Evaluation And Analysis on Improving The Bearing Capacity of Marine Soil Using Industrial Solid Wastes

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Abstract- *It is very essential for a developing nation such as India, which has a huge geographical area and population to have large infrastructures such as road or buildings networks. In the design of road construction site engineers faces the problem of low strength of soil, due to which settlement and failure of road pavement occurs. Thus, for safe design such weak soils need to be improved before construction. Various techniques are available in practice and one of these processes of improving the properties weak or soft soils is stabilization. For improving the strength of soil pavement Hypo Sludge and Lime can be utilized to the soil. Soil stabilization is a procedure where natural or synthesized additives are used to improve the engineering properties of weak soil. Several reinforcing methods are available for stabilizing soils. Therefore, the techniques of soil stabilization can be classified into several categories such as physical stabilization, chemical stabilization, and mechanical stabilization. There is a substantial history of use of soil stabilization admixtures to improve poor subgrade soil performance by controlling volume change and increasing strength. This paper investigates the use of Hypo sludge and lime to improve the strength of weak soil. To understand the performance of stabilized soil, laboratory tests like Atterberg's limits, compaction parameters and strength parameters were studied.*

Keywords- Marine clay, Hypo sludge, Lime, Atterberg's limit test, CBR test, Unconfined compression test, maximum dry density and optimum moisture contenttest.

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.

Soil stabilization is a technique to improve the soil parameters such as shear strength, compressibility, density, hydraulic conductivity etc. Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. The main objectives of the soil stabilization are 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, Therefore soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil.

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 to study on improving marine clay sub grades with coir fibre and Bitumen.

All over the world, problems associated with marine clay includes cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, canal and reservoir linings. These problems are of great concern to the present world due to the higher cost of damages caused by them.

Various remedial measures like soil replacement, pre-wetting, moisture control, chemical stabilization have been practiced with varying degrees of success. Unfortunately the limitations of these techniques questioned their adaptability in all conditions. So work is being done all over, to evolve more effective and practical treatment methods, to alleviate the problems caused to any structures laid on marine clay strata.

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.

1.1 MARINECLAY

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.

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 Hypo Sludge as an admixture and its suitability for the pavement sub grade.
- To evaluate the performance of stabilized Marine clay with an optimum of Hypo Sludge and Lime and their suitability for the pavements.

II. LITERATUREREVIEW

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.

D. KoteswaraRao et al.(2011) studied the efficiency of CaCl2,KCl,GBFS with marine clay and the test results concluded that load carrying capacity of the marine clay foundation soil bed has been improved.

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Rao et al. (2005) conducted the triaxial tests on sand reinforced with coir fibre. The aim of the experiment was to calculate the strength parameter the percentage of coir varied was 0.5% and 1%. He concluded that longer fibres were stiffer than the shorter ones the length of the fibre selected to study the stiffness of fibre was between 150-199 mm (type A1) and with fibre length less than 100 mm (type A2).for experimental work the length of fibre selected was 25mm. It was concluded that deviator stress at the time of failure increases with increase in the fibre content, at the lower value of confining pressures A2 type coir fibre shows higher value of deviator stress as compared to A1 type of fibre. At fibre content of 0.5% coir content A2 type shows higher strength than A1 type and at fibre content of 1% both A1 and A2 type shows near about similar strength when coir fibre was randomly distributed.

Chauhan et al. (2008) studied the effect of inclusion of coir fibre with polypropylene fibre in the silty sand mixed with fly ash. The percentage of fly ash was mixed at 10%, 20%, 30% and 40% of the dry weight of the soil and it was found that the optimum value percentage inclusion of fly ash was 30%. Both the fibres at 0.5%, 1%, 1.5% and 2% by dry weight were used in the study. UCS values increased up to 0.75% making it as an optimum value. Optimum dose of polypropylene fibre optimum dose was found out to be 1% finding from the triaxial tests resulted that the coir fibre exhibit more improvement in shear strength (up to 47.5%) of soil than the synthetic fibre(up to 70%).

Osinubi (2006) studied the effect of compactive effort and elapse time on the strength of lime-Hypo Sludge stabilized expansive clay from Gombe, Nigeria. The experimental study involved unconfined compressive strength. The following conclusions are drawn from the study: The results obtained indicate that UCS values increase with lime and Hypo Sludge treatment.

Korean marine clay. Sing et al., (2008) reported an improvement in the engineering properties of peat soils stabilizing with cement and ground granulated blast furnace slag and proved a remarkable increase in the pH and unconfined compressive strength, significant reduction in linear shrinkage, compressibility and permeability of the stabilized peat soils.

A substantial literature has concluded the severity and extent of damage inflicted by soil deposits of selling nature, to various structures, throughout the world (Ganapathy, 1977; Jones and Jones, 1995; Abduljauwad, 1995; Osama and Ahmed, 2002; Zhan, 2007). The loss caused due to damaged structures proved the need for more reliable investigation, of such soils and necessary methods to eliminate or reduce the effect of soil volume change.

A comprehensive review of literature indicates that considerable amount of work related to determination of engineering behavior of marine soils has been carried out worldwide since last 50 years. Amongst various contributions, the investigations on physical, chemical and mineralogical properties of marine clay conducted by Eden et al. (1957), Noorani (1984), Sridharan et al. (1989), Mathew et al. (1997) and Chew et al. (2004) are worthy of note. Significant research on strength and stiffness characteristics was performed by Koutsoftas et al. (1987) and Zhou et al. (2005). Marine structures are usually subjected to wave induced cyclic stresses which are induced in the soil. Remarkable works of Idriss et al. (1978), Vucetic et al. (1988), Kagawa (1992) and Hyde et al. (1993) related to properties of marine soil under cyclic stress are notable.

T.K. Roy , B.C. Chattopadhyay , S.K. Roy (2009) explained that Procurement of conventional materials in huge quantity required for construction of subgrade of road is becoming very difficult in many locations due to various problems. On the other hand, due to increasing economic growth and industrialization, a huge quantity of waste materials generated needs land for disposal and from that generally creates problems for public health and ecology. So need has arisen for proper disposal of the waste materials. Utilizing these materials in the area of road construction after improving their characteristics suitably can provide useful solution of this problem. So keeping this in view, an experimental study was undertaken to explore the possibility of utilization of the alternative materials like rice husk ash by mixing with local alluvial soil by adding small percentage of lime for the construction of road subgrade as cost effective mix.

Chittaranjan, and Keerthi, (2011) studied the 'Agricultural wastes as soil stabilizers'. In this study Agricultural wastes such as sugar cane Hypo Sludge , rice husk ash and groundnut shell ash are used to stabilize the weak sub grade soil. The weak sub grade soil is treated with the above three wastes separately at 0%, 3%, 6%, 9%,12%and 15% and CBR test is carried out for each per cent .The results of these tests showed improvement in CBR value with the increase in percentage of waste.

H. P. SINGH, (October 2012) Soil reinforcement technique is one of the most popular techniques used for improvement of poor soils. Metal strips, synthetic geotextiles, geogrid sheets, natural geotextiles, randomly distributed, synthetic and natural fibres are being used as reinforcing materials to soil. Further, the soil reinforcement causes significant improvement in tensile strength, shear strength, other properties, bearing capacity as well as economy.

Kiran and, Kiran (2013) carried out for different percentages (4%, 8% and 12%) of Hypo Sludge and additive mix proportions. The strength parameters like CBR, UCS were determined. It was observed that blend results of Hypo Sludge with different percentage of cement for black cotton soil gave change in density, CBR and UCS values. The density values got increased from 15.16 KN/m3 to 16.5 KN/m3 for addition of 8% Hypo Sludge with 8% cement, Then CBR values got increased from 2.12 to 5.43 for addition of 4% Hypo Sludge with 8% cement and UCS values got increased to 174.91 KN/m2 from 84.92 KN/m2 for addition of 8% Hypo Sludge with 8% cement.

B.Suneel Kumar, T.V.Preethi (May 2014) carried out a research & found that In India the soil mostly present is

Clay, in which the construction of sub grade is problematic. In recent times the demands for sub grade materials has increased due to increased constructional activities in the road sector and due to paucity of available nearby lands to allow excavate fill materials for making sub grade. In this situation, a means to overcome this problem is to utilize the different alternative generated waste materials, which comparison of subgrade soil strength using lime & cost analysis cause not only environmental hazards and also the depositional problems. Keeping this in view stabilization of weak soil in situ may be done with suitable admixtures to save the construction cost considerably.

Kharade, Suryavanshi, Gujar, and Deshmukh, (2014) stated that Hypo Sludge can be used as stabilizing material for expansive soils. Various experiments were conducted on black cotton soil with partial replacement by Hypo Sludge at 3%, 6%, 9% and 12% respectively. It was seen that due to addition of Hypo Sludge , CBR and Compressive strength increases almost by 40%, but density showed only significant change. The blend suggested 6% Hypo Sludge , without any addition of cementing or chemical material would be an economic approach. Furthermore if any cementing material is added in suggested blend, then there will be definitely more improvement in properties of expansive soils.

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 Marineclay

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 differentproperties.

TABLE 3.1 Properties of Marine clay

Properties of Marine Clay		
S. No.	**Property**	**Value**
1	Specific gravity	2.61
2	Differential free swell Index (%)	39
3	Atterberg's Limits	
	i) Liquid limit (%)	72.8
	ii) Plastic limit (%)	27.2
	iii) Plasticity index (%)	45.6
5	Grain Size Distribution	
	i) Sand Size Particles (%)	8
	ii) Silt & Clay Size Particles (%)	92
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.36
	ii) Optimum Moisture Content (%)	29.5
8	Penetration Parameters	
	ii) CBR - Soaked (%)	1.4
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	36
	ii) Angle of Internal Friction, Øu (Degrees)	0

3.2HYPO SLUDGE

Hypo Sludge is industrial waste material collected from paper mill industries. Hypo Sludge generates continuously throughout the operating year and it behaves like a clayey material consisting of short fiber, ink and other impurities. Due to presence of some hydrated lime (Cao: Calcium hydroxide) with other chemical impurities to the Hypo Sludge is also called Lime Sludge. It is found that high percentage of moisture content is available in the Hypo Sludge after de-inking and re-pulping process in the paper industries.

It dried up in the presence of sun before conducting a series of laboratory test for the proposed study.

TABLE 3.2 Chemical properties of coir fiber

S.No	Constituents	Cement (%)	Hypo Sludge (%)
1	Lime (CaO)	62.0	49.2
2	Silica (SiO2)	22.0	18.00
3	Magnesium Oxide	5.00	0.63
4	Aluminum (Al2O3)	1.00	3.60
5	Calcium Sulphate (Ca2SO4)	3.00	3.03
6	Other	1.00	1.02

3.2LIME

The use of lime-soil mixture as a construction material has been known from ancient times in various parts of the world. Romans used it in their roads nearly 2000 years ago. The use of lime has by now gained considerable popularity in view of its simplicity, efficacy and economy.

Source of Lime

Lime is manufactured from limestone. Limestone is a naturally occurring material and is abundantly available in various parts of the country. In some states, it is also available in an impure form mixed with clay, and is popularly known as kankar. In the coastal areas of the country, marine shells are also used for the production of lime. Lime waste available as by-product from carbide, sugar, paper and PVA industries is another source of lime.

IV. 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 marineclay.

- Grain sizedistribution
- Specificgravity
- Index properties –liquid limit, plasticlimit
- Compaction tests
- Penetration tests-California bearing ratiotest.
- Unconfined CompressionTest-Triaxial

V. RESULTS AND DISCUSSIONS

5.1GENERAL

Details of the laboratory experimentation carried-out with different combinations of materials have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on Weak Marine Soil are presented.

In the laboratory, various experiments were conducted by replacing different percentages of Hypo Sludge and Adding Lime to the optimum percentage in the Weak marine Soil. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Hypo Sludge and as Lime in weak marine soil and CBR and UCS are conducted for durability studies.

5.2 EFFECT OF % HYPO SLUDGE ON THE PROPERTIES OF WEAK MARINE SOIL

The individual influence of Hypo Sludge on the Index, Compaction and Strength properties of marine soil are clearly presented in Figures. The percentage of Hypo Sludge was varied from 0%, to 40% with an increment of 10%. From the above graphs, it was observed that the treatment as individually with 20% Hypo Sludge 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 Hypo Sludge up to 20% with an improvement of about 11.01%. Also maximum dry density is improved by an amount of 3.67% and it was about 23.6% for UCS and 157% for Soaked CBR respectively.

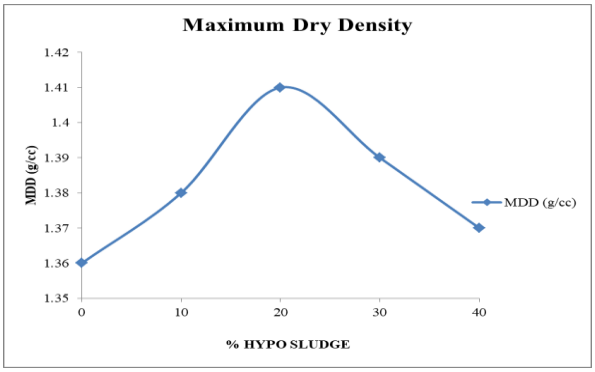

Fig 5.1 Plot showing the Variation in MDD with % Replacement of Hypo sludge

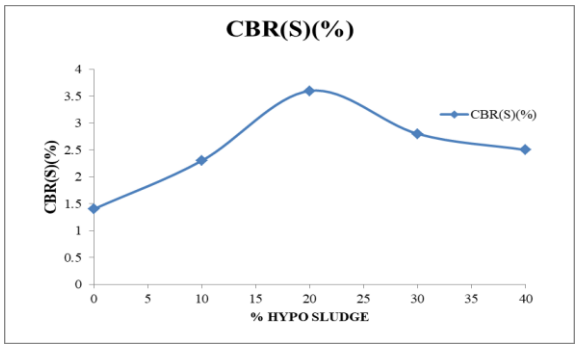

Fig 5.2 Plot showing the Variation in CBR VALUES with % Replacement of Hypo sludge

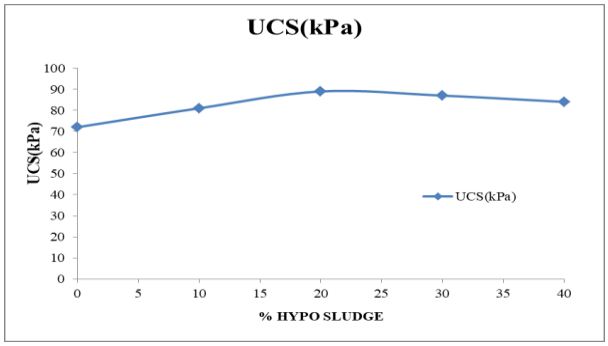

Fig 5.3 Plot showing the Variation in UCS with % % Replacement of Hypo sludge

It can be inferred from the above results the treatment as individually with 20% hypo sludge has moderately improved the marine soil. The optimum content of hypo sludge as % replacement of marine clay is 20%.

5.3 EFFECT OF % LIME AS BINDER ON THE PROPERTIES OF WEAK MARINE SOIL

The influence of lime on the Index, Compaction, CBR, UCS properties of marine soil are clearly presented in Figures. The percentage of lime was varied from 0%, 3%, 6%, and 9%. From the above graphs, it was observed that the treatment with 6% 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 % addition up to 6% with an improvement of about 33.4%. Also maximum dry density is improved by an amount of 3.54% and it was about 80.5% for UCS and 80.5% Soaked CBR respectively

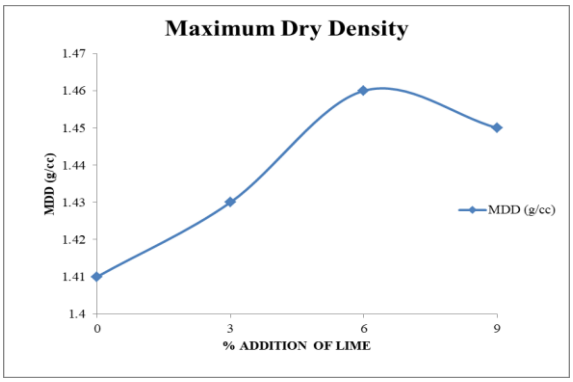

Fig 5.4 Plot showing the Variation in MDD with different % of lime

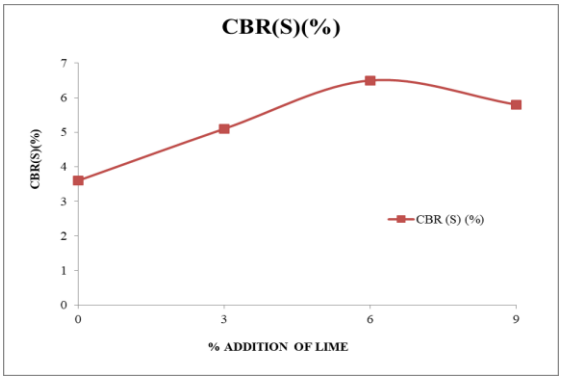

Fig 5.5 Plot showing the Variation in CBR with different % of lime

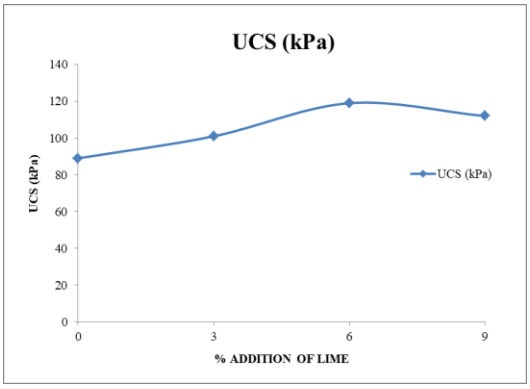

Fig 5.6 Plot showing the Variation in UCS with different % of lime

It can be inferred from the above results the optimum content of lime with 20% hypo sludge as replacement of marine clay is 6%.

5.4 EFFECT OF (CURING) ON SAMPLES PREPARED WITH 6% LIME + 20% HYPO SLUDGE AS REPLACEMENT OF MARINE CLAY

From the above results It is observed that samples prepared with 6% Lime + 20% Hypo sludge as replacement of marine clay and the graph shows increment of UCS and CBR values with increment of curing periods.

Finally from the above discussions, it is clear that there is improvement in the behavior of Weak Marine soil stabilized with Hypo Sludge + lime. It is evident that the addition of Hypo Sludge and Lime to the virgin Marine soil showed an improvement in plasticity, compaction and strength properties to some extent and on further blending it with Lime, the improvement was more pronounced. The Hypo Sludge and lime in the weak marine soil has reduced the plastic nature of the clay. It can be summarized that the materials Hypo Sludge and Lime had shown promising influence on the properties of

marine soil, thereby giving a two-fold advantage in improving problematic marine soil and also solving a problem of waste disposal.

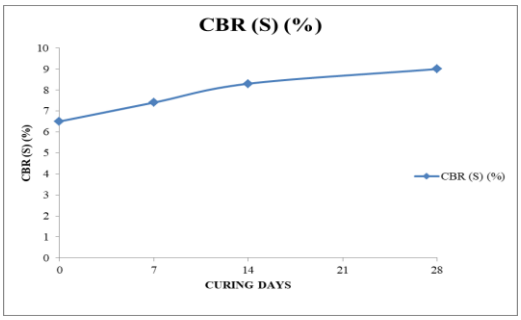

Fig 5.7 Plot showing the Variation in CBR at different curing periods

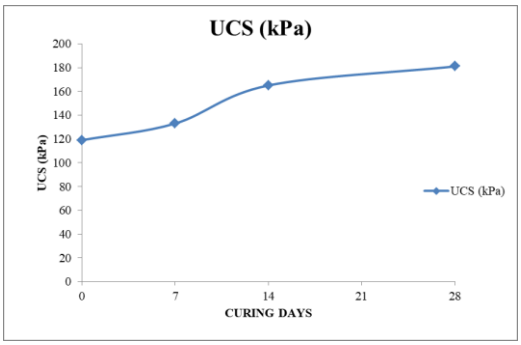

Fig 5.8 Plot showing the Variation in UCS at different curing periods

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 Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.

- It was observed that the treatment as individually with 20% of Hypo Sludge has moderately improved the marine soil.
- There is a gradual increase in maximum dry density with an increment in the % Replacement of hypo sludge up to 20% with an improvement of about 3.67% and it was about 10.3% for plasticity characteristics.
- There is an improvement in CBR, Shear parameters also by an amount of 23.6% for UCS and 157% for Soaked CBR respectively.
- Further addition of Lime to the Hypo Sludge stabilized marine clay It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % Addition of lime up to 6% with an improvement of about 33.4%. Also maximum dry density is improved by an amount of 3.54% and it was about 33.7% for UCS and 80.5% for Soaked CBR respectively.
- It is evident that the addition of Hypo Sludge and lime to the virgin Marine soil showed an improvement in properties of Marine Clay.
- Finally it can be summarized that the materials Hypo Sludge and lime had shown promising influence on the properties of Weak Marine soil, thereby giving a two-fold advantage in improving problematic Marine soil and also solving a problem of waste disposal.

REFERENCES

[1] Chu,J, Myint Win Bo, M.F.Chang and V. Choa (2002), Consolidation and Permeability Properties of Singapore Marine Clay. Journal of Geotechnical and Geo environmental Engineering, Vol.128, No.9, September 2002, pp.726-732.

[2] Clare, K.E. and Cruchley, A.E (1957), Laboratory experiments in the stabilization of clays with hydrated LIME, Geotechnique, Vol. 7, 1957, pp. 97-111.

[3] Felt, E.J (1955), Factors Influencing Physical Properties of Soil-Lime Mixtures, Portland Lime Association, Skokie, Illinois, DX016, 1955.

[4] GopalRanjan and A.S. R. Rao (2006), Basic and Applied Soil Mechanics, New Age International Publishers.

[5] I.S: 2720, Part VII, (1980), Determination of Water Content Dry Density Relation Using Light Compaction.

[6] I.S: 2720-Part III, Section I, 1980, Determination Specific Gravity.

[7] I.S: 2720-Part IV, 1975, Determination of Grain Size Distribution.

[8] I.S;2720-Part V, 1970, Determination of Liquid Limit and Plastic Limit.

[9] KoteswaraRao, D (2006), The performance studies on Geo-grid as reinforcemnt in the flexible pavement construction, IGC-2006, pp 657-660.

[10] KoteswaraRao, 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.

[11] NarasimhaRao, S., Rajasekaran, G. and Prasad, C.V (1993), LIME column method of stabilization in a marine clay, Proc. of the 11th Asian Geotechnical Conf., Singapore, 1993, pp.397-602.