulfonate is a lignin based product and is obtained as waste product from paper industry [1]. Lignosulfonate can

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be regarded as poly-electrolyte that establishes electrostatic stabilization for colloidal systems [2]. Sodium lignosulfonate is observed to increase strength and failure strain and thus makes it less brittle. Marine clay is a type of soil with high organic content and liquid limit.

C. Methodology

The whole study was divided into four main parts i.e. literature review, sample collection, laboratory tests and result interpretation. As the first step, literature review was conducted to study the scope and relevance of the topic. The sample was then collected, and surface dried. All the preliminary tests were then done on the sample to find its physical and engineering properties. The third step was the determination of mix proportions of the samples to be prepared to obtain the desirable properties. The results were then analysed properly and the optimum percentage of lignosulfonate was then concluded.

II. MATERIALS AND METHODS

A. Marine clay

The marine clay was collected from the outskirts of Palluruthy, Fort Kochi. Most of the Greater Cochin area, which is undergoing rapid industrialization, consists of extremely soft marine clay calling for expensive deep foundations.

B. Sodium lignosulfonate

Sodium lignosulfonate is derived from wood as is obtained as waste product from paper industry. For the purpose of this study, it was obtained from S.V Enterprises Mumbai. The chemical properties of lignosulfonate as given by the company are as listed in Table 1.

Table 1. Properties of Sodium Lignosulfonate

PROPERTIES	STANDARD VALUES	TEST RESULTS
Appearance	Yellow Brown Powder	Meets the requirement
pH Value	9-11	9.48
Dry Matter	92%min	93.40%
Moisture	6%max	4.42%
Water insoluble matter	2.8%max	1.64%
Total reducing matter	4% max	2.13%
Conclusion	Complies with	Standard requirements

C. Methods

The color and odor of the marine clay sample was noted to analyze its physical properties. The preliminary tests were then conducted on the sample to determine its engineering properties. The various properties such as determination of its liquid limit, plastic limit, specific gravity and dry density were determined. The liquid limit was determined using Casagrande's apparatus and results showed a high value, validating the property of marine clay. Plastic limit was found by following the procedure enlisted in IS: 2720 (Part 5) – 1985. The standard proctor test was conducted to determine the optimum moisture content and dry density. Specific gravity of the sample was found using density bottle test. The unconfined compressive strength of soil was found using UCC test and the result showed that the soil has low compressive strength. The electrical conductivity of the soil treated with different proportions of soil sample was determined in 1:5 (soil: water) suspension to find out the ionic concentration of pore fluid in soil matrix. The soil-water suspension was prepared by mixing 10 g air-dried soil (<2 mm) with 50 ml de-ionised water. The soil-water mixture was then stirred with a magnetic stirrer for 10 minutes to completely dissolve the soluble salts in water. Then the EC of soil suspension was measured with an electrically conductivity meter. The results of the preliminary tests conducted are as shown in Table 2.

Table 2. Properties of Marine clay

PROPERTIES	TEST RESULTS
Colour	Grey black
Specific gravity	2.6
Liquid limit	66%
Plastic limit	46.67
Sand	1%
Silt	36%
Clay	63%
Max dry density	1.217g/cc
Optimum moisture content	40%
Unconfined Compressive Strength (q_u)	8.46 KN/m^2
C value	4.23 KN/m^2
Electrical conductivity	1780 µS/cm

III. RESULT AND DISCUSSION

A. Unconfined compressive strength

The test was done to find the compressive strength of sample with lignosulfonate treated as well as cement treated clay. The results obtained gave the optimum content of stabilizer to be added to obtain maximum compressive strength. A 52.4% increase in strength was observed for 5% LS treated marine clay. The values obtained for various mix proportions is as recorded in Table 3. The variation of E/q_u with strain was plotted as shown in Fig 1. It was observed from this that the failure strain for lignosulfonate treated soil is more than that of cement treated soil. This indicates that addition of lignosulfonate to soil makes it less brittle when compared with that of cement.

B. Electrical conductivity

The electrical conductivity of soil samples for different proportions of stabilizers were noted using electrical conductivity meter. It was observed that the EC for LS treated soil decreased for a curing period of 7days and remained almost constant for further curing (Fig 2). This indicated the formation of clay mineral-lignosulfonate amorphous compounds, which are stable in contact with water and thus form stable soil aggregates. While EC for cement treated soil increased for initial 7 days and remained constant there after (Fig 2). The increase of EC with 2.0% cement indicated the existence of excess ions in the pore fluid. The excessive amount of cementitious compounds produces reticulation (opening structure) resulting in the reduction of modulus and failure strain and thus exhibits brittle behavior. Electrical conductivity is also an important

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method to determine the fertility of soil. Lower the value, lesser amount of fertilizers are to be provided. Ideal value of electrical conductivity of soil to be used for vegetation lies between 1800- 2200 µS/cm. Thus from Fig 2 we can conclude that addition of LS is non- toxic to the soil.

Table 3. Unconfined Compressive Strength(q_u)(28 day curing)

% STABLIZER ADDED	UNCONFINED COMPRESSIVE STRENGTH (q_u) KN/m^2	COHESION KN/m^2
0%	25.4	12.7
2%LS	24.6	12.3
4%LS	28.9	14.45
5%LS	38.7	19.35
2%CEMENT	48.5	24.25
4%CEMENT	31.4	15.7

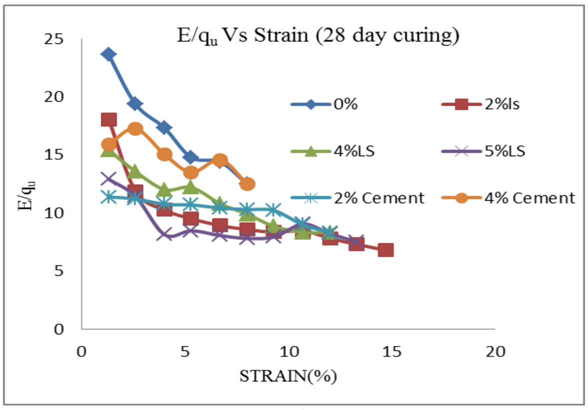

Fig 1. Variation of E/q_u with strain

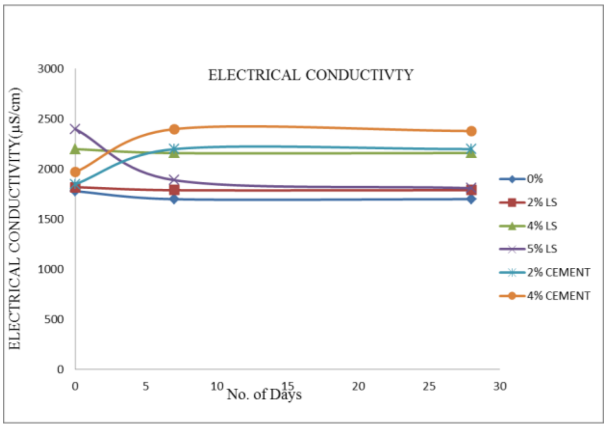

Fig 2. Electrical conductivity test results

CONCLUSIONS

The marine clay treated with sodium lignosulfonate and cement was tested for determining its engineering properties. An increase of 52.4% in compressive strength of lignosulfonate treated marine clay was observed. The plot showing variation of modulus of elasticity with strain showed an increase of failure strain for lignosulfonate treated soil when compared with cement treated soil which proved that LS treated soil is less brittle when compared with cement treated soil. Electrical conductivity tests conducted showed that lignosulfonate treated soil are non- toxic and re-vegetation on the land is possible, whereas cement treated soil has been observed to make the soil more toxic.

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