A Study on The Use of Bagasse Ash, Cement And Nylon Fibres In Improving The Strength Characteristics of Soft Marine Clays

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Abstract- *India being a peninsular country, has a long coastline and also been the habitat for a good amount of population. This gives scope for major developmental activity and hence exposes the soft marine clay deposits that are found these areas. These usually have low density and low shear strength in nature. Chemical stabilization has been extensively used for the improvement of these soft marine clays, in enhancing the shear strength and limiting the deformation behavior. This project is aimed at investigating the possibility of utilizing an agriculture waste, Bagasse Ash in combination with cement to stabilize poor soft marine clays and studying the results from further addition of nylon fibers t the marine clay 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 Bagasse Ash and Lime to soft marine clay and the results will be analyzed to assess the efficacy of the materials used.*

Keywords- soft marine clay, Bagasse Ash, cement, Nylon fibre (NF)

I. INTRODUCTION

1.1 GENERAL

Vast areas, particularly along the coast, are covered with thick soft marine clay Deposits having very low shear strength and high compressibility. 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. These soils are generally found in the states of west Bengal, Orissa, and Andhra Pradesh, tamilnadu, Kerala, Karnataka, Maharashtra and some parts of India. So Regions for easy access. Marine clays exist in these regions are weak and highly compressible in nature continued efforts have been made all over the world to devise ways to means to solve the problems of marine clays. Placement of adequate surcharge load, chemical stabilization and using various reinforcement techniques are some of the tried and tested remedial measures to avoid problems posed by the marine clays.

A comprehensive review of literature indicates that considerable amount of work of work related to determination of engineering behavior of marine soils has 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),Shridharametal.(1989), Mathwetal. (1997) and Chew et.al. (2004) are worth of note. Significant research on strength and stiffness characteristics was performed by Koutsoftas et al.(1987) and Zhou et al. (2005). ; Zhuge et.al, (2007); Ameta,(2007); Basack et. Al,(2009); Kamuruzzaman et.al, (2009) and Fairfax country , Virginia, (2010). The loss caused due to the damaged structures proved the need for more reliable investigation of such soils and necessitates methods to eliminate, or reduce, the effect of settlements. To overcome these problems, there is no other alternative, except to improve the sub-soil or sub grade for expected loads with suitable treatment to the in-situ soil.

In this work it is attempted to study the effect of BAGGASSE ASH and CEMENT And Nylon fibers on the properties of marine clay.

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are as follows.

To identify the strategy of techniques to overcome the problems posed by marine clays with a view to adopt suitable methodology through critical review of literature.

To study the impact of proposed additives and admixtures on the properties of marine clays through laboratory experimentations.

To evaluate the performance of marine clay when stabilized with proposed additives and admixtures and their suitability for fill material and sub grade material.

To investigate the suitability and adoptability of nylon fibres as discrete reinforcement.

II. REVIEW OF LITERATURE

2.1 GENERAL

For any developing nation like India transportation and communication facilities are vital. The technology of road construction is subjected to changes to cope up with the vehicular pattern, construction materials and sub grade condition.

Sub grade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climate and loading conditions. The formation of waves, corrugations, rutting and the phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally attributed due to the poor sub grade conditions.

All over the world, problems 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.

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.

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.

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..

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.

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.

(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.

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.

Fig2.1: 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 2.2 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.

STABILIZATION

The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Typically, this is important for road constructions and other concerns related to the building and maintenance of infrastructure. Soil that has been stabilized will have a vastly improved weight bearing capability, and will also be significantly more resistant to being damaged by water, frost, or inclement conditions.

STABILIZATION ALTERS THE FOLLOWING ENGINEERING PROPERTIES

Increases the load bearing capacity and shear strength of soil

Decreases the permeability and compressibility

There are different types of stabilization. they are:-

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

III. METHODOLOGY

3.1 MATERIALS USED AND THEIR PROPERTIES

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

3.1.1 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 at 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.

3.1.2 CEMENT

Cement is a commonly used binding material in the construction. The cement is obtained by burning a mixture of calcareous (calcium) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. It was first produced by a mason Joseph Aspdin in England in 1924. He patented it as portland cement.we used commercial cement.

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 (%)	38
3	Atterberg's Limits	
	i) Liquid limit (%)	70.3
	ii) Plastic limit (%)	25
	iii) Plasticity index (%)	45.3
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)	1.38
	ii) Optimum Moisture Content (%)	29
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.3
	ii) CBR - Soaked (%)	1.6
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	38
	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

3.1.2 NYLON FIBER

Nylons are semi-crystalline polymers. The amide group -(-CO-NH-)- provides hydrogen bonding between polyamide chains, giving nylon high strength at elevated temperatures, toughness at low temperatures, combined with its other properties, such as stiffness, wear and abrasion resistance, low friction coefficient and good chemical resistance. These properties have made nylons the strongest of all man-made fibers in common use. Because nylons offer good mechanical and thermal properties, they are also a very important engineering thermoplastic. For example, 35% of total nylon produced is used in the automobile industry. There are several commercial nylon products, such as nylon 6, 11, 12, 6/6, 6/10, 6/12, and so on. Of these, the most widely used nylon products in the textile industry are formed of nylon 6 and nylon 6/6. The others are mainly used in tubing extrusion, injection molding, and coatings of metal objects.

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.

3.2 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.

3.2.1 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

IV. 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 nylon fibers. 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 CEMENT as a binder and different discrete reinforcing inclusions like nylon fibre.

Table 5.1: Results of the tests conducted on marine clay replacement with different percentages of Bagasse Ash

BA (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	70.3	25	45.3	1.38	29	3.3	1.6	76
5	68.8	26.7	42.1	1.39	28.6	3.9	2	85
10	66.9	27.9	39	1.4	28.2	4.7	2.6	97
15	64.6	29.4	35.2	1.42	27.8	5.8	3.5	104
20	63.1	31.2	31.9	1.41	27.3	5.4	3.1	98
25	61.5	33.3	28.2	1.39	26.7	5.1	2.7	91

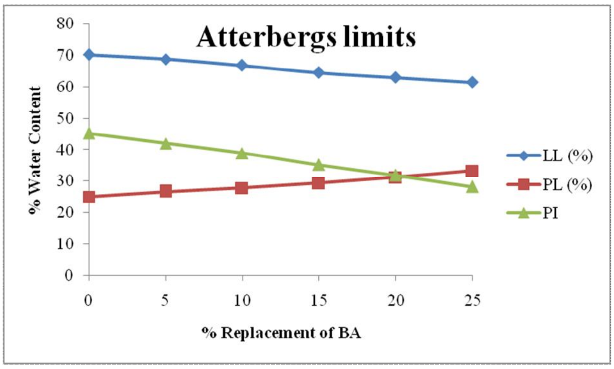

Fig 4.1 Plot showing the Variation in Atterberg's Limits with % Replacement of BA

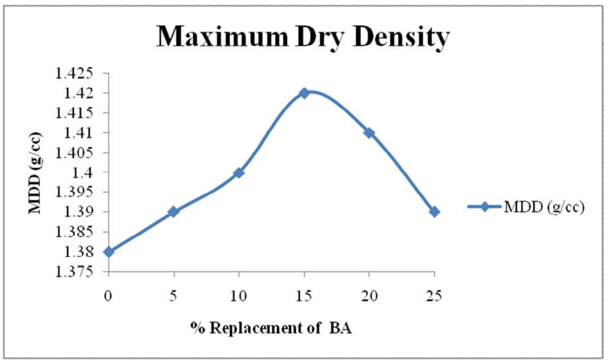

Fig 4.2 Plot showing the Variation in MDD with % Replacement of BA

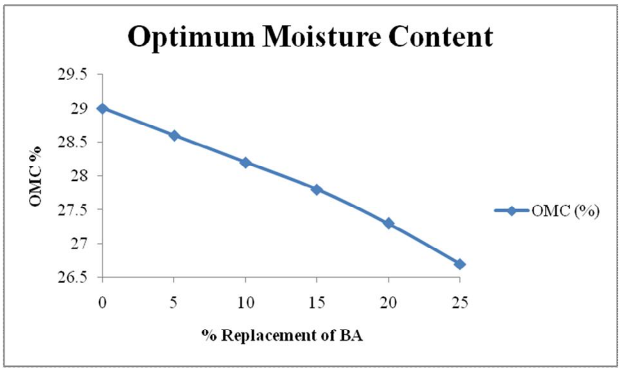

Fig 4.3 Plot showing the Variation in OMC with % Replacement of BA

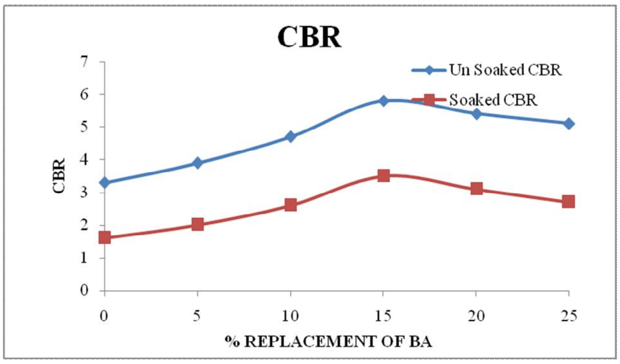

Fig 4.4 Plot showing the Variation in CBR VALUES with % Replacement of BA

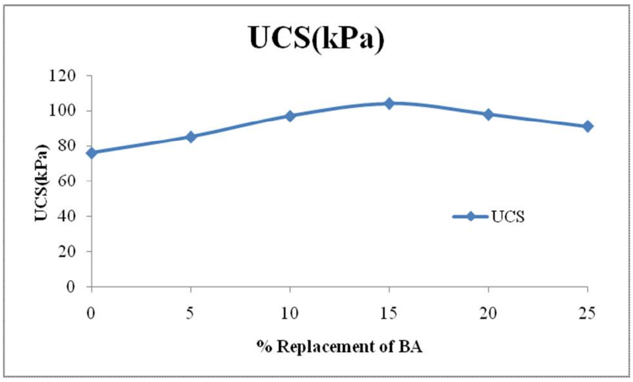

Fig 4.5 Plot showing the Variation in UCS with % Replacement of BA

IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF % BAGASSE ASH AS REPLACEMENT OF MARINE CLAY IS **15%.**

4.4 EFFECT OF % CEMENT AS BINDER ON THE PROPERTIES OF WEAK MARINE SOIL

The influence of CEMENT on the Index, Compaction, CBR, UCS properties of marine soil are clearly presented in Table 4.2 and Figures 4.6, 4.7, 4.8, 4.9, and 4.10 respectively. The percentage of CEMENT was varied from 0%, 0.5%, 1%, and 1.5%. From the above graphs, it was observed that the treatment with 1.5% CEMENT 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 1.5% with an improvement of about 44.3%. Also maximum dry density is improved by an amount of 7.74% and it was about 78.8% for UCS and 50%, 111.4% for UnSoaked, Soaked CBR respectively

4.2 Results of the tests conducted on marine clay with different percentages of CEMENT Content with 15% BA as replacement

Cement (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	64.6	29.4	35.2	1.42	27.8	5.8	3.5	104
0.5	60.2	28.5	31.7	1.45	27.2	6.6	4.8	137
1	57.3	31.8	25.5	1.48	26.5	7.9	6.1	162
1.5	53.9	34.3	19.6	1.53	25.7	8.7	7.4	186

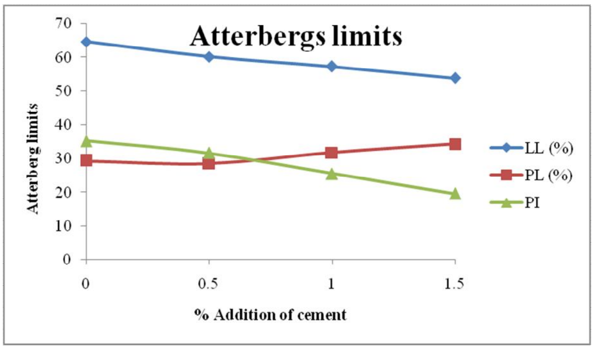

Fig 4.6 Plot showing the Variation in Atterberg limits with different % of CEMENT

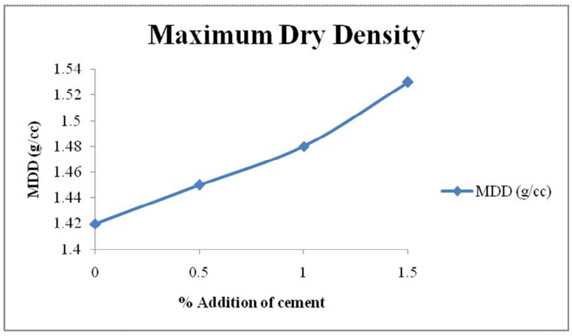

Fig 4.7 Plot showing the Variation in MDD with different % of CEMENT

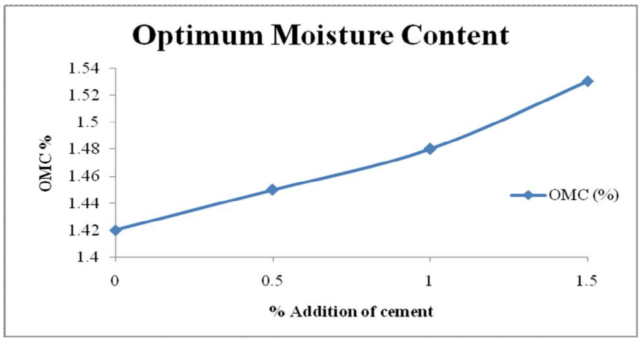

Fig 4.8 Plot showing the Variation in OMC with different % of CEMENT

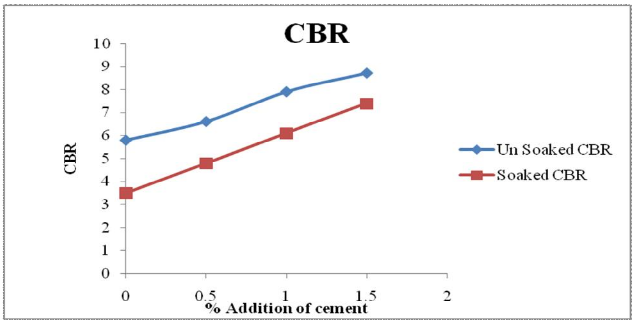

Fig 4.9 Plot showing the Variation in CBR with different % of CEMENT

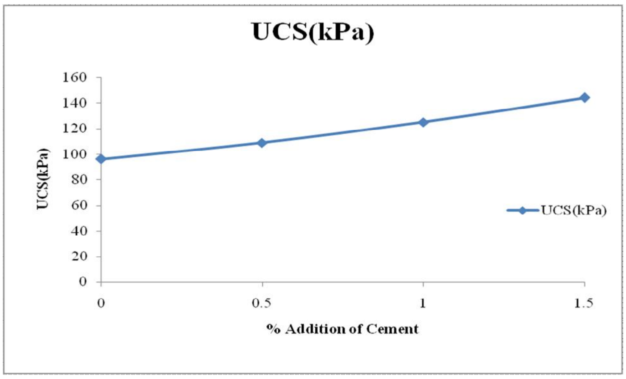

Fig 4.10 Plot showing the Variation in UCS with different % of CEMENT

IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF CEMENT WITH 15% BAGASSE ASH AS REPLACEMENT OF MARINE CLAY IS 1.5%

4.5 EFFECT OF NYLON FIBRE ON THEPROPERTIES OF WEAK MARINE SOIL + BAGASSE ASH AND CEMENT

The influence of NYLON FIBRE on the Compaction CBR, UCS properties of weak marine Soil + Bagasse Ash and CEMENT mixes are clearly presented in Table 4.3Figures 4.11, 4.12, 4.13, 4.14, and 4.15 for different percentages of NYLON FIBRE respectively. The percentage of NYLON FIBRE was varied from 0%, to 2 % with an increment of 0.5%.In the laboratory, tests were conducted by inclusing different percentages of NYLON FIBRE to Weak Marine Soil + Bagasse Ash and CEMENT .It is observed from the graphs, that there is an improvement in Maximum dry density is improved by an amount of 2.61% and it was about 37.09% for UCS and 12.6%, 16.2% for Unsoaked, Soaked respectively.

4.3 Results of the tests conducted on marine clay Different percentages of NYLON FIBRE with 15% Bagasse Ash as replacement + 1.5% CEMENT Content

NF (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	1.53	25.7	8.7	7.4	186
0.5	1.54	25.4	9.2	7.9	203
1	1.55	25.1	9.5	8.2	229
1.5	1.57	24.8	9.8	8.6	255
2	1.56	24.6	9.6	8.1	240

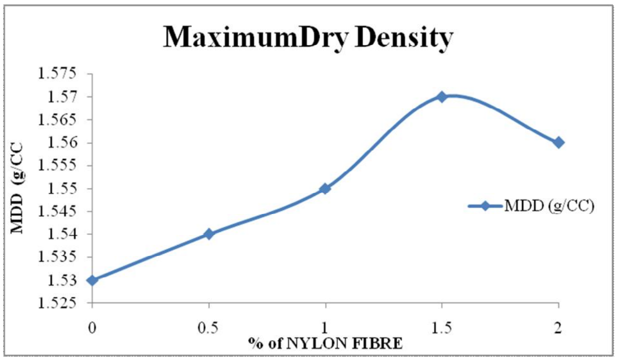

Fig 4.11 Plot showing the Variation in MDD with different percentages of (NYLON FIBRE) with 15% BA + 1.5% CEMENT Content

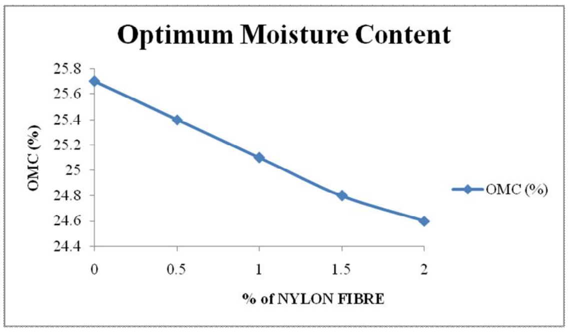

Fig 4.12 Plot showing the Variation in OMC with different percentages of (NYLON FIBRE) with 15% BA + 1.5% CEMENT Content

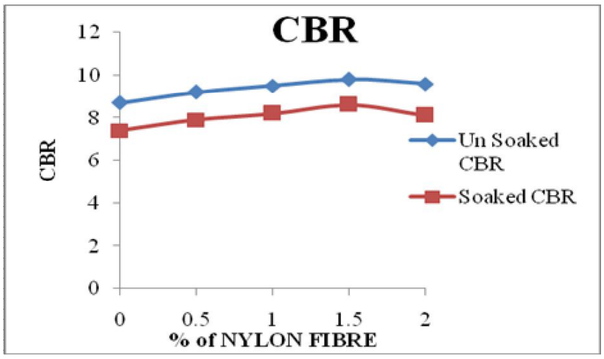

Fig 4.13 Plot showing the Variation in CBR with different percentages of (NYLON FIBRE) with 15% BA + 1.5% CEMENT Content

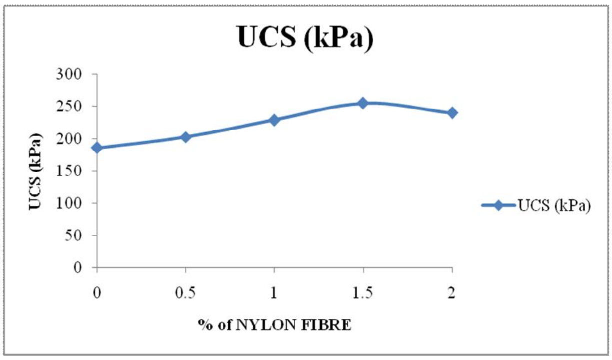

Fig 4.14 Plot showing the Variation in UCS with different percentages of (NYLON FIBRE) with 30% BA + 6% CEMENT Content

IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF NYLON FIBRE WITH 1.5% CEMENT + 15% BAGASSE ASH AS REPLACEMENT OF MARINE CLAY IS 1.5%

CURING PERIOD (DAYS)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	9.8	8.6	255
7	10.1	8.8	279
14	10.4	9.1	292
28	10.8	9.5	316

4.6 EFFECT OF (CURING) ON SAMPLES PREPARED WITH 1.5% NYLON FIBRE + 1.5% CEMENT + 15% BA AS REPLACEMENT OF MARINE CLAY

From the above results It is observed that samples prepared with 1.5% NYLON FIBRE + 1.5% CEMENT + 15% BA 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 Bagasse Ash and crumb+ NYLON FIBRE+ CEMENT. It is evident that the addition of Bagasse Ash and CEMENT to the virgin Marine soil showed an improvement in plasticity, compaction and strength properties to some extent and on further blending it with CEMENT, the improvement was more pronounced. This made the problematic weak marine soil which if not stabilized is a discarded material, a useful fill material with better properties. The Bagasse Ash and CEMENT in the weak marine soil has reduced the plastic nature of the clay and upon further blending with CEMENT, the plasticity was even reduced. It can be summarized that the materials Bagasse Ash and CEMENT and NYLON FIBRE 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.

4.4 Results of Durability Studies (Curing) on samples prepared with 1.5% NYLON FIBRE + 1.5% CEMENT + 15% BA as replacement of Marine Clay

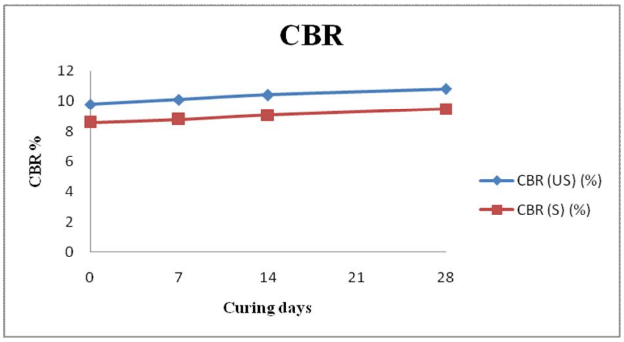

Fig 4.12 Plot showing the Variation in CBR at different curing periods

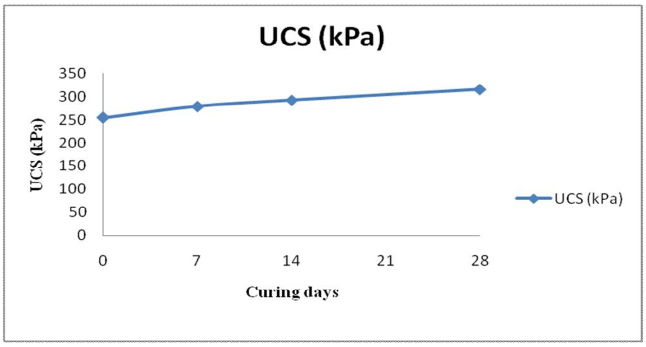

Fig 4.13 Plot showing the Variation in UCS at different curing periods

V. 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 15% of Bagasse Ash has moderately improved the marine soil.

There is a gradual increase in maximum dry density with an increment in the % replacement of BA up to 15% with an improvement of about 2.89% and it was about 22.29% for plasticity characteristics.

There is an improvement in CBR, Shear parameters also by an amount of 36.84% for UCS and 75.75%, 118.75% for Unsoaked, Soaked CBR respectively.

It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % Addition of CEMENT up to 1.5% with an improvement of about 44.3%. Also maximum dry density is improved by an amount of 7.74% and it was about 78.8% for UCS and 50%, 118.4% for Unsoaked, Soaked CBR respectively.

There is an improvement in plasticity & Strength characteristics with an increase in the NYLON FIBRE from 0% to 1.5% with an improvement of 0..5% for MDD.

There is an improvement by an amount of 37.09% for UCS and 12.6%, 16.2% for UnSoaked, Soaked respectively.

It is evident that the addition of Bagasse Ash and CEMENT to the virgin Marine soil showed an improvement in properties to some extent and on further addition of NYLON FIBRE, the improvement was more pronounced.

Finally it can be summarized that the materials Bagasse Ash and CEMENT and NYLON FIBRE had shown promising influence on the properties of Weak Marine soil, thereby giving a two-fold advantage in improving problematic expansive 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.724-732.

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

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

[4] Gopal Ranjan 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] Koteswara Rao, D (2004), The performance studies on Geo-grid as reinforcement in the flexible pavement construction, IGC-2004, pp 457-460.

[10] 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.

[11] Narasimha Rao, S., Rajasekaran, G. and Prasad, C.V (1993), CEMENT column method of stabilization in a marine clay, Proc. of the 11th Asian Geotechnical Conf., Singapore, 1993, pp.397-402.

[12] Abduljauwad, S.N (1991), Characteristics and chemical treatment of soft clay in Al- Qatif, Saudi Arabia. Journal of Engineering Geology, Vol.31 Issue, 2, 1991.

[13] Al-Rawi, N.M (2000), The effect of curing and temperature on CEMENT stabilization, Proc. Of Second Australian Conf. on Engineering Materials, Sydney, 1981, pp.611-662.

[14] Sridharan, A. et al.(2005) "Utilization of Bagasse Ash to Improve the Geotechnical Properties of Soils in Highway Construction", Geotechnical Testing Journal (GTJ) Volume 28, Issue 4.

[15] Balasubramaniam, A.S., Bergado, D.T., Buensuceso, B.R. and Yang, W.C.,(1989), Strength and deformation characteristics of CEMENT treated soft clays, Geotechnical Engineering (AIT), 20, 1989, pp. 49-65.

[16] Basack and Purkayastha (2009), Engineering properties of Marine Clays from the eastern coast of India. Journal of Engineering and Technology Research Vol.1 (6), pp. 109-114, September,2009.

[17] Bjerrum, L and Heiberg, S (1971), A review of the data on shear strength of Marine Clay, www. the free library. Com.

[18] S. Narasimha Rao and Rajasekaran.G (1994), CEMENT Injection Technique to improve the behavior of Soft Marine Clay, Ocean Engineering, Vol.21, Issue 1, January 1994, p.p 29-43.
[19] Sridharan, A. et al.(2005) "Utilization of Bagasse Ash to Improve the Geotechnical Properties of Soils in Highway Construction", Geotechnical Testing Journal (GTJ) Volume 28, Issue 4.
[20] VIJAY KUMAR PATIDAR, DR. SUNEET KAUR Done a Literature review on the Use of Waste Plastic to Improve Geotechnical Properties of Soil conclusions are drawn based on the studied conducted by various researchers.
[21] Sridharan A, Rao SM, Chandrasekaran S (1989), Engineering Properties of Cochin and Mangalore Marine Clays, Indian Geotech, J.1:265-278.
[22] Sridharan, A. and Miura, N (2000), Physico-chemical and engineering behaviour of Ariake clay and its comparison with other marine clays, proc. lnt. Symposium. IS Yakahama 2000. 2:203-213.
[23] Boardman, D.I., Glendenning, S. and Rogers C.F.D (2000), Development of stabilization and solidification in CEMENT-clay mixes, Geotechnique, 51, 2001, pp. 533-543.
[24] BS EN 15237: Execution of Special Geotechnical Works – Vertical Drainage.
[25] Chandrashekar, B.P., Prasada Raju, G.V.R (1999), Relative Performance of CEMENT and Calcium Chloride on Properties of Expansive Soil For Pavement Subgrades, Proc. Of IGC-99, Calcutta, 1999, pp 279-282.
[26] Charles M et al (2012), "Compactive effort influence on properties of Bagasse Ash-black cotton soil mixtures", International Journal of Geotechnical Engineering.
[27] Narasimha Rao, S and Rajasekaran.G (1993), Strength and Deformation behavior of CEMENT treated Marine Clay, 3rd int. conf. on offshore and polar Engg, Singapore, June 1993, Vol.1, pp 585-590.
[28] Narasimha Rao,S and Swamy. K. K. R (1984), Geotechnical Properties of Indian Marine Clays, Ind. Geotech conf., Calcutta, Dec 84, Vol.1.
[29] Prasada Raju, G.V.R (2001), Evaluation of Flexible Pavement Performance with Reinforcement and Chemical Stabilization of Expansive Soil Sub grade, a Ph.D. thesis, Kakathiya University, Warangal,(A.P).
[30] Rajasekaran, G and Narasimha Rao, S (2002), Compressibility behaviour of CEMENT treated marine clay, Ocean Engineering, 29,545-559.
[31] Rajasekaran, G and Narasimha Rao. S (2000), Strength Characteristics of CEMENT treated marine clay, Journal of Ground Improvement, Vol.3, pp 127-136.
[32] Abduljauwad, S.N (1991), Characteristics and chemical treatment of soft clay in Al- Qatif, Saudi Arabia. Journal of Engineering Geology, Vol.31 Issue, 2, 1991.