Improving the Strength of Soft Marine Clay By Using Lime And Palm Oil Fuel Ash

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Abstract- *Marine clays located in coastal and offshore areas of the world forms one of the important groups of fine grained soils and lots of civil construction activities take place in such marine clays throughout the world. Since these clays are characterized by low strength and high compressibility, the design and construction of many coastal and offshore structures in these deposits are confronted with many geotechnical problems. It is prohibitively expensive to remove large volumes of unsatisfactory soils present at sites and replace them with more suitable material particularly, if it is to be transported for large distances. Therefore, much emphasis has been placed upon finding methods of modifying the properties of soils and improving their Engineering behavior. Chemical stabilization has been extensively used for the improvement of these soft marine clays, in enhancing the shear strength and limiting the deformation behaviour. This project is aimed at investigating the possibility of utilizing an agriculture waste, Lime in combination with Palm oil fuel Ash to stabilize poor soft marine clays to pave way for its use in civil engineering projects. Different tests will be conducted on these weak clays with varying percentages of the chosen materials for stabilization. The testing programme will involve addition of different percentages of Lime and Palm oil fuel Ash to soft marine clay and the results will be analyzed to assess the strength of the materials used.*

Keywords- Marine clay, Palm oil fuel ash, Atterberg's limit test, CBR test, Un confined compression test, maximum dry density and optimum moisture content test.

I. INTRODUCTION

Soil is a fundamental engineering material. The quality of soil used in construction affects the overall stability of a structure. Cohesion, angle of internal friction, capillarity, permeability, elasticity and compressibility are the properties of soil taken into account while considering it as a construction material**.** Transportation is necessary for the proper functioning and development of economic activities for any country, which involves production and distribution of goods and services from one place to other. Construction works on soft clay foundations are often very challenging and very complex task since they are since they are generally characterized by its low strength properties. Still clayey soils are widely used for construction purposes due to economic reasons. Performance and life of road network is generally depending upon the design and construction. Sub grade is generally made up of locally available natural soils.

The strength and performance of a pavement is dependent on the load-bearing capacity of the Sub grade soil. In case of poor soil in construction site, the poor soil can be removed or replaced with the soil of high strength. Design of pavement is depend upon the strength of the sub grade soil, which affects the thickness of pavement ultimately increase the cost of construction. Improvement in load bearing capacity of soil will improve the load-bearing capacity of pavement and thus, pavement strength and its performance.

The performance of these soft fine grained deposits under different conditions of environment varies over wide limits. Due to the poor sub grade conditions formation of fractures, fissures, rutting and the phenomena of pumping, blowing and consequent cracking of cement concrete pavements occur. Effects of marine clay have appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, Irrigation systems, water lines, canal And reservoir linings. The estimated damage was very expensive to the pavements running over the marine clay sub grades. So considerable changes have to be made in the construction of various coastal and offshore structures.

In order to improve the engineering behaviour of these soils, several improvement techniques are available in geotechnical engineering practice. The selection of any of these methods to overcome any problem can be proved to be efficient only after the comparison of that with other techniques, then it can be said that the particular method is well suited for a specific system. In general, the soils which are existing in the coastal corridors are Soft Marine Clays formed by the deposits and generally weak and possesses high deformation values in nature. It is essential to study the various techniques for the improvement of marine clays, especially in case of infra-structure development.

Aggregate crusher units produce large quantities of Lime, a waste product, produced during crushing of Gravel and rock. Disposal of these large quantities of Lime produces serious problem in environment and health hazard. There is requirement to utilize these waste materials. Lime can be used in very large quantity, reducing the total cost of construction

in addition to providing a solution to an environmental problem.

One of the main environmental problems today is the disposal of the waste plastics. The use of plastics in various places as packing materials and the products such as bottles, polythene sheets, containers, packing strips etc., are increasing day by day. Since plastic is non-Biodegradable, recycling is a part of global efforts to reduce plastic in the waste stream, especially the approximately eight million metric tonnes of waste plastic that enter the Earth's ocean every year. This helps to reduce the high rates of plastic pollution.

Soil stabilization is a technique to improve the soil parameters such as shear strength, compressibility, density, hydraulic conductivity etc. The techniques of soil stabilization can be categorized into a number of ways such as consolidation, vertical drains, vibration, surcharge load, admixtures, grouting and reinforcement and other methods. Geotechnical engineers around the world are in search of new alternate materials which are required both for cost effective solutions for ground improvement and for conservation of scarce natural resources.

In this work it is attempted the study the effect of binary blends of LIME and Palm oil fuel ash on the properties of weak marine clay .

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are to develop correlations between engineering characteristics of marine clay.

- To determine the characteristic of marine clay in particular the basic Properties, strength and compressive characteristics.
- To evaluate the performance of Marine clay when stabilized with lime as an admixture and its suitability for the pavement sub grade.
- To evaluate the performance of stabilized Marine clay with an optimum of lime and palm oil fuel ash and their suitability for the pavements.

1. GENERAL

Transportation fulfills the basic need of humanity. For the time immemorial everyone travels either for food or leisure. There is a strong correlation between the quality of transportation facilities and development of country, because of which everyone places a great expectation from transportation facilities. Major challenges among civil engineers today is that transportation system must be analytically based, economically sound, eco-friendly, socially credible, sustainable and practically acceptable. In current scenario, conventional construction methods are unsuitable and driving interest in technologies like ground improvement. Among all transportation modes, economical road network plays a vital role for advancement in the economy of developing countries like India. In case of a highway, if the sub grade layer of the pavement is weak then they require greater thickness of pavement that results in increase of pavement construction cost.

2. MARINE CLAY

Soft marine clay is very sensitive to change the stress system, moisture content and system chemistry of the pore fluid. Geotechnical engineers feel a necessity to improve the behavior of these deposits using anyone of the available ground improvement techniques for the construction of foundations. Soft clays known for their high compressibility, low stiffness and low shear strength are always associated with large settlement. The marine clay got cracks as shown in the plate on drying and in the worst cases the width of the cracks is almost 250mm to 500mm and travel down to 1.00m beneath the ground level.

II. LITERATURE REVIEW

2.1 **Studies on marine clay**

In general, the soils which are existing in the coastal corridors are Soft Marine Clays formed by the deposits and generally weak and possesses high deformation values in nature. It is essential to study the various techniques for the improvement of marine clays, especially in case of infra-structure development.

George R. Otoko, Isoteim Fubara - Manuel and Ibekwe S. Chinweike presents the experimental study on Soft Soil Stabilization Using Palm Oil Fibre Ash and the analysis shows that Palm oil trees are abundant in the Niger Delta of Nigeria and the effectiveness of using its fly ash (waste from the process of burning the palm oil fibre) in soft soil stabilization was investigated. Soft soil investigated is an extremely soft marine clay in the Niger Delta area locally known as "Chikoko". The fly ash (palm ash) is classified as class F according to ASTM C618. It is siliceous and aluminous with virtually little or no cementation value. Therefore for pozzolanic reaction it has to be combined into a little lime. An Optimum of 5% lime was obtained for pozzolanic reaction. This combines with 3% optimum palm ash to give best results

of soaked and unsoaked CBR. Thus, the palm ash can successfully be used for soil subgrade stabilization

Koteswara Rao. D, M.Anusha, P.R.T. Pranav, G.Venkatesh presents the experimental study on effect of Saw Dust and Lime on strength properties of marine clay.

Basack,S et.al (2009), reported that the Engineering characteristics of marine clay collected form Visakhapatnam, India and the physical, chemical and mineralogical properties were presented and the strength, stiffness of the soil water matrix were established..

Purushotham G. Sarvade and Prashant R Shet reports the findings of experimental studies with regard to geotechnical properties of both problem clay and stabilized clay, and to evaluate their suitability in tile industry. Also an investigation was carried out to study the effect of cement and lime on CRP stabilized clay.

Shiva Prasad.A, P.T.Ravichandran, R.Annadurai, P.R.Kannan Rajkumar paper presents the stabilization of soils using crumb rubber at varying percentages (5%, 10%, 15% and 20%). The soil properties, compaction and unconfined compression strength were used to gauge the behavior and performance of the stabilized soils.

Balasubramaniam, A.S et.al (2003), proved the effects of additives on Soft Clay behavior and concluded that the strength characteristics of the soft clays are improved by using various additives.

Koteswara Rao, D (2006), the efficacy of Granulated Blast Furnace Slag- Fly ash mix as a fill material on soft soil beds for the foundations, CES-2006, Osmania University, Hyderabad.

B N M Kiran And DVS Prasad presents an experimental work on stabilization of marine clay using ferric acid and Lime and he concluded that From the experimental results it was observed that 1.0% FeCl3 treatment individually along with the combination of 20% Lime with marine clay had effectively improved the CBR value. It was noticed that, the load carrying capacity of the treated marine clay sub grade model flexible pavement has been increased by 254% at OMC and 225% at FSC. The total deformation of the treated marine clay sub grade model flexible pavement has been decreased by 40% at OMC and 38% at FSC when compared with the untreated marine clay sub grade model flexible pavement.

G.Rajasekharan and **S.Narasimha Rao** done a experimental work on Strength characteristics of lime-treated marine clay The test results indicate an improvement in soil strength by eight to ten times that of untreated soil except for the quicklime-sodium sulphate system. This aspect encourages the application of both lime column and lime injection techniques to improve the engineering behavior of marine clay

2.2 STABILIZATION

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils.. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

3.2 METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

MATERIALS USED AND THEIR PROPERTIES

3.1 Marine clay

Marine clay is a type of clay found in coastal regions around the world. In the northern, deglaciated regions, it can sometimes be quick clay, which is notorious for being involved in landslides. Clay particles can self-assemble into various configurations, each with totally different properties.

TABLE 3.1 Properties of Marine clay

S. No.	Property	Value
1	Specific gravity	2.61
2	Differential free swell Index (%)	38
3	Atterberg's Limits	
	i) Liquid limit (%)	71.4
	ii) Plastic limit (%)	29.2
	iii) Plasticity index (%)	42.2
5	Grain Size Distribution	
	i) Sand Size Particles (%)	8
	ii) Silt & ClaySize Particles (%)	92
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.36
	ii) Optimum Moisture Content (%)	29.8
8	Penetration Parameters	
	i) CBR - UnSoaked (%)	2.8
	ii) CBR - Soaked (%)	1.5
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	36
	ii) Angle of Internal Friction, Øu (Degrees)	0

3.2 PALM OIL FUEL ASH

Palm oil trees are abundant in the Andhra Pradesh and the effectiveness of using its fly ash (waste from the process of burning the palm oil fiber) in soft soil stabilization was investigated. It exhibits high shear strength which is highly beneficial for its use as a geotechnical material. It has a good permeability and variation in water content does not seriously affect its desirable properties.. The dry density increased with the addition of Palm Oil Fuel Ash with attendant decrease in the optimum moisture content.

TABLE 3.2 Properties of POFA

S. No.	Property	Value
1	Specific gravity	1.69
2	Classification	Class. F
3	Particle size Distribution	
	Sand (%)	0.05
	Silt (%)	99.5
	Clay (%)	0.0

LABORATORY EXPERIMENTATION:-

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marine clay.

The following tests were conducted as per IS codes of practice.

- Grain size distribution
- Specific gravity
- Index properties –liquid limit, plastic limit
- Compaction tests
- Penetration tests-California bearing ratio test.
- Unconfined Compression Test-Triaxial

Fig shows Collecting soil sample

Fig shows pulverization and sieving of marine clay

Fig shows Conducting liquid limit test

Fig Shows Conducting CBR test

IV. LABORATORY EXPERIMENTATION

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- Grain size distribution
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- Compaction tests
- Penetration tests-California bearing ratio test.
- Unconfined Compression Test-Triaxial

V. RESULTS AND DISCUSSIONS

4.1 GENERAL

In the laboratory, various experiments were conducted by replacing different percentages of Lime and different waste plastic inclusions in the Weak marine Soil and also further stabilizing it with lime as a binder. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Lime and different waste plastic inclusions as replacement in weak marine soil and Lime as a binder and CBR and UCS are conducted for durability studies.
The influence of the above said materials on the Index, Compaction and Strength properties were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice.

4.2 EFFECT OF % LIME AS ADDITION ON THE PROPERTIES OF WEAK MARINE SOIL

The individual influence of Lime on the Index, Compaction and Strength properties of marine soil are clearly presented in Figures 5.1, 5.2, 5.3, 5.4, and 5.5 respectively. The percentage of LIME was varied from 0%, to 10% with an increment of 2%. From the above graphs, it was observed that the treatment as individually with 8% Lime has moderately improved the marine soil. It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % replacement of Lime up to 10% with an improvement of about 46.5%. Also maximum dry density is improved by an amount of 7.35% and it was about 65.2% for UCS and 160.7%, 300% for Unsoaked, Soaked respectively.

5.1 Results of the tests conducted on marine clay additive with different percentages of lime

LIME (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	71.4	29.2	42.2	1.36	29.8	2.8	1.5	72
2	69.5	30.4	39.1	1.37	29.6	3.5	2.4	84
4	67.1	31.5	35.6	1.39	29.3	4.7	3.6	93
6	65.3	32.8	32.5	1.42	29	6.1	4.7	106
8	62.9	34.1	28.8	1.46	28.5	7.3	6	119
10	60.6	36.3	24.3	1.43	28.3	6.8	5.5	110

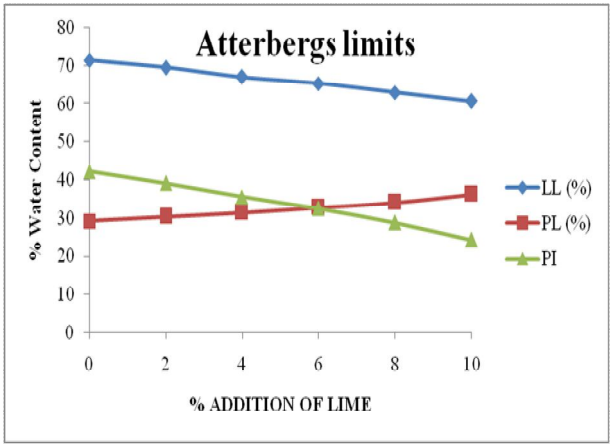

Fig 5.1 Plot showing the Variation in Atterberg's Limits with % addition of LIME

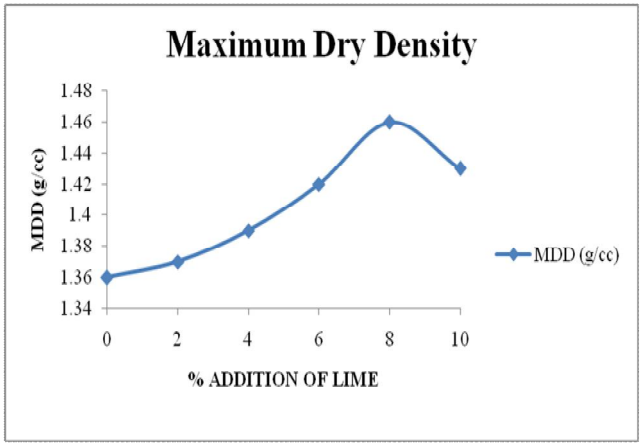

Fig 5.2 Plot showing the Variation in MDD with % addition of LIME

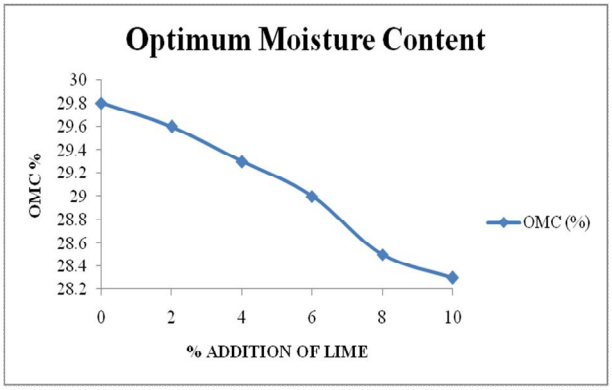

Fig 5.3 Plot showing the Variation in OMC with % addition of LIME

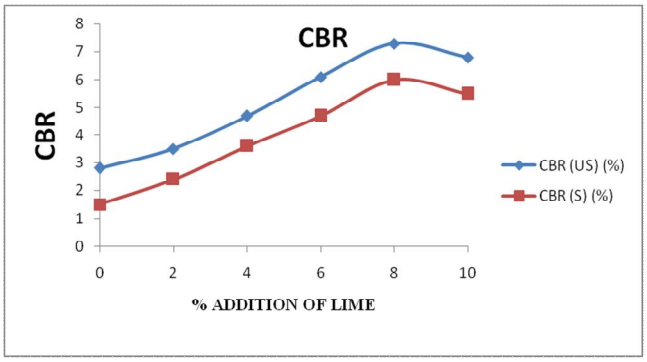

Fig 5.4 Plot showing the Variation in CBR VALUES with % addition of LIME

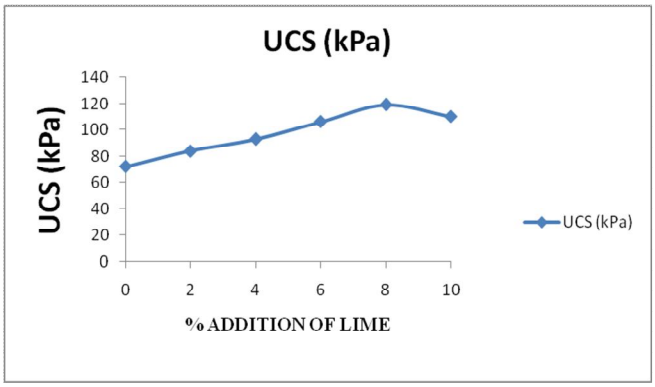

Fig 5.5 Plot showing the Variation in UCS with % addition of LIME

- **IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF LIME AS ADDITION OF MARINE CLAY IS 8%**

5.2 Results of the tests conducted on marine clay with different percentages of POFA Content with LIME

POFA (%) + LIME (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0 + 8% LIME	1.46	28.5	7.3	6	119
2 + 8% LIME	1.48	28.3	8.1	6.9	132
4 +8% LIME	1.5	27.8	8.9	7.7	147
6 + 8% LIME	1.53	27.2	9.4	8.2	168
8 + 8% LIME	1.51	27	9.1	7.8	156

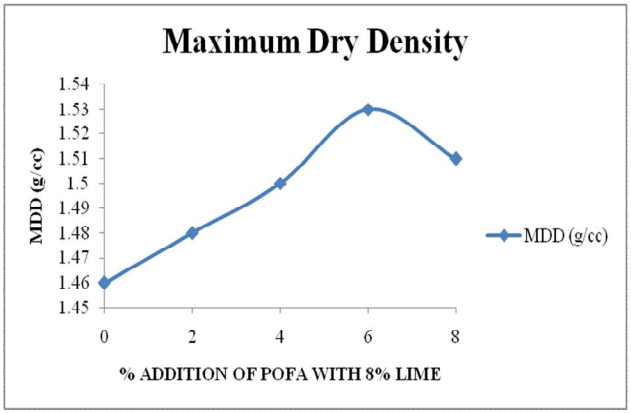

Fig 5.6 Plot showing the Variation in MDD % addition of POFA with 8% LIME

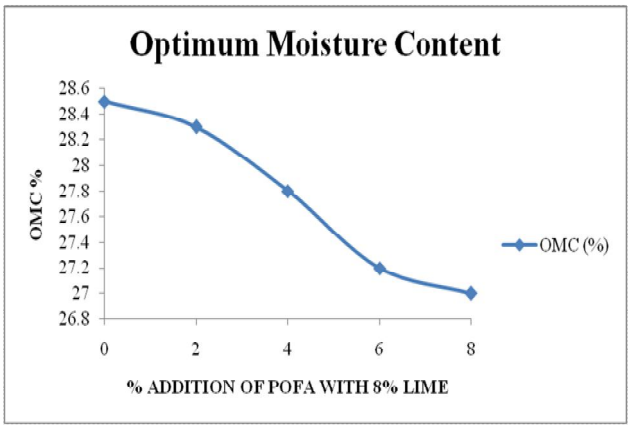

Fig 5.7 Plot showing the Variation in OMC with different % of POFA with 8% LIME

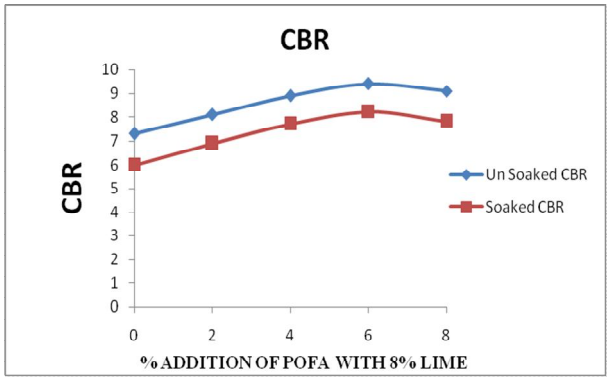

Fig 5.8 Plot showing the Variation in CBR with different % of POFA with 8% LIME

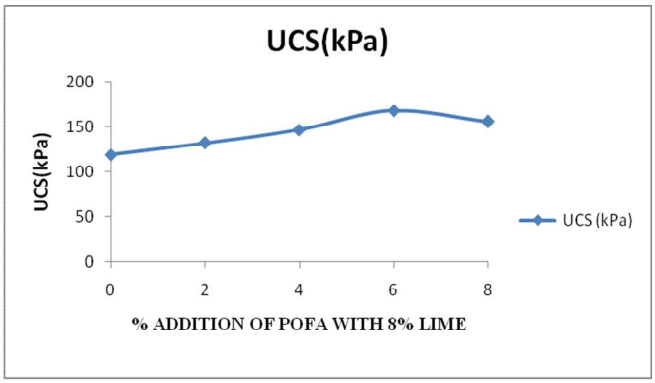

Fig 5.9 Plot showing the Variation in UCS with different % of POFA with 8% LIME

- IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF POFA WITH 8% LIME AS ADDITIVE OF EXPANSIVE SOIL IS 6.0%.

Table Shows Strength Values of SMC treated with 6.0% POFA + 8% LIME mix for different curing periods.

Curing Period (Days)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	9.4	8.2	168
7	9.8	8.5	187
14	10.1	8.9	205
28	10.5	9.3	214

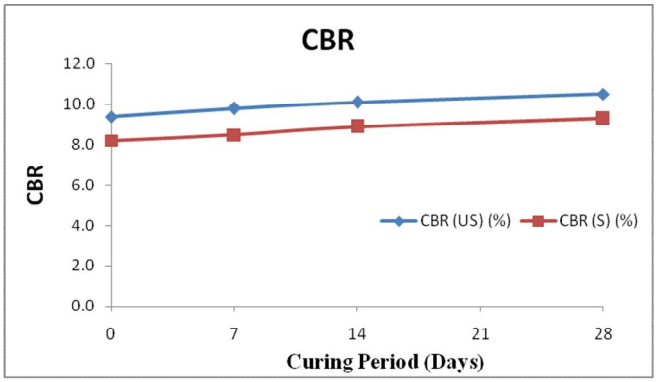

Fig 5.10 Plot showing the Variation in CBR at different curing periods

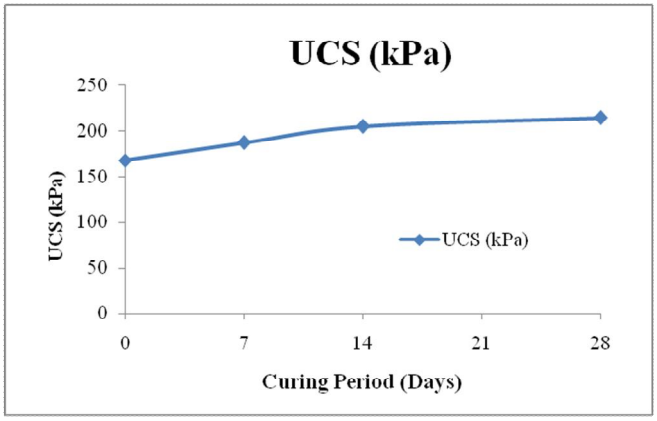

Fig 5.11 Plot showing the Variation in UCS at different curing periods

VI. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- From the laboratory studies, it is observed that the Marine clay chosen was a problematic soil having high compressibility characteristics.
- It was observed that Marine clay treated with lime has moderately improved the Marine clay.
- There is a gradual increase in maximum dry density with an increment in the % addition of lime up to 10% with an improvement of about 2% and it is observed that for the addition of 8% there is gradual increase in Maximum dry density about 7.35 %. Further addition of POFA content from 0% to 10% with an increment of 2%. For MDD increases about 4.79%
- There is an improvement in strength characteristics with an addition of lime from 0% to 10% with an increment of 2%.There is an improvement of 160.7% for CBR un soaked and 300% for soaked. Also there is an improvement about 65.27% UCS values. Further addition of POFA from 0% to 8% with an increment of 2%. For POFA content of 6 % There is an improvement of 28.7% for CBR unsoaked, 36.6% for soaked CBR and 41.17% in UCS values
- Durability Studies (Curing) on samples prepared with 8.0% LIME + 6.0% POFA as Addition of Marine clay graph shows increment of CBR and UCS values with increment of curing periods.
- It is evident that the addition of lime to the virgin Marine clay showed an improvement in compaction, strength and penetration characteristics to some extent and on further addition with POFA strength mobilization was more pronounced.
- Finally it can be summarized that the materials LIME and POFA had shown promising influence on the strength characteristics of Marine clay, thereby giving a two-fold advantage in improving problematic Marine clay and also solving a problem of waste disposal.

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