Experimental Study on The Strengthening of Pavement Subgrade Layer By Chemical Admixtures And Organic Materials

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Abstract- *Expansive soils, popularly known as black cotton soils, are basically susceptible to detrimental volumetric changes, with changes in moisture. This behaviour of soil is attributed to the presence of mineral montmorillonite, which has an expanding lattice. These types of soils are generally found in arid and semi-arid regions of the world and are considered as a potential natural hazard, which if not treated well can cause extensive damages to the structures built upon them. Among several techniques adopted to overcome the problems posed by expansive soils, lime stabilization gained prominence during the past few decades due to its abundance and adaptability. Various remedial measures like moisture control, pre-wetting, and lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability. Stabilization using solid wastes is one of the emerging techniques to improve the engineering properties of expansive clays to make them suitable for use in construction. Flexible pavement construction in expansive soils is expensive due to large pavement section resulting from low CBR values in wet condition. The volume instability of soil affects constructed pavements and demands frequent maintenance. Hence efforts are to be made for reducing large pavement section and also to suppress swelling of subgrade. The main objective of this work is to study the properties of the expansive subgrade soil treated with chemicals like Fly ash, NaCl2 and also by adding Rice husk ash based Geopolymer in different percentages. The swelling properties of the collected expansive soil samples were determined based on the parameters like compaction, strength and penetration characteristics with the help laboratory experimentation.*

Keywords- Clayey soil, Sodium Chloride (NaCl2), Geopolymer, plasticity, compaction and strength characteristics

I. INTRODUCTION

Expansive soils, also termed as swelling soils or shrink-swell soils pose a major challenge to civil engineers all over the world as they cause severe distress to structures constructed on them. In India, these soils are also called as Black soils or Black cotton soils. Soil stabilization involves addition of a binder to improve mechanical and chemical properties of the soil. Stabilization of expansive soils has been successfully done with various chemicals. Sodium chloride is a hygroscopic material and absorbs water. Chemical stabilization is a technique commonly used to improve the expansive soil properties. In this regard, an attempt has been made to evaluate the influence of Sodium chloride ($NaCl_2$) stabilizer on the engineering properties of expansive soil.

The 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 India and not easy to avoid clay regions for the construction of pavements and foundations due to the population density. The performance of pavements constructed on expansive soils will be critically affected by vertical deformations of the supporting subgrade soils in addition to the traffic loading conditions that affect all pavements.

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are as follows.

- To study the impact of proposed additives and admixtures on the properties of expansive clays through laboratory experimentations.
- To evaluate the performance of expansive soil when stabilized with proposed additives and admixtures and their suitability for fill material and sub grade material for flexible pavement.
- To investigate the suitability and adoptability of different chemicals as an additive.
- The objective of the current work is to determine the suitability of geopolymer (alkali-activated rice husk ash) as soil stabilizing agent for expansive soil and to replace the existing soil with stabilized soil

block which will reduce the cost of construction, environmental pollution and waste deposition.

II. LITERATUREREVIEW

2.1 GENERAL

Research about stabilization of the clay with adding stabilizer is usually done in order to increase the quality of the clay soils. The addition of stabilizer is usually intended to reduce the swelling on the clay soils that can reduce the strength. Clay has high plasticity index and swelling potential, so the stabilization is usually done in order to overcome the problems. Research about clay soils stabilization is commonly done with adding some additive such as lime, Fly ash, cane pulp ash. Nowadays, a research of clay stabilization is still interesting subjects to be observed.

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 soil using different types of admixture at different percentages. A brief review of previous studies on residual soil is presented in this section and past efforts most closely related to the needs of present work.

In this section, the experiences of various investigators concerning chemical stabilization using Sodium chloride have been reviewed.

ERDAL COKCA (2001):

Effect of Fly ash on expansive soil was studied by ErdalCokca, Fly ash consists of often hollow spheres of silicon, aluminum and iron oxides and unoxidized carbon. There are two major classes of fly ash, class C and class F. The former is produced from burning anthracite or bituminous coal and the latter is produced from burning lignite and sub bituminous coal. Both the classes of fly ash are puzzolans, which are defined as siliceous and aluminous materials. Thus Fly ash can provide an array of divalent and trivalent cations under ionized conditions that can promote flocculation of dispersed clay particles. Thus expansive soils can be potentially stabilized effectively by cation exchange using fly ash.

He carried out investigations using Soma Flyash and Tuncbilek fly ash and added it to expansive soil at 0-25%. Specimens with flyash were cured for 7days and 28 days after which they were subjected to Oedometer free swell tests. And his experimental findings confirmed that the plasticity index, activity and swelling potential of the samples decreased with increasing percent stabilizer and curing time and the optimum content of flyash in decreasing the swell potential was found to be 20%. The changes in the physical properties and swelling potential is a result of additional silt size particles to some extent and due to chemical reactions that cause immediate flocculation of clay particles and the time dependent puzzolanic and self hardening properties of flyash and he concluded that both high –Magnesium and low Magnesium class C fly ashes can be recommended as effective stabilizing agents for improvement for improvement of expansive soils.

PHANIKUMAR AND SHARMA (2004):

A similar study was carried out by Phanikumar and Sharma and the effect of fly ash on engineering properties of expansive soil through an experimental programme. The effect on parameters like free swell index (FSI), swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied.

The ash blended expansive soil with flyash contents of 0, 5, 10,15 and 20% on a dry weight basis and they inferred that increase in fly ash content reduces plasticity characteristics and the FSI was reduced by about 50% by the addition of 20% fly ash. The hydraulic conductivity of expansive soils mixed with fly ash decreases with an increase in flyash content, due to the increase in maximum dry unit weight with an increase in fly ash content. When the flyash content increases there is a decrease in the optimum moisture content and the maximum dry unit weight increases. The effect of fly ash is akin to the increased compactive effort. Hence the expansive soil is rendered more stable. The undrained shear strength of the expansive soil blended with flyash increases with the increase in the ash content.

PRAMOD K (2014)

Hedone a project on stabilization of black cotton soil using fly ash and geopolymer and conclusions are based on various laboratory tests carried out on Black Cotton Soil stabilized with Fly ash and Geopolymer. Through experiments by addition of stabilizing agents like Fly ash and Geopolymer in quantities like 2%, 4% and 6% has showed the increase in specific gravity of the soil to 2.51, 2.58, and 2.72 respectively. The liquid limit of the soil should be less for construction purpose. Liquid limit was reduced to 70%, 65% and 53% respectively. The shrinkage limit of the Black cotton soil of this project was 13.16% further by addition of stabilizing agents like Fly ash and geopolymer in percentages like 2%, 4% and 6% the shrinkage limit of the soil was reduced to

13.05%, 12.78 and 12.07 respectively. The Black Cotton soil was subjected to compaction test by Jodhpur mini compacting mould where the Maximum Dry Density (MDD) and Optimum Moisture Content obtained is 1.48 g/cc and 21%. The soil for construction purpose should have good load bearing characteristics. This load baring capacities was determined by Unconfined Compression Strength test.

The soil of this project had strength of 0.056 N/mm2. By addition of stabilizing agents like Fly ash and Geopolymer in percentages like 2%, 4% and 6% the results obtained are 0.04 N/mm2, 0.095 N/mm2 and 0.083 N/mm2 respectively. Compressive strength was increasing up to addition of stabilizing agent till 4% on further addition there will be decrease in the soil strength. Finally it can be concluded that the stabilizing agents like Fly ash and geopolymer will help in increasing the engineering properties of the Black Cotton soil like specific gravity, liquid limit, shrinkage limit, compaction characteristics and unconfined compressive strength.

VAIBHAV R. DHAWALE (2016)

He published a paper in October 2016 on black cotton soil stabilization by using fly ash, lime and nylon fiber and gave some conclusions by carrying some laboratory investigations:

The moisture –density relationship of soil-fly ash mixtures significantly affected due to addition of fibers. The MDD is increases and OMC decreases in fly ash and soil mixtures. Whereas the soil has shown reverse trend but less noticeably. With Fly ash percentage increased with soil BC soil optimum moisture content decreased from 21% to12. The MDD of BC soil increases with the addition of lime with corresponding increase in OMC. The adhesion between the water and soil particles increases with the increase in lime content up to 2%. With the further addition of lime beyond 2% .MDD reduces and OMC increases. .

The relative benefit in CBR values due to fibers increases only up-to 1.00 % by dry weight and length up to 12mm for all soil-fly ash specimens. By addition of fly ash alone the CBR of the mixture is increased nearly 2.7 times whereas by addition of fiber only CBR is increased by 1.6 times only. Effect of fiber on fly ash Soil mixture is limit because of the high plasticity of the Clay soil while lime alone works well to establish clay soil, a combination of lime and fly ash is beneficial for lower plasticity, higher silt content. The peak unconfined compressive strength, stiffness and ductility of clayey soil increase with increasing fibre content. The post peak softening drop in compressive resistance is found to be decrease with increase in fibre content. But, clayey soil containing nylon fibres shows poor result than clayey soil containing palmyra fibres. The bearing resistance of specimens is found to increase with the fibre content. However, the rate of increase of strength with fibre content is not uniform. At low strain levels the bearing resistance is found to remain almost constant with fibre.

2.2 STABILIZATION

Using rice husk ash, flyash have been more attractive recently due to its promising results compared to other sources. Overview about the methods and the basis of application will be presented in this section. Soil stabilization is the process of improving engineering properties of the soil and thus making it more stable. Soil stabilization means the improvement of the stability or bearing power of the soil by the controlled compaction; proportioning and/or addition of suitable admixture or stabilizers. Soil stabilization is the alteration of soil to enhance their physical properties.

METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Fly ash Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

The methodology of this project is carried out by collection of brown clayey soil sample from proposed area and various tests on soil have been performed as per IS (2720) on expansive soil with proportion of Sodium Chloride ($NaCl_2$), fly ash. 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 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.

IV. MATERIALS USED AND THEIR PROPERTIES

4.1 SOIL

The soil used was a typical black cotton soil collected from Appaniramuni Lanka, Near Dindi village, SakhinetipalliMandal, 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 4.1 Properties of expansive soil

S. No	Property	Value
1	Specific gravity	2.62
2	Differential free swell Index (%)	98
3	Atterberg's Limits	
	i) Liquid limit (%)	69.3
	ii) Plastic limit (%)	24.1
	iii) Plasticity index (%)	45.2
5	Grain Size Distribution	
	i) Sand Size Particles (%)	12
	ii) Silt & Clay Size Particles (%)	88
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.37
	ii) Optimum Moisture Content (%)	26.8
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.3
	ii) CBR - Soaked (%)	1.7
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	39
	ii) Angle of Internal Friction, Øu (Degrees)	0

4.2 FLY ASH

Fly ash is the oldest binding agent since the invention of soil stabilization technology in 1960's. It may be considered as primary stabilizing agent or hydraulic binder because it can be used alone to bring about the stabilizing action required. Fly ash is used to stabilize a wide range of soils. Numerous types of Fly ash are available in the market such as ordinary Portland Fly ash, blast furnace Fly ash, sulfate resistant Fly ash and high alumina

4.3 SODIUM CHLORIDE (NaCl2)

Sodium Chloride (NaCl2) It is white or colorless crystalline solid. It is most commonly used for dust control and road stabilization. When Sodium chloride is applied to roads and bare soil areas, both positive and negative performances issues occur which are related to many applications factors. In this study, the effect of NaCl2 solution on the characteristics of dispersibility and swelling potential of clay soils were investigated. Below Fig shows the photograph of Sodium chloride used.

4.4 RICE HUSK ASH

Rice husk is a potential material, which is amenable for value addition. The usage of rice husk either in its raw form or in ash form is many. Most of the husk from the milling is either burnt or dumped as waste in open fields and a small amount is used as fuel for boilers, electricity generation, bulking agents for composting of animal Manure, etc. The exterior of rice husk are composed of dentate rectangular elements, which themselves are composed mostly of silica coated with a thick cuticle and surface hairs. The mid region and inner epidermis contain little silica Jauberthie et al., confirmed that the presence of amorphous silica Is concentrated at the surfaces of the rice husk and not within the husk itself. The chemical composition of rice husk is similar to that of many common organic fibers and it contains of cellulose 40-50 percent, lignin 25-30 percent, ash 15-20percent and moisture 8- 15 percent.

After burning, most evaporable components are slowly lost and the silicates are left. No other plant except paddy husk is able to retain such a huge proportion of silica in it. Plants absorb various minerals and silicates from earth into their body.

The rice husk ash is collected from the brick manufacturing unit, East Godavari District, Andhra Pradesh.

V. LABORATORY EXPERIMENTATION

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the Expansive clay to find the properties of virgin Expansiveclay.

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

VI. RESULTS AND DISCUSSIONS

6.1GENERAL

Details of the laboratory experimentation carried-out with different combinations of different chemical additives have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on untreated and treated expansive soil are presented.

In the laboratory, various experiments were conducted by adding different percentages of Chemical Additives (CA) in the expansive soil and also durability studies done on the chemical additives treated expansive soil further. DFSI, Compaction, Strength and CBR and UCS tests were conducted with a view to determine the optimum combination of chemical additives (CA) as additive in expansive soil and ash as a binder.

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

6.2 INFLUENCE OF THE % CHEMICAL ADDITIVES (CA) ON DFSI AND ATTERBERG'S LIMITS OF EXPANSIVE CLAY

The individual influence of chemical additives (CA) on the DFSI and ATTERBERG LIMITS of expansive soil are clearly presented in Figures 6.1 and 6.2. The percentage of chemical additives (CA) was varied from 0%, to 6% with an increment of 2%. From the above graphs, it was observed that the treatment as individually with 4% and 9% chemical additives has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual decrease in DFSI with an increment in the % Addition of chemical additives up to 6% with an improvement of about 2%. The addition of chemical additives had mobilized little amount DFSI and ATTERBERG LIMITS to the pure Clayey soil without friction.

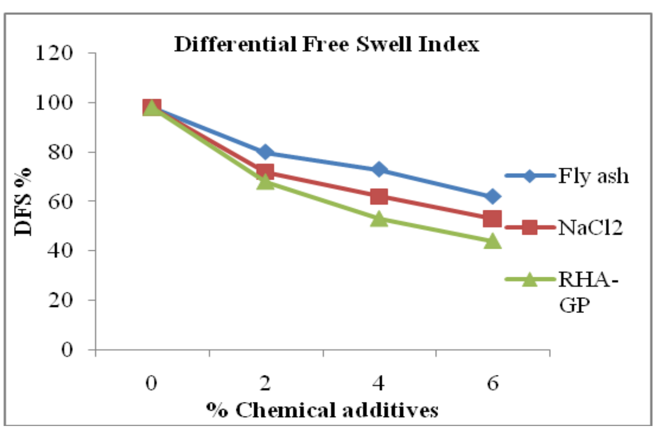

Fig 6.1 Variation of DFSI with percentage addition of chemical additives

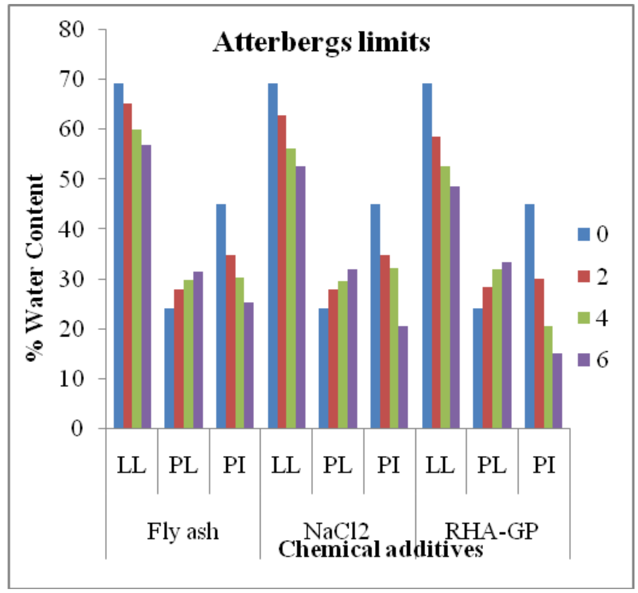

Fig 6.2 Variation Atterberg limits with percentage addition of chemical additives

6.3INFLUENCE OF THE CHEMICAL ADDITIVES(CA) ON COMPACTION, PENETRATION AND STRENGTH PARAMETERS OF EXPANSIVE CLAY

Figures 6.3 and 6.4 shows the variation of compaction parameters like MDD, OMC for addition of different chemical additives like Fly ash.NaCl2, RHA-GP. These all chemicals are used as additives for Expansive soil from 0% to 6% with an increment of 2 %. From above figures we can conclude that the OMC get reduced for all the chemical additives. For 4% and 6% addition of chemical additives OMC get reduced and MDD increased.

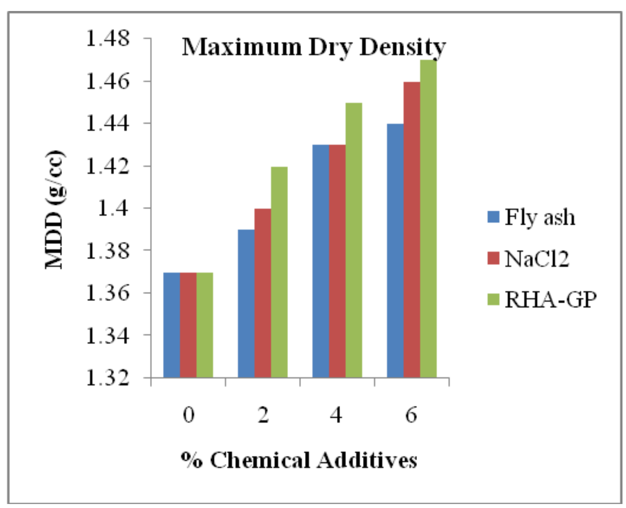

Fig. 6.3 Variation of maximum dry density with % addition of chemical additives.

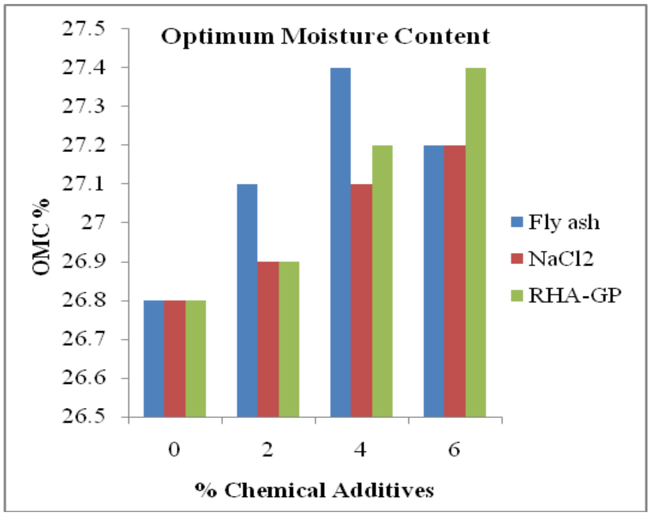

Fig. 6.4 Variation of Optimum Moisture Content with % addition of chemical additives

6.4 VARIATION OF PENETRATION PARAMETERS FOR PERCENTAGE ADDITION OF DIFFERENT CHEMICAL ADDITIVES

Figure 6.5 shows the variation of penetration parameters for unsoaked CBR for addition of different chemical additives like Fly ash. NaCl2, RHA-GP. These all chemicals are used as additives for Expansive soil from 0% to 6% with an increment of 2 %. From above figures we can conclude that the CBR value increases with an increment of percentage of chemical additives in that addition of 4% and 6% addition of chemical additives got good results. For addition 4 % the unsoaked CBR value increased about 41%, 52% and 64% for Fly ash, NaCl2 and RHA-GP Respectively and for 6% addition the CBR value increased about 70%, 88%, and 111% for Fly ash, NaCl2 and RHA-GP Respectively..

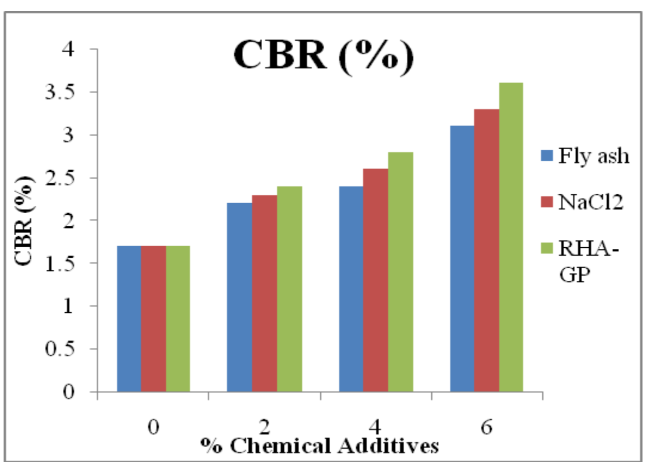

Fig. 6.5 Variation of soaked CBR values with % addition of chemical additives**.**

6.6 VARIATION OF STRENGTH PARAMETERS FOR PERCENTAGE ADDITION OF DIFFERENT CHEMICAL ADDITIVES

Figure 6.6 shows the variation of strength parameters for UCS for addition of different chemical additives like Fly ash. NaCl2, RHA-GP. These all chemicals are used as additives for ES from 0% to 6% with an increment of 2%. From above figures we can conclude that the UCS value increases with an increment of percentage of chemical additives in that addition of 4% and 6% addition of chemical additives got good results. For addition 4 % the UCS value increased about 24%, 29% and 47% for Fly ash, NaCl2 and RHA-GP Respectively and for 6% addition the UCS value increased about 35%, 43%, and 74% for Fly ash, $NaCl_2$ and RHA-GP Respectively.

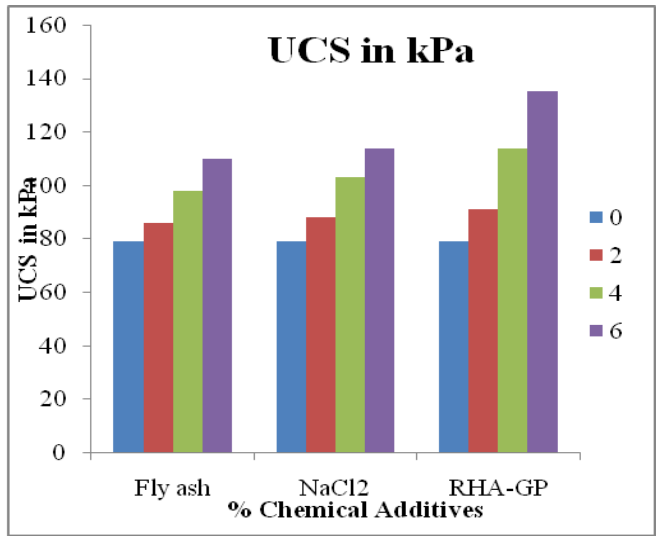

Fig. 6.6 Variation of UCS with % addition of chemical additives

6.5DURABILITY STUDIES - (CURING)

Figure 6.7 shows the variation of soaked CBR values for addition of different chemical additives like Fly ash. $NaCl_2$, RHA-GP. These all chemicals are used as additives for Expansive soil from 4% to 6% with an increment of 2 %. From above figures we can conclude that the soaked CBR value increases with an increment of percentage of chemical additives in that for the 4% and 6% addition of chemical additives soaked CBR value increases with increase in number of days. For 4% and 6% addition of chemical additives, fly ash geopolymer shows prominent results at 28 days.

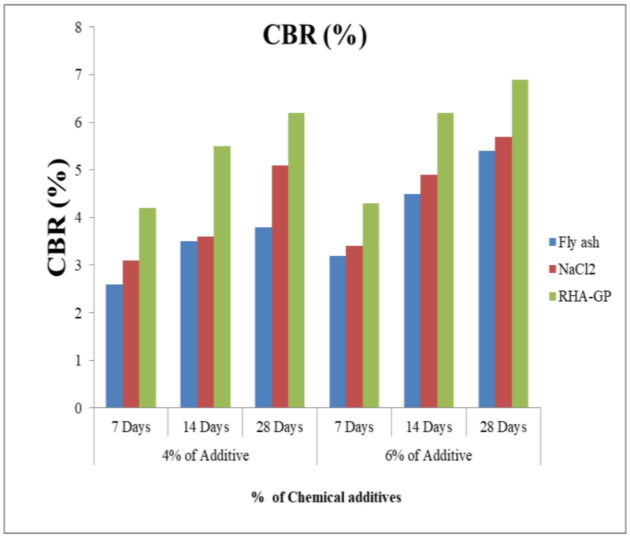

Fig 6.7 Shows the soaked CBR for different curing periods

Figure 6.8 shows the variation of UCS values for addition of different chemical additives like Fly ash. NaCl2, RHA-GP. These all chemicals are used as additives for Expansive soil from 4% to 6% with an increment of 2 %. From above figures we can conclude that the UCS value increases with an increment of percentage of chemical additives in that for the 4% and 6% addition of chemical additives UCS value increases with increase in number of days. For 4% and 6% addition of chemical additives, fly ash geopolymer shows prominent results at 28 days.

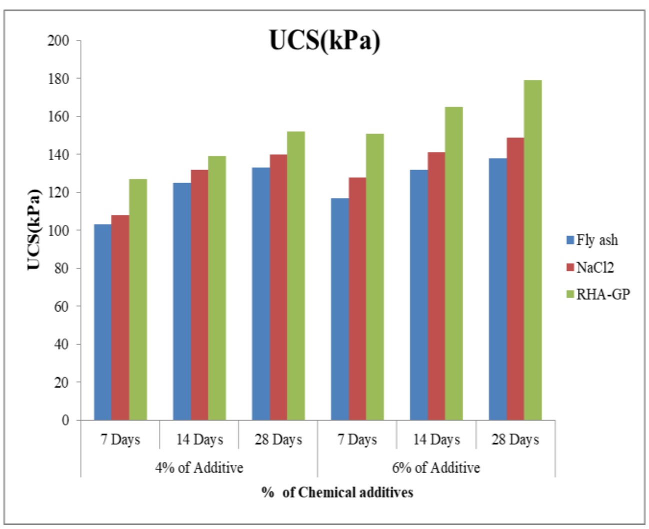

Fig 6.8 shows the UCS (kPa) for different curing periods

VII. CONCLUSIONS

An experiment was undertaken to investigate the effects of chemical additives and organic materials stabilised expansive soil. The following conclusions can be drawn from the results of the investigation.

- From the laboratory studies, it is observed that the Expansive soil chosen was an expansive soil with IS classification as CH and found that it problematic soil having high swelling, and high plasticity characteristics.
- It is observed from the laboratory test results that the plasticity index of the expansive soil has been decreased by 78% % on the replacement of expansive soil with 6 % Fly ash and reduction of about 125% and 200% for $NaCl_2$ and RHA-GP respectively.
- The pozzolanic reaction between the Fly ash activated by sodium chloride, soil and Rice husk ash results in the formation of cementitious compounds.
- It is noticed from the test results that the maximum dry density of the expansive clay has been improved for the % addition up to 6% with an improvement of about 2% and it was about 107% increases for fly ash based Geopolymer.
- It is observed from the test results that the C.B.R. value of the expansive soil has been increased for the addition of chemical additives from 0 to 6%. In that for the 6% addition of fly ash based Geopolymer the CBR value increases about 111%.
- It is noticed from the test results that the UCS Values of the expansive clay has been improved for the addition of chemical additives from 0 to 6%. In that for the 6% addition of fly ash based Geopolymer the UCS value increases about 74%.
- Durability (Curing) studies done on the 4% and 6% addition of different chemical additives modified expansive soil. The CBR of optimum mix proportion blended with expansive soil when cured for 28 days had shown more pronounced. For 4% and 6% addition of chemical additives, fly ash geopolymer shows prominent results at 28 days.
- Durability (Curing) studies done on the 4% and 6% addition of different chemical additives modified expansive soil. The CBR of optimum mix proportion blended with expansive soil when cured for 28 days had shown more pronounced. For 4% and 6% addition of chemical additives, fly ash geopolymer shows prominent results at 28 days.

Finally it can be summarized that the chemical additives like Fly ash $NaCl_2$ and RHA-GP had shown promising influence on the compaction, penetration and strength characteristics of expansive soil, In that 6 % addition of fly ash based Geopolymer shows better results compare to Fly ash and $NaCl_2$ and giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

REFERENCES

[1] Chandrashekar, B.P., PrasadaRaju, G.V.R (1999), Relative Performance of metakaolin and Calcium Chloride on Properties of Black cotton Soil For Pavement Subgrades, Proc. Of IGC-99, Calcutta, 1999, pp 279-282.

[2] Charles M et al (2012), “Compactive effort influence on properties of Rice Husk Ash-black cotton soil mixtures”, International Journal of Geotechnical Engineering.

[3] PrasadaRaju, G.V.R (2001), Evaluation of Flexible Pavement Performance with ReinforMetakaolin and Chemical Stabilization of Black cotton Soil Sub grade, a Ph.D. thesis, Kakathiya University, Warangal,(A.P).

[4] Balasubramaniam, A.S., Bergado, D.T., Buensuceso, B.R. and Yang, W.C.,(1989), Strength and deformation characteristics of metakaolin treated soft clays, Geotechnical Engineering (AIT), 20, 1989, pp. 69-65.

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

[6] Bansal, R.K., Pandey, P.K. and Singh, S.K (1996), Improvement of a Typical Clay for Road Subgrades, Proc. Of National Conf. on Problematic Subsoil Conditions, Terzaghi-96, Kakinada, India, 1996, pp. 193-197.

[7] GopalRanjan and A.S. R. Rao (2006), Basic and Applied Soil Mechanics, New Age International Publishers.I.S: 2720, Part VII, (1980), Determination of Water Content Dry Density Relation Using Light Compaction.

[8] IS 2720-Part XL: Methods of test for soils – Determination of Free Swell Index of Soils, Bureau of Indian Standards, New Delhi (1977).

[9] IS 2720-Part 5: Methods of test for soils – Determination of Liquid Limit and Plastic Limit, Bureau of Indian Standards, New Delhi (1985).

[10] IS 2720-Part 6: Methods of test for soils – Determination of Shrinkage Factors, Bureau of Indian Standards, New Delhi (1972).

[11] IS 2720-Part 10: Methods of test for soils – Determination of Unconfined Compressive Strength, Bureau of Indian Standards, New Delhi (1991).

[12] IS 2720-Part 16: Methods of test for soils – Laboratory Determination of CBR, Bureau of Indian Standards, New Delhi (1987).

[13] IS 2720-Part VII: Methods of test for soils – Determination of Water Content – Dry Density relation using Light Compaction, Bureau of Indian Standards, New Delhi (1980).