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A Study of Reaction Products in Soft Clay- Lime Mixture

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Abstract: *The deep deposits of highly compressible marine soils cover vast areas along the coastal belt of the Indian peninsula. These are very soft and contain large amount of shells. They possess low shear strength and high compressibility thereby causing larger settlements when structures are constructed in these soft soils. Many attempts were made in the past to improve the engineering properties of marine soil but still it is difficult to stabilize these soils. A laboratory investigation has been carried out by mixing the hydrated lime with soft marine clay at different proportions of 2%, 5% and 7% by weight of marine clay in the presence of sea water and distilled water separately. The mineralogical variations with XRD and fabric studies of marine clay are presented at curing periods of 10 and 40 days. The new minerals and reactive products formed by treating the soil with lime have been identified using XRD studies. A use of the SEM shows the increase in particle size and formation of flocculated structure in presence of sea water as well as distilled water.* *A use of the SEM shows the increase in particle size and formation of flocculated structure in presence of sea water as well as distilled water.*

Keywords: *Lime, Marine Clay, Soft Clay, Sea water, Distilled water*

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I. Introduction

The safety and economy of any construction depends to a large extent on the choice of a suitable substructure or foundation. This is intricately related to the soil deposit in which the construction is made. The nature of sub soils plays an important role on ultimate choice of foundation. Marine clay as foundation soil is meeting all over the world along the coastal plains, being deposited under marine environment. Marine clays by their very nature are highly compressible and posses low shear strength. The soil around Visakhapatnam is mostly marine clay. Many structures like dry docks, heavy bridges, roads and airport pavements are being constructed over the marine clay and causing large settlements and thereby instability to the structures. They give rise to problems of stability and settlement even under small super imposed loads. So, there is a need to improve the physical and engineering properties of marine clay. The mechanics responsible for the changes in the engineering properties are 1. Cation exchange 2. Flocculation 3. Carbonation reaction 4. Pozzolanic reaction. The first two reactions occur immediately after adding lime. Increase in soil workability results from changes in electrical changes of clay minerals, the other two are time bound and temperature dependent cementation reaction that produce increase in bearing strength and is a long term reaction. This lime stabilization is a success in the field of Highways and Airfield. This technique is now being extended for deep in situ treatment of clayey soils to improve their strength and reduce compressibility Eades and Grim [1]. In this investigation, an attempt has been made to bring out that the lime treatment can improve the engineering behavior of the soft clay and the improvements are attributed to certain physical and chemical changes occurring in this system. The new reaction products formed have also been identified using x-ray diffraction studies. Scanning electron micrographs have also been used to bring out the changes in soil fabric and the strength characteristics are found out by using laboratory vane shear test. Objective of the study is the effect of lime on the physical, chemical and engineering properties of the soft marine clay.

II. Literature Review

Soft and sensitive soils are encountered mostly in the coastal regions of Canada, Norway, Sweden, India, Japan, and several other countries. India has 6000km along coastal line stretches along nine states .in India , the contention shelf is very wide on the west coast , more than 200km at Bombay. High and is quite narrow on the east coast 30km in madras and 40km at Visakhapatnam. Understanding and predication of the engineering properties of clayey soil is vital importance in geotechnical engineering practice soil is a three-phase system, consisting of solids, liquids and gases. The mechanical properties of soils are derived directly from the interactions of the three phases with each other and also with applied potential like stress, hydraulic head etc……

III. Effect of Sea Water On Engineering Properties

It is important to know the mechanisms that control the engineering behavior of clays. Sea water chemistry and clay mineralogy have a significant effect on this behavior. Changing the pore fluid can cause reorientation of particles due to electrical attractive and repulsive forces. In addition to pore fluid clay mineralogy, is every significant on discussing the engineering behavior.

Yeliz Yukselen, Ali Hakan Oren and Abidin Kaya [7] examined seawater effect was investigated onto the soils having different mineralogical origins collected from different parts of Turkey. The obtained results showed that 50% liquid limit is the critical value for soils having different mineralogy. Despite negligible changes are observed on the liquid limit of soils lower than 50%, sea water causes no noticeable alterations in the hydraulic conductivity and undrained shear strength of soils in comparison with distilled water. However, pore liquid becomes more important on the soils having liquid limit higher than the 50%. Thus, hydraulic conductivity of soils, when pore medium was sea water, measured 10 times higher than that of distilled water. On the other hand, the undrained shear strength of distilled water treated soils was found higher than that of seawater treated soils at any water content. The results indicated that diffuse double layer surrounding the clay particles have an important role for the swelling clays. While treated with seawater, double layer compress and as a result of Vander Waals attractive forces, flocculated structure forms. Therefore, hydraulic conductivity increases, whereas undrained shear strength decreases.

Yong and Warkentin [6] have reported that the liquid limit and plastic limit values for different types of clays with different salt concentrations. In the case of montmorilontic soil increases in salt concentration decreases liquid and plastic limit values while the response of kaolinitic was opposite to that of montmorilontic (Sridharan et al [3]) have corroborated that the liquid limit of montmorilontic soils is controlled by thickness of the diffuse double layer and primary cation controlling the double layer is sodium.

A. Sridharan, S.M. Rao and S. Chandrakaram [4] studied on pore salt removal ,cochin marine clay attains a high equilibrium void ratio for a given pressure ,whereas no change was observed for Mangalore marine clay because of it low pre salinity .Secondary compression for undisturbed clays are relatively high because of its flocculent fabric .permeability coefficient seems to be unaffected on pore salt removal for both the clays .the naturally absorbed catons were displaced by ammonium ions, on successive treatment of the washed clay with neutral in ammonium acetate solutions. The displaced calcium, sodium, potassium and magnesium ions were measured using atomic absorption spectrophotometry. On pore salt removal shrinkage limit was found to be decreased.

A. Sridhram, S.M. Rao and S. Chandrakaram [5] studied that Mangalore clays it is well known that the removal of pore salts will eventually increase the diffuse double layer thickness. If montmorilontic clay mineral is predominant in the natural clays and increase in diffuse double layer thickness should increase the liquid limit.

IV. Methodology

Introduction

This section includes a brief description of the materials used, experimental procedures adopted, investigations carried out and methodology adopted during the course of this study are presented.

Materials used

- Marine clay
- Hydrated lime
- Sea water
- Distilled water

Marine clay

The marine clay used in this study was collected from air port, Visakhapatnam. This soil is collected from a depth of 2.5m below the ground level in a disturbed state. The soil used for this investigation is oven dried and sieved through 425 μ IS Sieve in the laboratory.

Sea water:
The sea water is collected from Rushikonda beach area and used directly without any filtration. The chemical properties of the sea water are furnished in the table 1.

P^H	7.9
Salts	35 gm/lit
Chlorides	19.3 gm/lit
Sulphates	2.69 gm/lit
Carbonates	0.073 gm/lit
Calcium	0.42 gm/lit
Potassium	0.39 gm/lit
Magnesium	1.34 gm/lit
Sodium	10.7 gm/lit

The variables are the two types of water and lime percentage increasing from 2% to 7% with curing time of 40 days in all tests carried out in this study.
(i). Grain size analysis, Atterberg limits, differential free swell, certain exchange capacity and vane shear test are performed as per I.S code.
(ii). X –ray diffraction (XRD) is used to study the clay and non- clay minerals present.
(iii). Scanning electron micrograph studies is used to study the micro structural (fabric) variations.

V. Results

The engineering and chemical properties of soft (marine) clay are given in table 2 and 3, respectively. The results of various parameters mentioned below in the (table 2) are analyzed and important conclusions are mentioned in the next sections (conclusions).

Table 2 Physical properties of soft marine clay

1	Gravel (%)		0
2	Sand (%)		17
3	Silt (%)		37
4	Clay (%)		46
5	Liquid Limit (%)	WL	69
6	Plastic Limit (%)	WP	33
7	Plasticity index (%)	IP	36
8	Soil classification		CH
9	Specific gravity	G	2.56
10	Optimum moisture content (%)	OMC	25
11	Natural moisture content	NMC	60%
12	Maximum dry density	Υ_d max	1.54
13	Free swell index		80
14	Vane shear strength (kg/cm^2)		0.02

Table 3 chemical composition of soft marine clay

1	P^H		4.21
2	Cation exchange capacity (meq/100gm))	Without curing	80
3	Cation exchange capacity (meq/100gm))	After 40 days curing	90
4	Calcium carbonate (%)	$CaCO_3$	1.08
5	Iron Oxide (mg/g)	$Fe2O_3$	0.0012
6	Chlorides (%)		2
7	Aluminum Oxide (mg/g)		0.0002
8	Organic matter (%)		3.4
9	Total soluble solids (%)		2.78
10	Sulphates (%)	SO_4	0.98

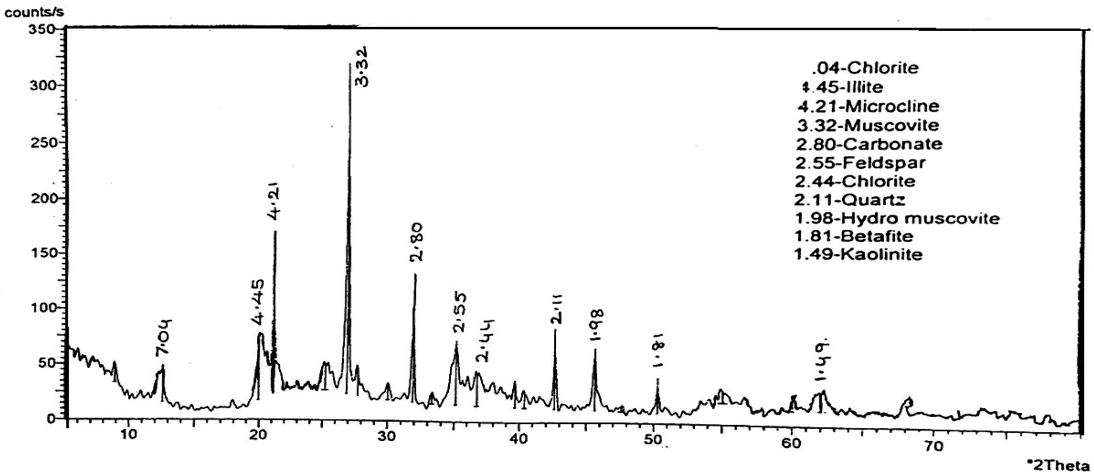

Fig. 1 Scanning Electron Micrograph for soft (marine) clay

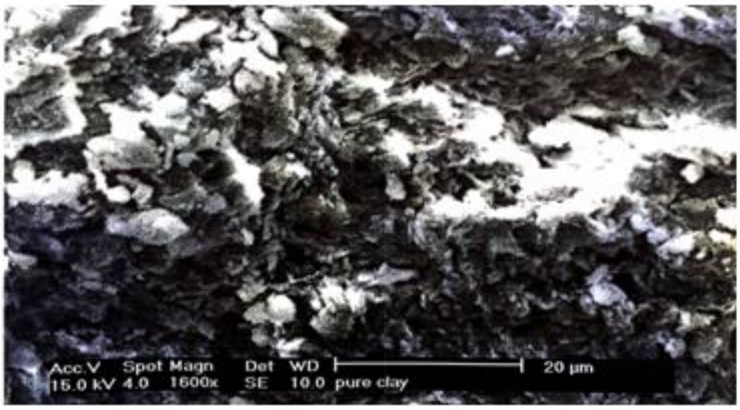

Fig. 2 XRD pattern for soft (marine) clay

The variations of various engineering properties (viz; Atterberg limits, swelling, etc with variables are studied and more important results are mentioned in next section; conclusions. The XRD pattern for soft (marine) clay is shown in Fig. 1 and Fig 2. The peaks of 7.04 A^o, 4.45 A^o and 1.49Ao indicate kaolinite. The peak at 3.32 Ao indicates muscovite. The other minerals presented are indicated on the graph. A similar approach is made with variables yielding 14 other diffractions patterns and most important conclusions after analyzing the results is mentioned in the next sections.

Scanning Electron Micrograph for soft (marine) clay In this micrograph it can see that lot of aggregates in a compacted form. There are considerable amount of pores present in the soil fabric which indicate high permeability. On similar lines, other micrographs are obtained on treated and untreated soils and the important conclusion drawn is mentioned in the next section (conclusions).

VI. Conclusion

The aim of the present investigation has been to study the effect of hydrated lime with sea water and distilled water on the engineering and physical properties of soft marine clay. Based on the analysis of results, the major conclusions of the study are summarized as follows.

1. In the presence of sea water and distilled water there is minor difference in the physico chemical and engineering behavior of the soft marine clay both in treated and untreated conditions. The decrease in the diffused double layer thickness due to the reduction in specific surface of soil account for lower liquid limit of lime treated soil during initial stages of curing at low lime content. However the increase in liquid limit may be due to flocculation effect resulting in formation of large voids that require more water at larger curing periods. However plastic limit gradually increases with increase in percentage of lime, this is due to the formation of edge-edge flocculated fabric.

2. The drastic reduction in free swell index of soil by the addition of lime with different curing conditions is due to the pozzalonic reaction between the silica/alumina and lime that results into formation of flocculated structure owing to decrease in sediment volume.
3. The increase in p^H value by the addition of lime in presence of both sea water and distilled water in due to the reaction of ca2+ ions with the clay minerals resulting in formation of CSH (Calcium Silicate Hydrate) compound which is also responsible for the increase in cation exchange capacity.
4. The XRD studies shows that the reaction products formed are Calcium Aluminate (CA), Calcium silicate Hydrate (CSH) including Unsubstituted Tobermorite (UT) and Calcium Aluminate Hydrate (CAH) in the form of cementing compounds which are not affected by the sea water. This indicates that the improvement in engineering behavior of the soft marine clay has been not much effected by sea water. These are found out through XRD studies.
5. From studies of microstructure in SEM studies it is concluded that there is an increase in fabric size and formation of flocculated structure with increase in lime content at 40 days curing period when compared to 10 days curing period.
6. The vane shear strength of treated sample has increased by to three time the shear strength of untreated sample, at 5% and 7% lime content cured with distilled water and seawater respectively for 40 days and the increase was four times with sea water.

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