A Performance Studies on The Use of Nylon Fibers and Lime In Improving Metakaolin Modified Expansive Soil

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Abstract- *Expansive Soils are causing severe damages to the structures such as buildings and pavements built over them because of their property of high degree of swelling and shrinkage. If the buildings constructed over weak soils, it will under large deformation owing to lower load carrying capacity of weak soils and severe volume change swell-shrink behaviour of soft soils. This phenomenon will result in rutting mode of premature failure requiring immediate strengthening or reconstruction of the whole structure. Thus, for safe design such weak/soft soils need to be improved before construction. Hence in order to improve the properties of such soils many methods are available like soil stabilization, soil replacement, moisture control, prewetting etc. In recent years, soil stabilization by using various industrial wastes was a most common practice. Keeping in view in the present work, experimentation was carried out to investigate the performance of different additives like Lime and Metakaolin which is a pozzolanic material and is obtained by calcination of Kaolinite clay at temperatures from 700°C to 800°C and also Reinforcement of problematic soil to improve its strength properties for civil engineering construction is a possible means to put to use the abundant Nylon fibres, which might become vital in contributing to sustainable development.*

To understand the performance of stabilized soil, its properties like Atterberg's Limits, Compaction Parameters, Swell Parameters and Penetration Parameters were studied. Hence, in this project, the use of nylon fibres and lime in different percentages as stabilizing materials for improving the Metakaolin modified expansive soil will be tried by conducting various tests and the results will be analyzed to assess the performance of the materials used.

Keywords- Expansive soil, Metakaolin, Nylon fibres, stabilization.

I. INTRODUCTION

For centuries mankind was wondering at the instability of earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Swelling soil always create problem for lightly loaded structure, by consolidating under load and by changing volumetrically along with seasonal moisture variation. As a result the superstructures usually counter excessive settlement and differential movements, resulting in damage to foundation systems, structural elements and architectural features. In a significant number of cases the structure becomes unstable. Even when efforts are made to improve swelling soil, the lack of appropriate technology sometimes results volumetric change that are responsible for billion dollars damage each year. It is due to this that the present work is taken up.

Expansive soil deposits occur in the arid and semi arid regions of the world and are problematic to engineering structures because of their tendency to heave during wet season and shrink during dry season. Expansive soils causes more damage to structures, particularly light buildings and pavements, than any other natural hazard, including earthquakes and floods. During the last few decades damage due to swelling action has been observed clearly in the semi arid regions in the form of cracking and breakup of pavements, roadways, building foundations, slab-on-grade members, and channel and reservoir linings, irrigation systems, water lines, and sewer lines.

Various remedial measures like soil replacement, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability, like longer time periods required for pre-wetting the highly plastic clays, difficulty in constructing the ideal moisture barriers, pulverization and mixing problems in case of lime stabilization and high cost for hauling suitable refill material for soil replacement etc.

Stabilization of expansive soils is an alternative for geotechnical engineers considering the economics of construction with expansive clay soils. Mechanical stabilization, such as compaction, is an option; however many

engineers have found it necessary to alter the physicochemical properties of clay soils in order to permanently stabilize them
.

1.1 Problems associated with expansive soils

The swelling and shrinking properties of the soil depends on the water content of the soil. The water content of soil is considerably reduced during summer hence the soil becomes stiff and shrinkage cracks develop. During the rainy season the water content of the soil is increased resulting in swelling when a building is constructed on this type of soils, the soil below the building is protected from excess heat even during summer. This soil swells because its evaporation is obstructed. However the soil adjacent to the building which is open to atmosphere will experience normal swelling and shrinkage. Thus, the differential movements occur during the hot weather. Because of this swelling and shrinking behaviour of soils,

The floor slab of a building is pushed up, it takes a dome shape and cracks develop in the floor. The footing wall is pushed outward due to swelling.

- Cracks occur at the junction between the wall and the floor slab and also between the wall and roof slab because movements are restricted at these points.
- Cracking also occur at the corners of the window and door openings because of diagonal cracking of walls.
- Utilities buried in the soil like water pipes, sewage lines, gas lines, telephone lines… may be damaged.

II. REVIEW OF LITERATURE

Expansive soils are highly problematic soils and cause damage to structures founded in them because of their potential to react to changes in moisture regime. They swell when they imbibe water and shrink when water evaporates from them. The specific characteristics of problem soils, however, vary from re-gion to region. It is a well-known fact that expansive soils pose considerable problems in civil engineering constructions. In India, predominantly expansive soils are found in Deccan trap region of Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Gujarat, and Tamilnadu. About 20% of the total land area of the Indian subcontinents covered with expansive soils. Expansive soil is considered as a potentially hazardous soil which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life.

Soil stabilization involves changes in properties like strength, density, swelling behaviour, etc. Using soil stabilization techniques, the low strength profiles of expansive soils can be improved to a considerable level. Such techniques are very economical which reduces the overall cost of a project. Industrial waste management is one of the major environmental concerns worldwide. The exponentially growing industrial waste needs to recycle or to be utilized in an eco-friendly manner.

According to (Collins and Ciesielski 1994) potential use of highest volumes of quarry waste are ce-ment treated sub base and flowable fill. (Sridharan et. al 2005), reported that quarry dust showed high shear strength and is beneficial for its use as a geotechnical material. The effect of stabilization on expan-sive soil using a mixture of fly ash and stone dust in the proportions of 1:1 up to 50% to an expansive soil is studied by (Ali and Koranne 2011). Tests were conducted and concluded that the strength was reported to increase. (Arun Kumar and Kiran Biradar 2013) were studied the effect of different percentages of quarry dust mixing in expansive soil. Atterberg limits, compaction and California bearing ratio tests were performed to determine the strength properties. From the experimental results, the addition of the waste to the soil reduces the clay content and thus increases in the percentage of coarser particles, reduces the liquid limit by 26.86%, plasticity index by 28.48% of unmodified soil, optimum moisture content decreased by 36.71%, maximum dry density is increased by 5.88% by addition of (40%) quarry dust and it is also identified that addition of 40% quarry dust yield high California bearing ratio value.

Fly ash (FA) is a residual or by-product that is generated during the thermal processing of pulverized coal in coal-fired electric and steam generating plants. In a study by Pandian and Krishna, 2003, examined the effects of lime and FFA adding upon the expansive soil behaviour and observed positive results. Another research by Phani Kumar and Sharma (2004) also investigated the influence of FFA addition on some geotechnical properties of expansive soil. Their study also noticed improvements in these properties with addition of FA. FFA and cement stabilization of expansive soil was investigated by Amu et al. (2005). They noticed that the effect of 9% cement and 3% FA was better as compared with that of 12% cement in terms of soil stabilization.

Laboratory Experimentation is done to evaluate the optimum contents of fly ash and waste tire rubber Content to check the California Bearing Ratio strength (CBR), Differential Free Swell % and Unconfined Compressive Strength (UCC) strength. The results indicated that the 25% addition of fly ash to the medium plastic clay soils (CI) resulted in a CBR value of 10% and a 7 Days UCC strength of 330kN/Sq.m.

Hoare D.J. (1979), the study was undertaken as a preliminary investigation aimed at determine the feasibility of using randomly oriented discrete fibres as a inclusion to improve the properties of a soil, a granular soil reinforced with polypropylene fibres (in the form of twisted and stapled) was tested to evaluate strength parameters, concluded that both strength and ductility increases considerably by the inclusion of randomly oriented discrete fibres.

Gosavi et.al., (2003) investigated the strength behavior of locally available black cotton soil reinforced with randomly oriented geotextile woven fabric & fiberglass fibre reported an increase in the value of cohesion & slight decrease in the value of angle of internal friction with addition of 2% of these fibres in black cotton soil.

Study regarding, the effects of different percentages and lengths of nylon fiber on physical properties of BC soil and effect of fly ash mixing in BC soil are available in the literature. But studies on effect of mixing fly ash and different fibers in BC soil are limited. Hence, the present study has been undertaken to investigate the, effects of different fibers on compaction properties and soaked CBR of BC soil stabilized with optimum percentage of fly ash, and the economy of, fly ash stabilization - fiber reinforcement.

III. METHODOLOGY

MECHANICS OF SOIL STABILIZATION

Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soils stabilized by additives often provide an all-weather working platform for construction operations

MATERIALS USED

Properties of soil sample

The soil used was a typical black cotton soil collected from the soil used was a typical black cotton soil collected from Appaniramuni Lanka, Near Dindi village, Sakhinetipalli Mandal, East Godavari district, Andhra Pradesh State, India. The properties of soil are presented in the Table All the tests carried on the soil are as per IS specifications.

Table 3.1 shows properties of soil.

Properties of Expansive Soil		
S. No.	Property	Value
1	Specific gravity	2.67
2	Differential free swell Index (%)	104
3	Atterberg's Limits	
	i) Liquid limit (%)	69.3
	ii) Plastic limit (%)	25.6
	iii) Plasticity index (%)	43.7
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)	1.44
	ii) Optimum Moisture Content (%)	28.3
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.1
	ii) CBR - Soaked (%)	1.4
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	39
	ii) Angle of Internal Friction, Øu (Degrees)	0

MetaKaolin (MK):-

Metakaolin (MK) is a thermally activated aluminosilicate material, white in colour with a dull luster, obtained by calcining kaolin clay within the temperature range 6500-80000C. In the present investigation, Metakaolin marketed by Jeetmull Jaichandlall Pvt. Ltd. Chennai, Tamilnadu was used. The physical and chemical characteristics furnished by the manufacturer are moisture content of 0.18 %, specific gravity of 2.65, bulk density of 710 kg/m3 and pH of 7.0. Metakaolin consists majorly of SiO_2, Al_2O_3, and Fe_2O_3 contributing 53.7 %, 39.2 %, 3.84 %, of the total. The next most abundant component is titanium oxide, TiO_2 (5.97 %). According to ASTM standard specification (C 618 – 2012), the sum of SiO_2, Al_2O_3, Fe_2O_3 be ≥ 70 % for any material to be used as a pozzolana.

Lime:-

The use of lime-soil mixture as a construction material has been known from ancient times in various parts of the world. Commercial Birla lime was used for this project.

Nylon fibre:-

Nylon was the first truly synthetic fiber to be commercialized. It is a polyamide fiber, derived from a diamine and a dicarboxylic acid, because a variety of diamines and dicarboxylic acids can be produced, there are a very large number of polyamide materials available to produce nylon fibers. The two most common versions are nylon 66 (polyhexamethylene adiamide) and nylon 6 (Polycaprolactam, a cyclic nylon intermediate). Raw materials for these are variable and sources used commercially are benzene (from coke production or oil refining), furfural (from oat hulls or corn cobs) or 1,4-butadiene.

Physical properties

Tenacity: 4-9 gm/den (dry), in wet 90% of dry.
Elasticity: Breaking extension is 20-40%.
Stiffness: 20-40 gm/den.
Moisture regain: 3.5-5%; (not absorbent due to crystallinity).
Specific gravity: 1.14.
Softening point: Nylon 6,6 – 2290C, Nylon 6 – 1490C.
Melting point: Nylon 6,6 – 2520C, Nylon 6 – 2150C.
Hand feel: Soft and smooth.

IV. RESULTS AND DISCUSSIONS

In the laboratory, various experiments were conducted by replacing different percentages of MetaKaolin (MK) in the expansive soil and also further stabilizing it with lime as a binder and further reinforced with Nylon Fibres. Compaction, Strength and CBR tests were conducted with a view to determine the optimum combination of MetaKaolin (MK) as replacement in expansive soil and Lime as a binder and Nylon Fibres as reinforcing inclusions.

The influence of the above said materials on the Compaction and Strength characteristics were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice.

4.1 EFFECT OF METAKAOLIN (MK) AND LIME ON THE SWELLING PROPERTY OF EXPANSIVE SOIL

Figures 4.1, 4.7, shows the variation of DFSI for replacement of MK and to the optimum percentage of MK, percentage addition of lime respectively. The percentage of MetaKaolin (MK) was varied from 0% to 20% with an increment of 5%. From the optimum percentage of MK percentage addition of lime was varied from 0% to 6%. All these materials showed a decrease in DFSI value with increase in % of material as replacement. Among these MK as a 15% replacement shows optimum decrease in DFSI about 29.8% and optimum percentage of MK and percentage addition of lime from 0% to 6%. Among these 6% addition shows optimum decrease in DFSI about 49.3%.

4.2 EFFECT OF METAKAOLIN (MK) AND LIME ON THE ATTERBERGS LIMITS VALUES OF EXPANSIVE SOIL

The percentage of MetaKaolin (MK) was varied from 0% to 20% with an increment of 5%. From the optimum percentage of MK percentage addition of lime was varied from 0% to 6%. All these materials showed an improvement in plasticity characteristics. For all increase in % of replacement of MK in virgin soil a good improvement i.e. decrease in Plasticity Index about 28.1%, LL get reduced, PL get increased where resultant Both LL, PL is PI get reduced and further addition of lime to the optimum percentage of MK, For all increase in % of addition of lime a good improvement i.e. decrease in Plasticity Index about 68.8 %, LL get reduced, PL get increased where resultant Both LL, PL is PI get reduced.

4.3 EFFECT OF % METAKAOLIN (MK) AS REPLACEMENT AND LIME AS AN ADDITIVE ON THE COMPACTION PROPERTIES OF EXPANSIVE SOIL

From the optimum percentage of MK percentage addition of lime was varied from 0% to 6%. From the graphs, it was observed that the treatment as individually with 15% MK has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in maximum dry density with an increment in the % replacement of MK up to 15% with an improvement of about 10.41% and further addition of lime to the optimum percentage 6% of lime that there is a gradual increase in maximum dry density with an increment in the % addition of lime 6% with an improvement of about 10.7%.

4.4 EFFECT OF % METAKAOLIN (MK) AS REPLACEMENT AND LIME AS AN ADDITIVE ON THE CBR VALUES OF EXPANSIVE SOIL

The percentage of MetaKaolin (MK) was varied from 0% to 20% with an increment of 5%. From the optimum percentage of MK percentage addition of lime was varied from 0% to 6%. From the graphs, it was observed that the treatment as individually with 15% MK has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in CBR values for soaked and unsoaked with an increment in the % replacement of MK up to 15% with an improvement of about 87.10% for unsoaked , 135.7% for soaked and further addition of lime to the optimum percentage 6% of lime that there is a gradual increase in CBR values with an increment in the % addition of lime 6% with an improvement of about 58.6% for unsoaked and 81.8% for soaked CBR.

4.5 EFFECT OF % METAKAOLIN (MK) AS REPLACEMENT AND LIME AS AN ADDITIVE ON

THE STRENGTH PARAMETERS OF EXPANSIVE SOIL

The percentage of MetaKaolin (MK) was varied from 0% to 20% with an increment of 5%. From the optimum percentage of MK percentage addition of lime was varied from 0% to 6%. From the graphs, it was observed that the treatment as individually with 15% MK has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in UCS values with an increment in the % replacement of MK up to 20% with an improvement of about 61.5 % further addition of lime to the optimum percentage 6% of lime that there is a gradual increase in UCS values with an increment in the % addition of lime 6% with an improvement of about 50%.

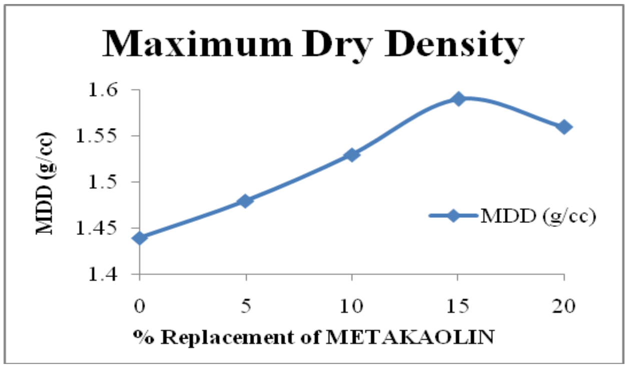

Fig 4.1 Variation of MDD with % Replacement of MetaKaolin

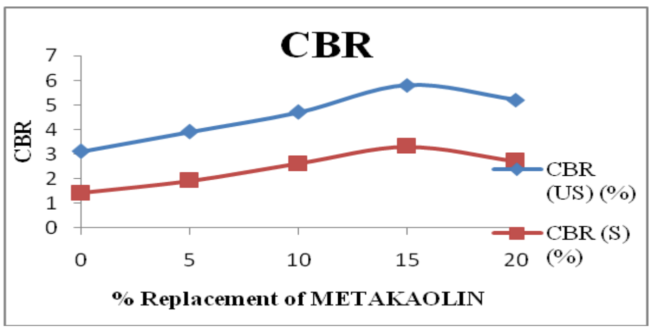

Fig 4.2 Variation of CBR with % Replacement of MetaKaolin (MK)

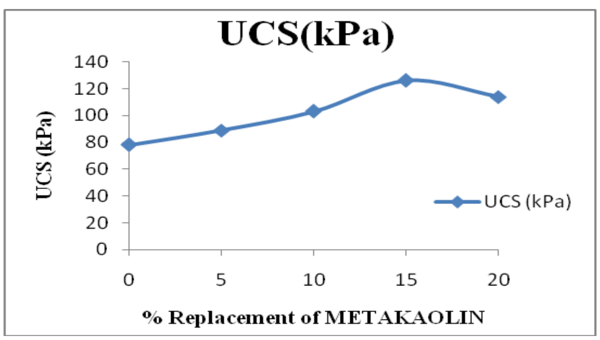

Fig 4.3 Variation of UCS with % Replacement of MetaKaolin

It can be inferred from the graphs, that there is a gradual increase in SOIL PROPERTIES With percentage replacement of MetaKaolin (MK). From the above results the 15% replacement of Expansive Soil with MK can be considered as optimum.

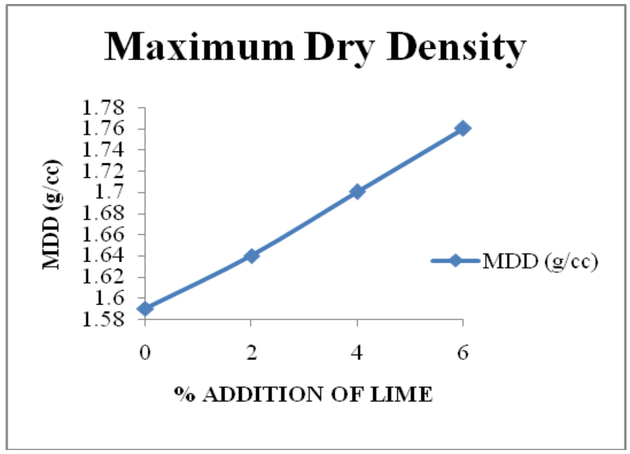

Fig 4.4 Variation of MDD with % Addition of LIME

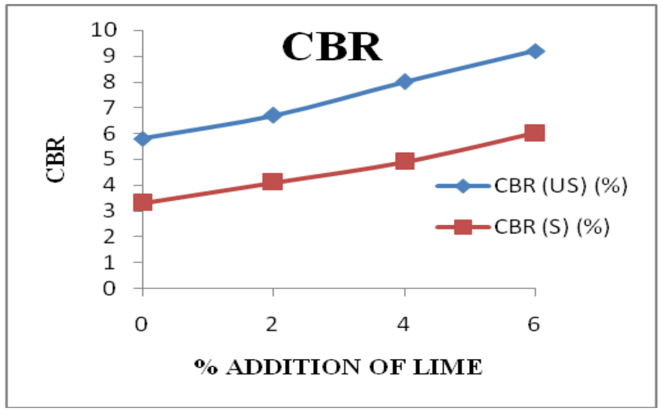

Fig 4.5 Variation of CBR VALUES with % Addition of LIME

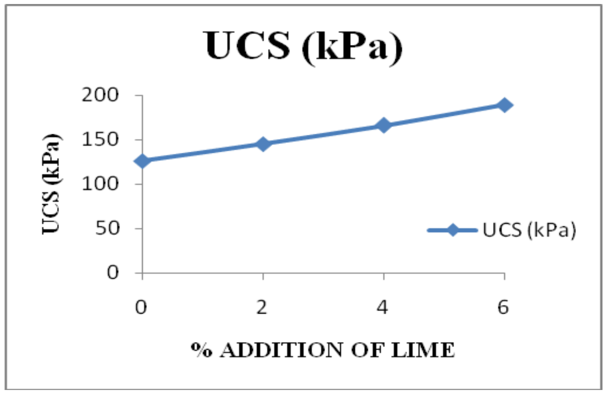

Fig 4.6 Variation of UCS with % Addition of LIME

It can be inferred from the graphs, that there is a gradual increase in SOIL PROPERTIES With percentage replacement of MetaKaolin (MK) and percentage addition of lime. From the above results the Optimum Content of Lime with 15% MetaKaolin as replacement of Expansive Soil is 6%.

Further different Nylon Fibres of 2mm Dia and 50mm long were added to the MetaKaolin (MK) treated expansive soil with an optimum percentage of lime i.e. 6% and the studies was done.

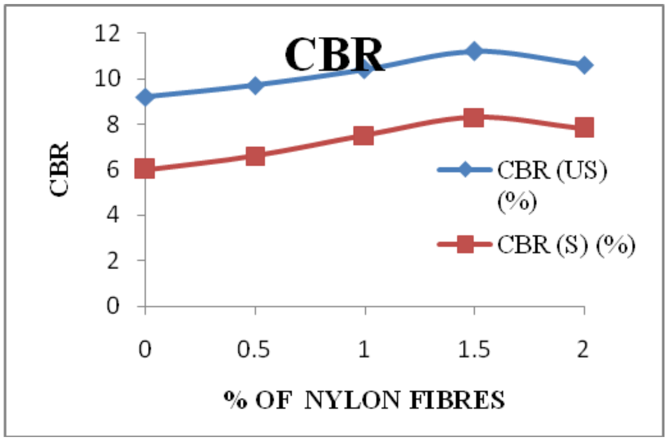

Fig 4.7 Variation of CBR with % of different Nylon Fibres

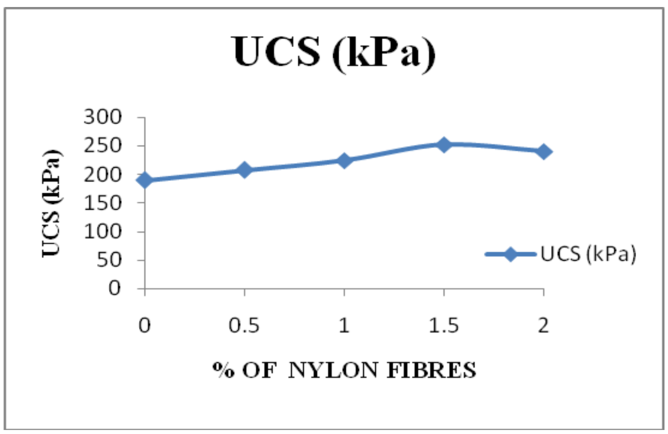

Fig 4.8 Variation of UCS with % of different Nylon Fibres

Finally from the above discussions, From the above results the Optimum Content of NF with 6% Lime + 15% MK as replacement of Expansive Soil is 1.5%. It is clear that there is improvement in the behaviour of Expansive soil stabilized with MetaKaolin (MK) + LIME +NF. It is evident that the addition of MetaKaolin (MK) to the virgin Expansive soil 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 discrete Nylon Fibres, the improvement was more pronounced. This made the problematic expansive soil which if not stabilized is a discarded material, a useful fill material with better properties. The MetaKaolin (MK) replacement in the expansive soil has improved its strength and upon further blending with NF, the strength has further improved and also these materials has imparted friction to the clayey soil. It is observed that MDD, CBR and UCS increased about 2.2%, 27.7%, 25% respectively. It can be summarized that the materials MetaKaolin (MK), LIME and NF had shown promising influence on the Strength and Penetration properties of expansive soil.

4.8 DURABILITY STUDIES - (CURING)

Durability Studies (Curing) on samples prepared with 1.5% NF + 6% Lime + 15% MetaKaolin as replacement of Expansive Soil

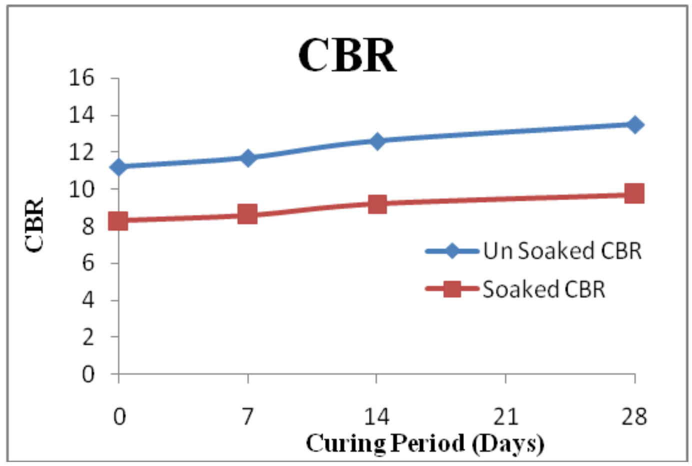

Fig 4.9 Variation of CBR with different Curing periods

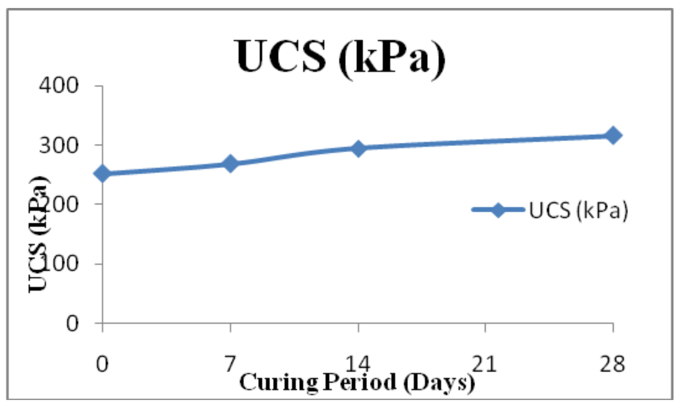

Fig 4.10 Variation of UCS VALUES with different Curing periods

4.9 VARIATION OF SHEAR AND PENETRATION PARAMETERS FOR DIFFERENT CURING PERIODS WITH OPTIMUM % OF FIBRE DOSAGE i.e. 15% METAKAOLIN+ 6% LIME CONTENT AND FOR 1.5% NF

Figures 4.9, 4.10 shows the variation of UCS VALUES, CBR (US) and CBR(S) For Different Curing Periods With 15% METAKAOLIN+ 6% LIME CONTENT

AND FOR 1.5% NF respectively. From above figures we can conclude that the UCS and CBR for both unsoaked and soaked values get increased for increment of 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 Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.

It was observed that the treatment as individually with 15% MK has moderately improved the expansive soil.

There is a gradual increase in maximum dry density with an increment in the % replacement of MK up to 20% with an improvement of about 5% and it is observed that for the replacement of 15% there is gradual increase in Maximum dry density about 10.41%.

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 135.7% and 61.5% in CBR and UCS respectively for MetaKaolin individually and further addition of 6% of lime there is an increment about 81.8% and 50% in CBR and UCS respectively.

Further blending with different Nylon Fibers with 0% to 2% with an increment of 0.5% there is increment of CBR and UCS values is about 27.7% and 25.1% respectively.

Durability Studies (Curing) on samples prepared with 1.5% NF + 6% Lime + 15% MetaKaolin as replacement of Expansive Soil graph shows increment of CBR and UCS values with increment of curing periods.

It is evident that the addition of MetaKaolin (MK) to the virgin Expansive soil showed an improvement in compaction, strength and penetration characteristics to some extent and on further blending it with lime and Nylon Fibers the strength mobilization was more pronounced.

Finally it can be summarized that the materials MetaKaolin (MK) and lime and different Nylon Fibers had shown promising influence on the strength characteristics of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

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