Stabilization Studies of Bagasse Ash Modified Marine Clays Treated With Lime And Different Fibre Inclusions

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Abstract- *Soft Marine Clays (SMC) is characterized with high moisture content and low shear strength, thereby exhibiting high compressibility. Utilizing such clays for resting the foundations is almost impossible without some means of improving the adverse properties. Although several methods, such as prefabricated vertical drains, Geotextile reinforcing, cement and lime stabilization, have been successfully implemented to treat such soils, there always remains the motivation for further improvement of the methods, especially in terms of efficiency. This gives the need for thinking different alternate stabilization techniques in improving the behavior of these soft marine clays. Hence, a project is aimed at finding the efficiency of utilizing an agriculture waste, Bagasse Ash in combination with Different Reinforcing inclusions to stabilize poor soft marine clays. 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 Bagasse Ash (BA), LIME and Different discrete fiber inclusions (DRI) to Soft Marine Clay (SMC) and the results will be analyzed to assess the efficacy of the materials used.*

Keywords- soft marine clay, Bagasse Ash, Lime, Different discrete fiber inclusions (DRI)

I. INTRODUCTION

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.

India has large coastline exceeding 6000kmps. In view of the developments on coastal areas in the recent past, large Number of ports and industries are being built. In addition the availability of land for the Development of commercial, housing, industrial and transportation, infrastructure etc. are Scarce particularly in urban areas. This necessitated the use of land, which has weak strata, where in the geotechnical engineers are challenged by presence of different problematic soils with varied engineering characteristics. Many of these areas are covered with tick soft Marine clay deposit, with very low shear strength and high compressibility. Majority of the population in India depends on road-based transport. There are many Deposits of fine clays on coastal corridor and those soils are suffering from high saturation, Low density, low shear strength, sensitivity, and deformation problems and are normally consolidated. The marine clays, because of the specific physico-chemical make-up, are subjected to volume change with the changes in their ambient environment. These soils are widely occupied in costal corridor and not easy to avoid marine clay regions for the Construction of pavements and foundations due to the population density.

The marine clays are not suitable as pavement sub grade & foundation soil beds and pose problems due to their inability of strength criteria. More and more construction projects are encountering soft clays and hence there is a need to better quantifying the properties of marine clays. 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.

This process is generally referred to as soil stabilization, and in its widest meaning comprises every physical, physico-chemical, and chemical methods employed to enable a soil to serve better its intended engineering purpose.

Here, in this project, soil stabilization has been done with the help of randomly distributed fibers obtained from waste materials. The improvement in the shear strength parameters has been stressed upon and comparative studies have been carried out using different methods.

II. REVIEW OF LITERATURE

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.

Marine deposits can be found all along the coastal belt of Indian Peninsula. Narasimha Rao and Kodandarama swamy (1984), based on investigations on samples from Cochin and Madras, have drawn some useful conclusions on Indian marine clays. Indian marine clays are deposited at high water contents close to liquid limit giving rise to poor consistency and high void ratio. The soils have high colloidal activity and are low to medium sensitive.

Jagadish Narain and Ramanathan (1967) were perhaps the earliest to observe the physical properties of marine clays in Kerala. According to them, the marine clays of this region undergo irreversible changes in plasticity characteristics. Air drying was found to cause formation of aggregates, which was considered responsible for the change in plasticity.

Narain anui Ramanathan (1970), while discussing the geotechnical properties of the marine clays from Kuttanad area, focusses attention on the peculiarity of the soil where there is a variation in properties caused by air drying. The liquid limit considerably reduced on air drying; They established that air drying caused formation of aggregates and this was responsible for the irreversible reduction in plasticity. They' also proved that correlation of the type proposed by Skempton and Bjerrum cannot be considered as valid for clays where changes in soil structure are predominant. They also showed that the mechanical properties are dependent (N1 soil structure which is a function of interparticle forces as well as particle size and arrangement.

Sridharan et al. (1975) have investigated in detail the possible mechanisms governing the liquid limit of kaolinite and montmorillonite types of clays. To alter the force fields governing the particulate system, six organic fluids and water 'with 'wide 'variations in their dielectric properties have been used in the investigation.

Narasimha Rao, S et.al (1994), reported that the soft marine clay deposits pose several foundation problems and such weak clay deposits have been found both along seacoasts and in offshore areas spread over many parts of the world. By introducing the lime by injection technique the plasticity index, strength, and compressibility of the marine clay are improved.

Abraham, B. M. (1993) "A study on the strength and compressibility characteristics of Cochin marine clays", Ph.D Thesis, School of Engineering, Cochin University of Science & Technology, Kochi.

2.1 PROBLEMS ASSOCIATED WITH MARINE CLAYS

2.1.1 General

Among the various damages, the damage caused by the marine soft soils to the pavements and also for foundation beds are mentioned here in detail.

High compressibility and moderate swelling nature of the marine clay soils on inhabitation of water during the monsoon and reduce density or shrinkage occurs because of evaporation of water in summer and become hard due to increased density and this trend of soil decreases with depth. The volumetric deformation in these soils is attributed to seasonal variations in the ground water profile resulting in changes in moisture content. During summer, polygonal shrinkage cracks occurs near the surface, extending to depth of about 1.5m, indicating a high potential for compressibility. The depth of cracking indicates the depth of active zone in which significant volume change occurs, which is defined as thickness of soil in which moisture deficiency exists.

The entire stratum of marine clay soils in the field may not be active. Besides, as most soils do not respond quickly to the climate changes, the depth of active zone is greater than the depth of seasonal moisture fluctuations. The buildings in marine soils have posed serious problem of distortion and cracking throughout the world because of unlimited quantity of water being readily available to the foundation soil.

2.1.2 Damages to the Pavement Subgrades

Majority of the pavement failures could be attributed to the poor sub grade conditions and marine clay is one such problematic situation (Evans and McManus, 1999). Roads running through marine clays regions are subjected to severe unevenness with or without cracking, longitudinal cracking parallel to pavement centerline, rutting of pavement surface and localized failure of pavement associated with disintegration of the surface. The extensive damage to highways running over expansive and high compressible soil sub-grades is estimated to be in billions of dollars all over the world. Even railway tracks are no exception and are affected by appreciable movements due to the nature of high compressibility of the marine clay soils.

(A) Rutting

The rutting is mainly due to consolidation of one or more layers of pavement and also due to repeated application of the load along the same wheel path resulting in deformation of pavements. Depending upon the width and depth of ruts it can be found out whether the deformations are in sub grade or subsequent layers of the pavements.

(B) Longitudinal Cracks

This is due to differential volume changes that occur in marine soils. The deformation characteristics of the marine clay soils results in cracking through the full pavement thickness. The visual which is represented below is an example for the pavements cracks which are developed longitudinally.

Fig 2.1: Sub-grade failure crack

Slope failure due to Liquefaction:

The shoulder and pavement from the north-bound lanes of Pan American highway were pushed into a near vertical face by a 400 m long slope failure induced by liquefaction at the toe of the slope.

Fig2.2: Failure Of Slopes

(C) Shrinkage Cracks:

A large sand boil feature at the southern end of the 400 m long slope failure with shrinkage cracks in the material.

Fig 2.3 Cracks in Marine Clay Deposits

Ground cracks in the marine terrace deposits. The Canetti formation, indicating the eastern edge of the failure mass, is seen in the background.

Fig 2.4: Failure of Pavement

Over the years, the slopes began to experience shallow slope failures at numerous locations and by 2002, the slope failures were widespread and affected many areas of the road pavement. A typical shallow failure is shown in the bottom photo.

III. 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 main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. 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.

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There are different types of stabilization. They are:-

- Mechanical stabilization
- Cement stabilization
- Lime stabilization
- Bituminous stabilization
- Chemical stabilization
- Thermal stabilization

IV METHODOLOGY

4.1 MATERIALS USED AND THEIR PROPERTIES

The details of the various materials used in the laboratory experimentation are reported in the following sections.

4.1.1 Marine clay

The marine clay used in this study and was typical soft clay. The marine clay was collected at a depth of 0.30m to 1.00m from ground level from YETIMOGA area, Kakinada, Andhra Pradesh State, India. The properties of soil are presented in the Table 3.1. All the tests carried on the soil are as per IS specifications.

Table 4.1: Properties of Marine Clay

Properties of Marine Clay		
S. No.	Property	Value
1	Specific gravity	2.6
2	Differential free swell Index (%)	37
3	Atterberg's Limits	
	i) Liquid limit (%)	70.8
	ii) Plastic limit (%)	26.2
	iii) Plasticity index (%)	44.6
5	Grain Size Distribution	
	i) Sand Size Particles (%)	11
	ii) Silt & Clay Size Particles (%)	89
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.37
	ii) Optimum Moisture Content (%)	29.2
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.3
	ii) CBR - Soaked (%)	1.6
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	39
	ii) Angle of Internal Friction, Øu (Degrees)	0

Table 4.2: Properties of Bagasse ash

S. No.	Property	Value
1	Specific gravity	2.49
2	Atterberg's Limits	
	i) Plasticity index (%)	NP
3	Grain Size Distribution	
	i) Sand Size Particles (%)	32
	ii) Silt & Clay Size Particles (%)	68
4	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.34
	ii) Optimum Moisture Content (%)	17.5

4.1.2 NYLON FIBER

Fibres are the base unit of all textile materials and products. They are slender threadlike structures that can be spun into yarns and thread, and woven, knitted or felted into materials composed of atoms of various elements, such as carbon, hydrogen, oxygen, sometimes of nitrogen and other elements (sulphur) in lower quantities come from plants, animals and minerals. The term nylon refers to a family of polymers called linear polyamides. Nylon is a synthetic polymer, a plastic. Nylon fibres are now used to make many synthetic fabrics, and solid nylon is used as an engineering material.

4.1.3 JUTE FIBRE

Today, jute geo textile fabric is available in two different varieties, one is woven and other is non-woven fabric. Both the varieties are reckoned for high moisture absorption capacity. Their flexibility and excellent drainage properties are the reason behind their usage in agricultural sector to conserve soil erosion. Their long life span makes them perfect to be used in those sectors that required long-term applications. Due to their high durability and long life performance, they are in huge demand to be used as separator, vegetation growing mesh, vertical drains, etc.

Development of this completely natural and strong Jute geo textile is likely to enable it to be widely accepted in the varied soil reinforcement applications that may include the construction of rural roads, access roads, and road and flood embankments. Their superior drape ability, jute geo textile has come up as the ideal solution for accomplishing varied tasks. Widely accepted for greater moisture retention capacity, they have given a competitive edge to the geo textiles of other fabric. Easy to install and remove, they are on the top whenever it comes to quality, durability, sturdiness and strong nature. They can be availed in various sizes and dimensions to match the requirement of every task. Jute geotextile is available in the market at very lowest prices than the synthetic geo textiles.

4.1.4 Waste plastic:-

More than a 100 million tones of plastic is produced world-wide each year. Disposal of plastic through recycling, burning, or land filling is a myth because it does not undergo bacterial decomposition. Once plastic is produced, the harm is done once and for all. Plastic wastes clog the drains and thus hit especially urban sewage systems. So recycling of waste plastics directly involved to protect the environment and save resources, is a major event in the continuing restrictions on plastic packaging to save resources and form energy saving society.

We are using the Pieces of polythene bags which may be cut into standard dimensions of 5mm In length and 2mm in width. These polythene bags are collected from waste.

4.2 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.

4.2.1 LIST OF TESTS CONDUCTED

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

- Specific gravity of soil
- Determination of soil index properties (Atterberg Limits)
  - Liquid limit
  - Plastic limit
- Particle size distribution by sieve analysis
- Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test.
- Penetration tests-California bearing ratio test
- Unconfined Compression Test-Triaxial

V. RESULTS AND DISCUSSIONS

In the laboratory, various experiments were conducted by replacing different percentages of Bagasse Ash (BA) in the Marine clay and also further stabilizing it with lime as a binder and further reinforced with different discrete reinforcing inclusions. Compaction, Strength and CBR tests were conducted with a view to determine the optimum combination of Bagasse Ash (BA) as replacement in Marine clay and Lime as a binder and different discrete reinforcing inclusions like nylon fibre, treated jute fibre and waste plastic as reinforcing inclusions

Table 5.1: Variation of properties of soil for the different percentages of Bagasse Ash (BA) in the marine clay

BA (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	70.8	26.2	44.6	1.37	29.2	3.3	1.6	78
10	69.1	27	42.1	1.38	29	3.8	1.8	84
20	67.4	27.6	39.8	1.4	28.7	4.6	2.4	92
30	65.7	28.8	36.9	1.39	28.5	4.4	2.3	90

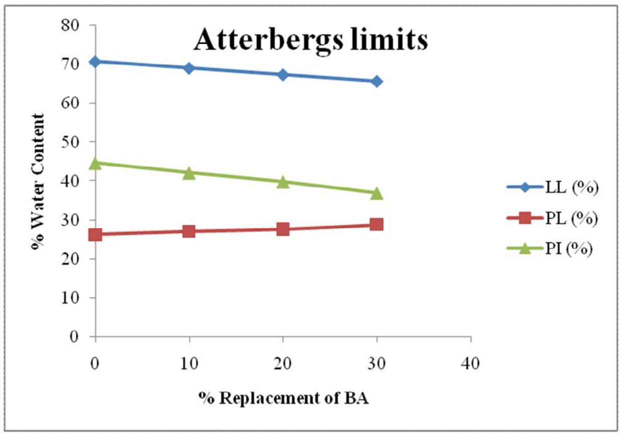

Fig 5.1 Variation of ATTERBERG LIMITS with % Replacement of (BA)

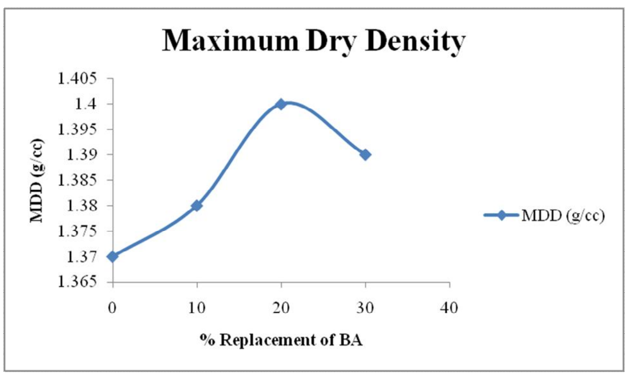

Fig 5.2 Variation of Maximum Dry Density with % Replacement of (BA)

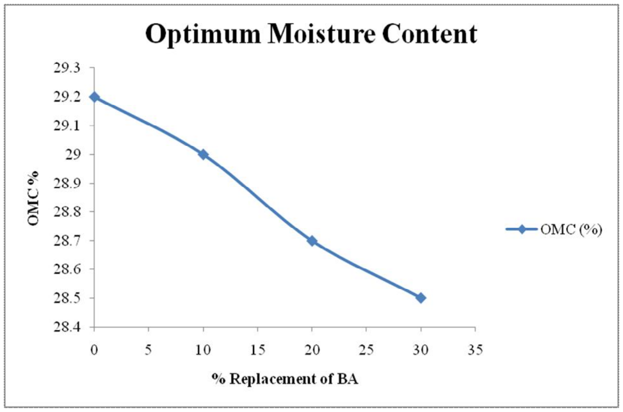

Fig 5.3 Variation of OMC with % Replacement of (BA)

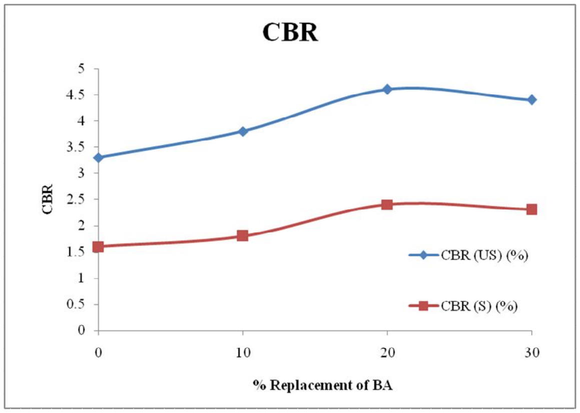

Fig 5.4 Variation of CBR with % Replacement of (BA)

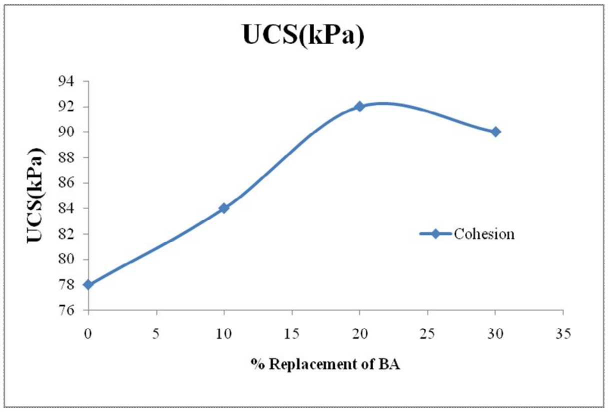

Fig 5.5 Variation of UCS (kPa) with %Replacement of (BA)

It can be inferred from the graphs, that there is a gradual increase in SOIL PROPERTIES With percentage replacement of Bagasse Ash (BA). From the above results the 20% replacement of Marine clay with Bagasse Ash (BA) can be considered as optimum.

Lime (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	67.4	27.6	39.8	1.4	28.7	4.6	2.4	92
2	61.6	29.5	32.1	1.42	28.9	5.2	2.8	99
4	59.3	30.8	28.5	1.46	29.1	5.9	3.5	114
6	56.9	32.4	24.5	1.49	29.4	6.7	4.1	127

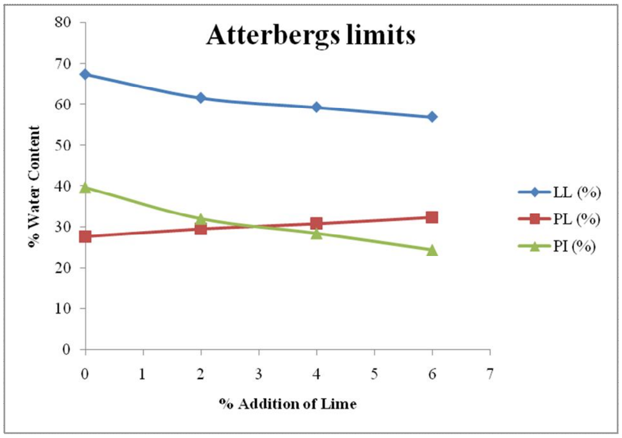

Fig 5.6 Variation of ATTERBERGS LIMITS with Lime

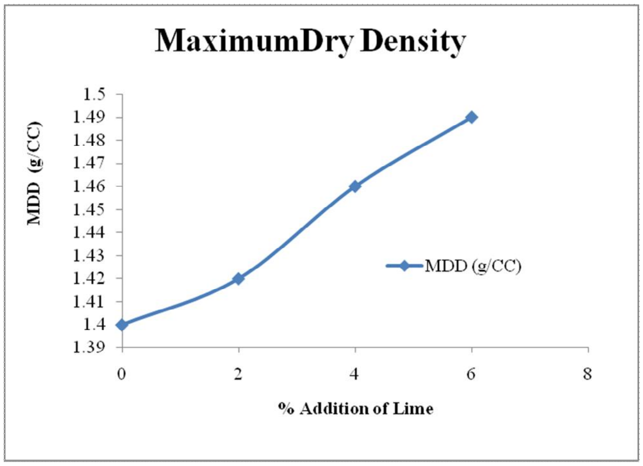

Fig 5.7 Variation of MDD with Lime

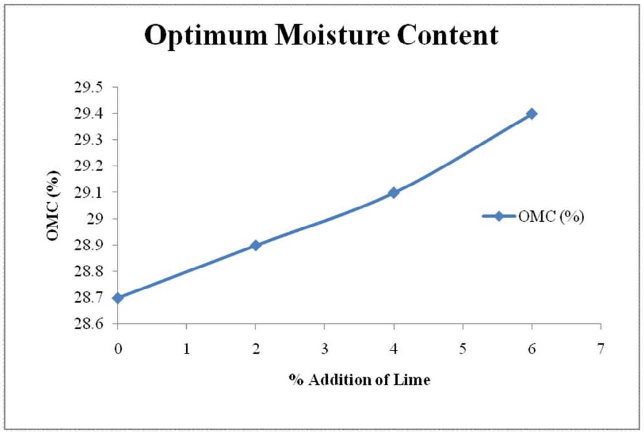

Fig 5.8 Variation of OMC with Lime

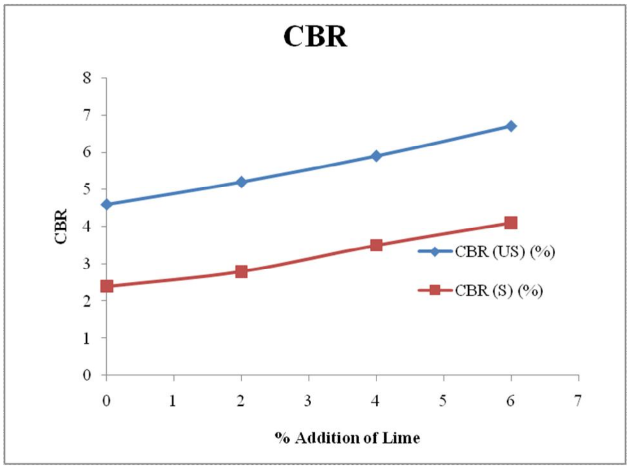

Fig 5.9 Variation of CBR VALUES with Lime

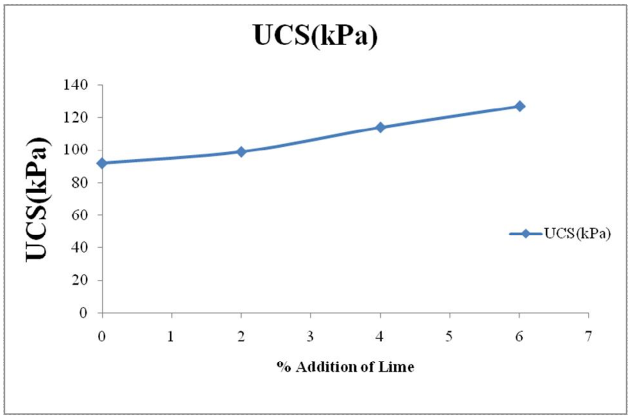

Fig 5.10 Variation of UCS VALUES with Lime

It can be inferred from the graphs, that there is a gradual increase in SOIL PROPERTIES With percentage replacement of Bagasse Ash (BA) and percentage addition of lime. From the above results the Optimum Content of Lime with 20% Bagasse Ash (BA) as replacement of Marine clay is 6%..

Further different discrete reinforcing inclusions like nylon fibre, jute fibre and waste plastic were added to the Bagasse Ash (BA) treated Marine clay with an optimum percentage of lime i.e. 6% and fibre content was kept constant at 1% by weight and the studies was done.

Table: 5.3 Evaluating the Influence of Different Fibre Inclusions (NF, TJF & WPI) with 20% Quarry Dust as replacement + 6% Lime Content and the fibre content was kept constant at 1% by weight

Type of Fibre (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
Without Fibre	1.49	29.4	6.7	4.1	127
NF	1.5	29.5	8.1	5	145
TJF	1.51	29.7	8.3	5.9	152
WPI	1.48	29.4	7.9	6.8	141

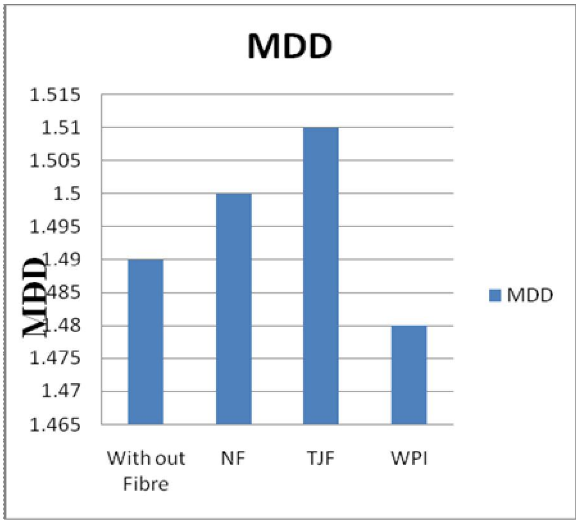

Fig 5.11 Influence of Different Fibre Inclusions on MDD with optimum of QD&LIME Content and fibre content was kept constant at 1% by weight

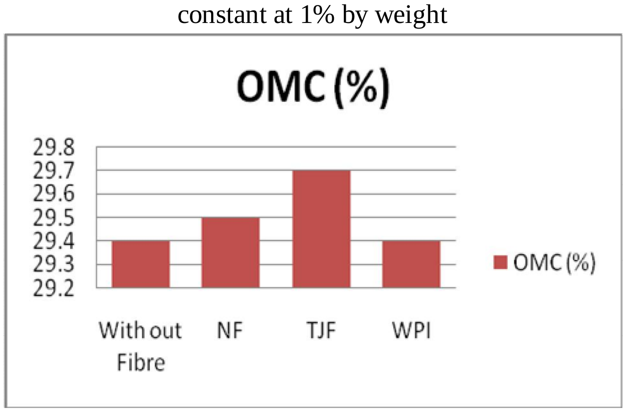

Fig 5.12 Influence of Different Fibre Inclusions On OMC with optimum of QD&LIME Content and fibre content was kept constant at 1% by weight

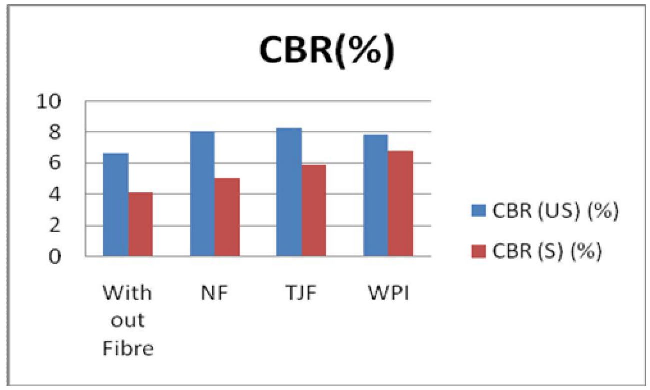

Fig 5.13 Influence of Different Fibre Inclusions on CBR with optimum of QD&LIME Content and fibre content was kept constant at 1% by weight

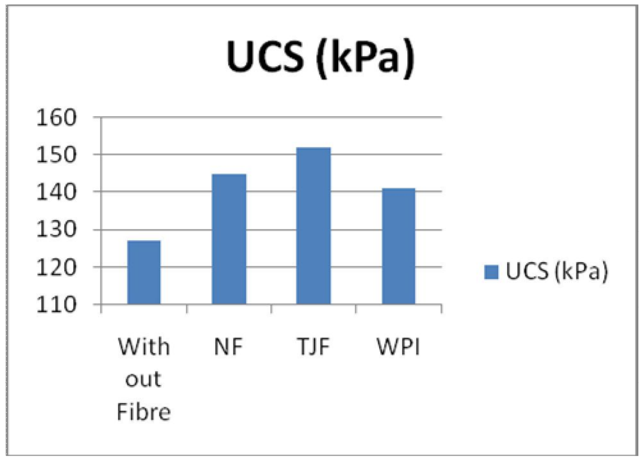

Fig 5.14 Influence of Different Fibre Inclusions on UCS VALUES with optimum of QD&LIME Content and fibre content was kept constant at 1% by weight

It can be inferred from the graphs, that there is a gradual increase in SOIL PROPERTIES With the addition different discrete reinforcing inclusions to the optimum opercentage replacement of Bagasse Ash (BA) and percentage addition of lime. From the above results the better performing Fibre with 6% Lime + 20% Bagasse Ash as replacement of Marine Clay is TREATED JUTE FIBRE.

Finally from the above discussions, from the above results the fibre content was kept constant at 1% by weight with 6% Lime + 20% Bagasse Ash as replacement of Marine Clay is TREATED JUTE FIBRE. It is clear that there is improvement in the behaviour of Marine Clay stabilized with Bagasse Ash (BA) + LIME +DRI. It is evident that the addition of Bagasse Ash (BA) to the virgin Marine clay showed an improvement in Compaction and Strength characteristics to some extent and on further addition of lime shows a prominent results and further blending it with different reinforcing inclusions, the improvement was more pronounced. This made the problematic Marine clay which if not stabilized is a discarded material, a useful fill material with better properties. The Bagasse Ash (BA) replacement in the Marine clay has improved its strength and upon further blending with DRI, the strength has further improved and also these materials has imparted friction to the clayey soil. It can be summarized that the materials Bagasse Ash (BA), LIME and DRI had shown promising influence on the Strength and Penetration properties of expansive soil.

And further Durability Studies (Curing) on samples prepared with 1.0% TJF + 6% Lime + 20% BA as replacement of Marine Clay

5.4 DURABILITY STUDIES - (CURING)

Durability Studies (Curing) on samples prepared with 1.0% WPI + 6% Lime + 20%VPW as replacement of Marine Clay

Table 5.4: Durability Studies (Curing) on samples prepared with 1.0% TJF + 6% Lime + 20% BA as replacement of Marine Clay

Curing Period (Days)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	8.3	5.9	152
7	8.8	6.7	168
14	9.5	7.8	195
28	9.9	8.6	204

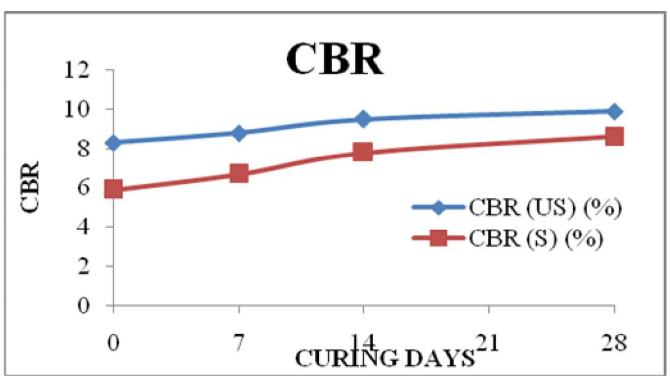

Fig 5.15 Variation of CBR VALUES with different Curing periods

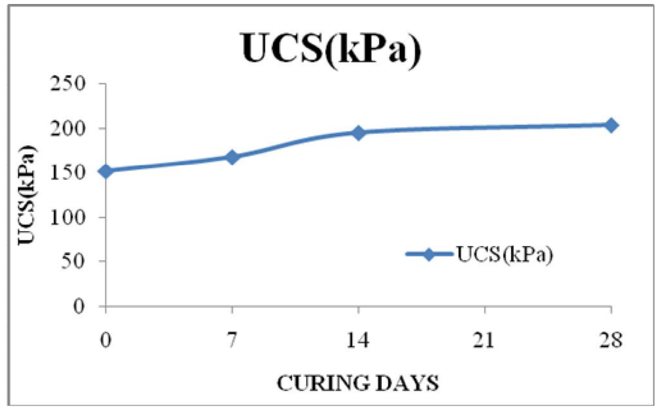

Fig 5.16 Variation of UCS VALUES with different Curing periods

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 swelling, and high plasticity characteristics.
- It was observed that the treatment as individually with 20% Bagasse ash has moderately improved the marine clay.
- There is a gradual increase in maximum dry density with an increment in the % replacement of Bagasse ash up to 30% with an improvement of about 10% and it is observed that for the replacement of 20% there is gradual increase in Maximum dry density about 2.18%.
- There is an improvement in maximum dry density and also corresponding strength characteristics with an increase in the lime content from 0% to 6% with an increment of 2%.There is an improvement of 70.8 % In CBR and 38.04 % in UCS values.
- Further blending with different discrete reinforcing inclusions like nylon fibre, treated jute fibre and waste plastic fibres, among all above with 1% by weight of treated jute fibre shows a prominent results.
- Durability Studies (Curing) on samples prepared with 1.0% DRI + 6% Lime + 20% Bagasse ash as replacement of Marine Clay graph shows increment of CBR and UCS values with increment of curing periods.
- It is evident that the addition of Bagasse ash to the virgin Marine Clay showed an improvement in compaction, strength and penetration characteristics to some extent and on further blending it with lime and different reinforcing inclusions the strength mobilization was more pronounced.

- Finally it can be summarized that the materials Bagasse ash and lime and different waste plastic inclusions 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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