Comparative Study On Geo Engineering Characteristics Of Glass Fibre And Polypropylene On Alkali Activated Binder Treated Expansive Soil

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Abstract- *Expansive Soils are causing severe damages to the structures such as buildings and pavements built over them due to their high degree of swelling and shrinkage. This phenomenon will result in rutting mode of failure requiring immediate strengthening or reconstruction of the whole structure. Thus, for safe design such 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. The reinforcing soil using randomly distributed natural or plastic fibers has been used since ancient times. However, reinforcing of subgrade with discrete fibers is still a relatively new technique in highways construction. Keeping in view the present paper emphasizes an experimental investigation on the effect of glass fiber (GF) and discrete polypropylene with alkali activated binder on properties of expansive soil. Hence the present study aims to compare the geo engineering characteristics between glass fiber (GF) and discrete polypropylene fiber on alkali activator binder treated expansive soil. Glass fiber and polypropylene fiber were varied from 0 to 0.4% with 5% alkali activator binder in the expansive soil. To understand the performance of stabilized soil, its properties like Compaction Parameters, and Penetration Parameters were studied in the laboratory.*

Keywords- Clayey soil, Metakaolin, alkali activator, glass fibre, Polypropylene fibre, compaction and strength characteristics

I. INTRODUCTION

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 (Mishra et al. 2008). Expansive soils are a worldwide problem that poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated (Al-Rawas, 2002). Expansive soils causes more damage to structures, particularly light buildings and pavements, than any other natural hazard, including earthquakes and floods (Jones and Holtz, 1973). During the last few decades damage due to swelling action hasbeen 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 (Çokça, 2001).

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 or uninhabitable. 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.

Soil is the collection of natural bodies on earth's surface containing living matter and supporting, or capable of supporting plants. Its upper limit is the atmosphere (air) or water, and at its lateral margins it grades to deep water or barren areas of rock and ice. Its lower limit is normally considered to be the lower limit of the common rooting zone (root zone) of the native perennial plants, a boundary that is shallow in the deserts and tundra and deep in the humid tropics. Soil itself is very complex. It would be very wrong to think of soils as just a collection of fine mineral particles. Soil also contains air, water, dead organic matter, and various types of living organisms. The formation of a soil is influenced by organisms, climate, topography, parent material, and time.
Various remedial measures like soil admixture, 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 admixture 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.

1.2 OBJECTIVES OF THE STUDY

The objective of the present work is to study the experimental programme undertaken to investigate the strength of soft soils using stabilisers metakaolin, alkali activator and glass and polypropylene fibre.

In view of the current understanding and the incomplete research to date, this study was conducted to determine the stabilization mechanism and performance of the expansive soil mixed with additives. Hence, the following objectives had been established to achieve the aim of the research:

The objectives of present experimental study are to develop correlations between engineering characteristics of expansive soils. The study is focused on

- Improvement of locally available soil using some eco-friendly and cheap waste materials.
- Evaluation of strength characteristics of virgin as well as blended soil using different materials like metakaolin, alkali activator and glass and polypropylene fibre.
- Determination of appropriate metakaolin and alkali activator content ratio to achieve the maximum gain in strength of soil. Further to compare the performance of soil mixed with glass and polypropylene fibre.

II. LITERATUREREVIEW

2.1PREVIOUS RESEARCH PAPERS AND CONCLUSIONS

Soil stabilization is a procedure where we improve engineering properties of soil with the use of natural or synthesized admixtures. In the past many researchers have carried out their research work for improving the strength of black cotton soil using different types of admixture at different percentages. A brief review of previous studies on black cotton soil is presented in this section and past efforts most closely related to the needs of present work.

Expansive soils pose the greatest hazards that many geotechnical engineers face. Such soils may cause heavy damages in light loaded structures such as water canals, reservoirs, highways, railways and airport runways etc., unless appropriate measures are taken. Various stabilization techniques are in practice for improving expansive soils by reducing its swelling potential and increasing its strength characteristics. Modification of expansive soil by chemical admixture is a common practice for stabilizing the swell-shrink tendency of expansive soil. Advantages of chemical stabilization are that they reduce the swell-shrink tendency of expansive soils and also render the soils less plastic. In this section, the experiences of various investigators concerning chemical stabilization using calcium chloride have been reviewed.

Numerous investigators, have studied the influence of lime, cement, lime-cement, lime-fly ash, and cement–fly ash mixes on soil properties, mostly focusing on the strength and swelling aspects. Among the chemical stabilization methods for expansive soils, lime stabilization is mostly adopted for improving the swell-shrink characteristics of expansive soils. As lime and cement are binding materials, the strength of soil-additive mixtures increases provided the soil is reactive with them. However, for large-scale field use, the problems of soil pulverization and mixing of additives with soil have been reported by several investigators. Calcium chloride is an inorganic salt, which is a by-product of sodium carbonates. The use of calcium chloride in place of lime, as calcium chloride is more easily made into calcium charged supernatant than lime. A recent study indicated that CaCl2 could be an effective alternative to conventional lime used due to its ready dissolvability in water and to supply adequate calcium ions for exchange reactions. Calcium chloride is known to be more easily made into calcium charged supernatant than lime and helps in ready cation exchange reactions. CaCl2 might be effective in soils with expanding lattice clays. The bibliography on stabilization of soil and calcium chloride is giving its wide use in highways.

Hausmann and Shepardhave stated that CaCl2 enjoyed its wide use as dust palliative and frost control of subgrade soil. Calcium chloride has hygroscopic property. This means that calcium chloride attracts and absorbs water. This is a function of relative humidity and temperature. It can easily liquefy in moisture of its own absorption.

Shepard reported that calcium chloride is highly soluble and can be dissolved easily so it can be easily washed away by rain and more than one treatment in a single season may be required to maintain its effectiveness. For the same humidity and temperature, the vapor pressure of calcium chloride is lower than water. Calcium chloride has a higher surface tension and a lower freezing point compared to water.

Shon et al. reported that treatment of soil with calcium chloride increases the density and strength of the compacted soil. They found that calcium chloride increases the surface tension of the retained moisture within the soil matrix, thus increasing the suction pressure of the system. This, in turn, increases the cohesive energy between the particles which result in greater strength.

M Muthu Kumar (2015)studied by waste marble dust which is the byproduct of marble industry, is used for the soil stabilization. Utilization of waste marble powder may reduce the disposal problem and preserve the ecological system. Use the marble powder is used to improve the Engineering property of expansive soil, thus making it more stable and also to stabilize the soil with a very low cost material. The marble powder has very high lime (CaO) content and is reported Many researchers. We have added the marble powder to the expansive soil as 5%, 10% 15%, 20%, 25% and studied the compaction characteristics and strength characteristics. The maximum unconfined compressive strength of the clay is 215kN/m2 at 15% of marble powder. The Marble Powder is added about 15% to the soil as strength. The expansive soil was modified in to low plasticity and silt behavior.

kshaya Kumar Sabatstudied the effect of polypropylene fiber on engineering properties of rice husk ash –lime stabilized expansive soil. He concluded that the addition of Rice Husk and Lime decreases the MDD and increases the OMC of the expansive soil.MDD goes on decreasing and OMC goes increasing with increase in percentage of polypropylene fiber in the rice husk ash –lime stabilized expansive soil. Addition of rice husk ash and lime increases the UCS and soaked CBR of the expansive soil with the addition of polypropylene fiber.

2.2 STABILIZATION

Soil stabilization may be defined as a modification of an existing soil so as to improve its bearing or load absorbing characteristics. Such an effect may be accomplished by mechanical consolidation (compaction) or by the incorporation within the soil of certain additives which would provide the desired qualities of permanent stability. Ever since the beginning of road building, it has been recognized that some soils were extremely unstable, particularly in the presence of moisture, and that other soils were stable and would support traffic with less deformation.

METHODS OF SOIL STABILIZATION

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

III. METHODOLOGY

The methodology of this project is carried out by collection of expansive soil sample from proposed area and various tests on soil have been performed as per IS(2720) on expansive soil with proportion of metakaolin and fibers. Based on test reports various discussions have been present as per the strength variations criteria.

The various physical properties of soil were assessed using methods below given in different parts of Indian standards (IS 2720). The specific gravity, grain size analysis, atterberg limits and shrinkage limits were derived as per the methods given in IS 2720: part 3(1980), IS 2720: part (1980), IS 2720: part 5(1980),IS 2720: part 6(1972) respectively. Compaction test as per IS 2720: part 7(1980) was performed to determine optimum moisture content and maximum dry density of the soil specimen.

In this chapter, a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

MATERIALS USED AND THEIR PROPERTIES

3.1 SOIL

For conducting the study, soil samples were collected from Komarigiripatnam (Odalarevu) in East Godavari District, A.P. The soil excavated from below 3ft depth. The soil sample is free from plant roots and stone pieces and rubbles. The sample is first spread on a flat surface. If more than 50% of the particles are visible to the naked eye, the soil is coarse grained otherwise it is fine grained.The fine grained particles are smaller than 75micron size and are not visible to naked eye.

Table 5.1 Properties of expansive soil

S. No.	Property	Value
1	Specific gravity	2.63
2	Differential free swell Index (%)	116
3	Atterberg's Limits	
	i) Liquid limit (%)	75.5
	ii) Plastic limit (%)	32.2
	iii) Plasticity index (%)	43.3
5	Grain Size Distribution	
	i) Sand Size Particles (%)	10
	ii) Silt & Clay Size Particles (%)	90
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.5
	ii) Optimum Moisture Content (%)	27.4
8	Penetration Parameters	
	i) CBR - Soaked (%)	1.9
9	Shear Parameters at OMC & MDD	
	Unconfined compressive strength	105

3.2 Metakaolin

Metakaolin (MK) is a thermally activated alumina silicate material, white in colour with a dull luster, obtained by calcining kaolin clay within the temperature range 650-800^{0}C. In the present investigation, Metakaolin marketed by Jeetmull Jai chandllall Pvt. Ltd. Vijayawada, Andhra Pradesh 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.

Table 3.2 Properties of Metakaolin

Oxide	Concentration (%)
Sio_2	57.32
Al_2O_3	23.70
Fe_2o_3	14.03
CaO	0.38
MgO	0.94
SO_3	ND
L.O.I.	1.18
Na_2O	0.38
K_2O	0.65
TiO_2	1.30
MnO	0.03

3.3 Glass fibre and polypropylene fibre

Polypropylene and Glass fiber used in this study are acquired by Kankadurga Industries Pvt. Ltd., Vijayawada. Both fibers length of 12 mm is adopted for all the tests. Figshows the physical appearance of both polypropylene and glass fiber.

Fibre properties	Quantity
Fibre length	12 mm
Aspect ratio	857
Specific gravity	2.68 g/cm3
Modulus of elasticity	72 GPa
Tensile strength	1700 MPa
Chemical resistance	Very high
Electrical conductivity	Very low
Softening point	860 °C
Material	Alkali Resistant Glass
Shape	Straight

Table 5.4 Properties of Polypropylene

Type of Fibre	Poly propylene
Length (mm)	12
Aspect ratio (L/d)	300
Diameter (mm)	0.04
Specific gravity	0.91
Tensile strength (Mpa)	450
Elongation break (%)	15-25
Melting point (°c)	165
Heat resistance (°c)	<130

3.4 Alkali activated solution

The most generally accessible chemical compounds among the activators are NaOH, Na2CO3, Na2SiO3, and Na2SO4. In laboratory experiments, certain potassium components have been employed. Their potential applications, however, would be severely limited due to their scarcity and high cost. The characteristics of sodium and potassium components, on the other hand, are extremely comparable. These alkaline activators are available in both liquid and solid form. Cements including the precursor and activator (in a solid state) are usually favored, with water as the mixing medium.

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

In the laboratory, various experiments were conducted by replacing different percentages of metakaolin and added alkali activated solution with different percentages to the soil. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of alkali activated solution and metakaolin and CBR and UCS are conducted for durability studies. Further polypropylene and glass fibers were added as a reinforcing materials to the soil.

The influence of the above said materials on the Index, Compaction and Strength properties were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice and the strength behaviour pertaining to unconfined compressive strength (UCS), Optimum moisture content (OMC), Maximum dry density (MDD) and Plasticity index (PI) of different combinations of soil and admixtures such as alkali activated solution and metakaolin have been performed.

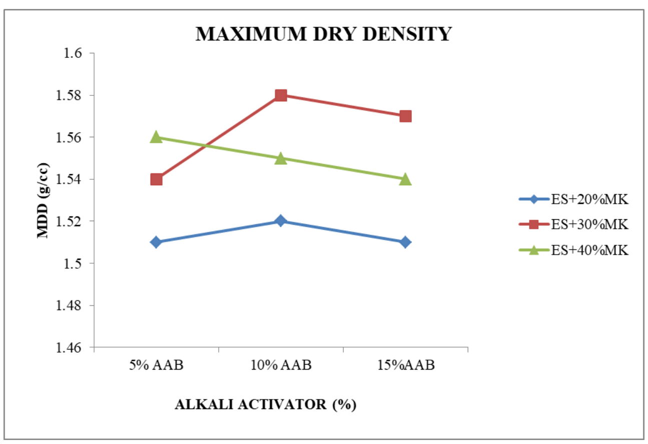

Fig Variation of MDD with % addition of alkali activator and metakaolin

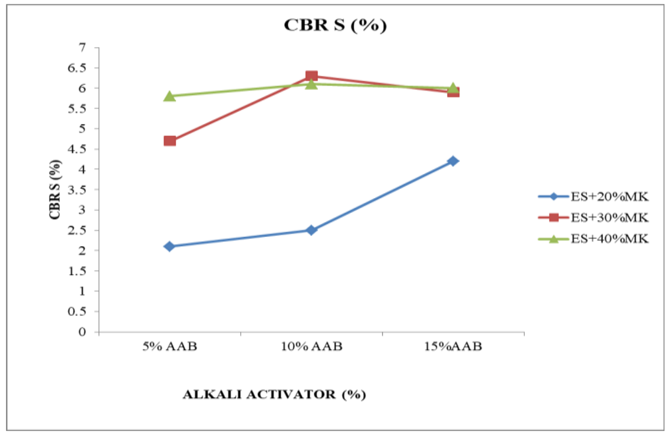

Fig Variation of CBR values with % addition of alkali activator and metakaolin

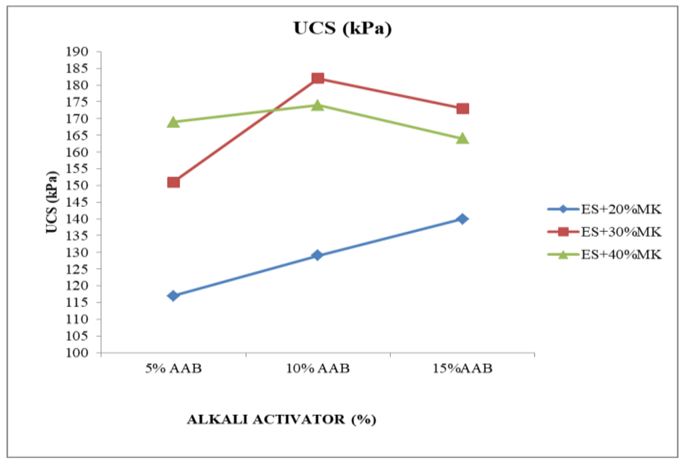

Fig Variation of UCS values with % addition of alkali activator and metakaolin

From the above results the 30% of metakaolin and 10% alkali activated binder can be considered. Finally from the above discussions, it is clear that there is improvement in the behaviour of Expansive soil stabilized with metakaolin and alkali activated binder. It is evident that the 30% of metakaolin and 10% alkali activated binder to the virgin expansive soil showed an improvement in Compaction and Strength characteristics to some extent since the CBR requirement as per IRC 37-2012 which is soaked CBR of 8% is not achieved for the optimum combination, use of glass fibres and polypropylene fibres is chosen and added to the optimum combination samples as discrete reinforcing elements to enhance the strength & penetration characteristics and further laboratory tests were done on the expansive soil with fibers comparing the results of glass and polypropylene fibre to know the best of the chosen fibres.

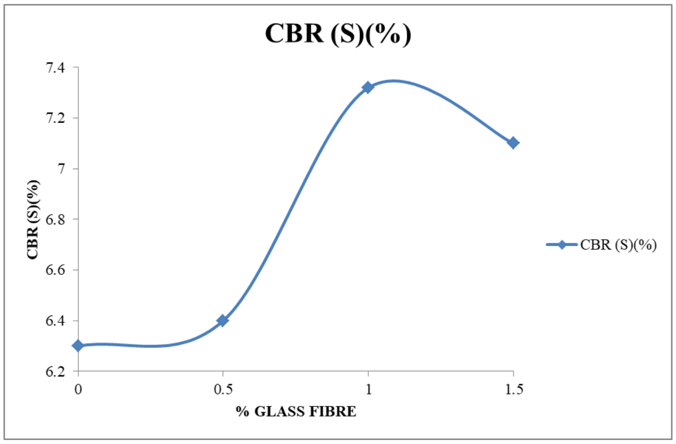

Fig Variation of CBR values with % addition of glass fibre

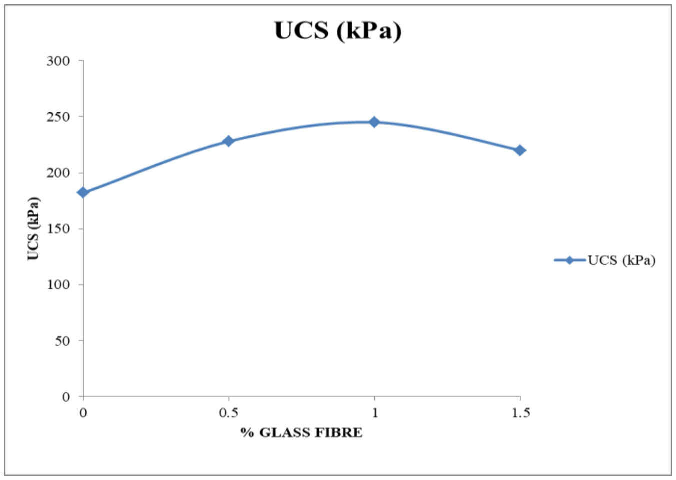

Fig Variation of UCS values with % addition of glass fibre

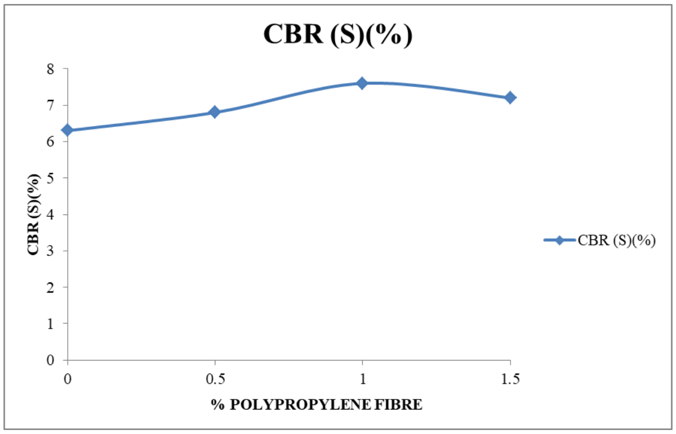

Fig Variation of CBR values with % addition of polypropylene fibre

From the above results the Combined Optimum Content of MK + ALKALI ACTIVATED BINDER + PF for improving the Weak expansive soil is 30% MK + 10% AAB + 1% PPF. Since the CBR requirement as per IRC 37-2012 which is 8% is achieved. On comparing the results when fibre added, polypropylene fibre shows significant results when compared to glass fibre.

VI. CONCLUSIONS

Metakaolin and palm oil fuel ash treated soil was examined intensively and drawn the following conclusions are made based on the laboratory experimentation done on the expansive soil with metakaolin and alkali activated binder and then further reinforced with glass and polypropylene fiber.

- It was observed that expansive soil treated with Metakaolin and alkali activated binder has moderately improved the properties of expansive soil.
- The compaction characteristics of the soil, showed increase in maximum dry density and decrease in optimum moisture content with subsequent addition of metakaolin and alkali activator content. It is observed that for the addition of 30% MK + 10% AAB, there is a gradual increase in Maximum dry density about 5.33 %.
- There is an improvement in strength characteristics with Metakaolin (MK) (%)+ AAB (%) as added to the Weak expansive soil. There is an improvement of 231% in CBR and 73% in UCS values. A strength gain of the soil-metakaolin and AAB mixtures shows that admixture has a long duration strength improving ability.
- The compaction, CBR and UCS tests indicated that at 30% metakaolin and at 10% AAB content the values are more pronounced.
- Further blending with glass fiber and polypropylene fiber, CBR and UCS values when reinforced randomly with polypropylene fiber shows higher values when compared to glass fibre. For the polypropylene fibre content of 1%, MDD increases about 2.55% improvement of 20.64% in CBR and 49% in UCS values.
- It can be concluded from this work that addition of polypropylene fibre to the expansive soil, has capacity of increasing the deformability resistance ability of the soil. The optimum polypropylene content is 1%.
- It is evident that the addition of Metakaolin and AAB to the expansive soil increases the strength and penetration characteristics to some extent and on further mixed it with polypropylene fiber the deformability resistance ability of the soil increased.

Finally, it can be summarized that the materials Metakaolin, AAB and polypropylene fiber had shown promising influence on the strength characteristics of expansive soil.

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