Use of Flyash Based Geopolymer and Magnesium Chloride on Pavement System Laid on Expansive Clays

Ch. Kiran Kumar[1], B. Ganesh[2]
[1]Dept of Civil Engineering
[2]Associate Professor, Dept of Civil Engineering
[1, 2] Lenora College of Engineering, Rampachodavaram

Abstract- *Expansive soils tend to swell and shrink with the variation in moisture content. As a result, significant distress in the soil occurs, causing severe damage to the overlying structure. These types of soils are generally found in arid and semi-arid regions of the world and may cause severe damage to the structures built upon them if not treated properly. Soils containing the clay mineral, montmorillonite generally exhibit high swelling and shrinkage characteristics due to high specific surface area. Stabilization using industrial by-products is one of the different techniques to improve the engineering properties of expansive soils and make them suitable for various engineering applications. 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 cement, MgCl2 and also by adding Fly 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, Magnesium Chloride (MgCl2), 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. Magnesium 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 Magnesium chloride Chloride ($MgCl_2$) 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.

The objective of the current work is to determine the suitability of geopolymer (alkali-activated fly 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.

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 expansive soils 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 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.

II. LITERATUREREVIEW

2.1 GENERAL

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 Magnesium chloride have been reviewed.

Dr.K.V KRISHNA REDDY made an attempt to determine the utility of industrial wastes in Stabilization of medium plastic clays (CI). Fly ash (FA) and waste tire rubber (WTR) have been considered to investigate their potential in stabilizing the CI soils.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 Day UCC strength of 330 kN/Sqm. 6% addition of waste tire rubber content to CI soil resulted in a CBR value of 4.36% and a 7 day UCC value of 80kN/Sqm. The differential free swell % evaluated for the optimal mixes indicated that the stabilized mixes exhibited low expansiveness. Industrial wastes namely fly ash and waste tire rubber can be effectively used to stabilize clay subgrades to achieve high strength values thus resulting in decreased pavement thickness and low maintenance.

ZORE T. D AND S. S. VALUNJKAR (2010) had reported about the utilization of fly ash and steel slag in road construction. In their study, it was aimed to replace natural aggregates in road construction, either for blanket courses, bases or sub bases using these waste by-products. It was concluded that steel industry waste by-product is suitable and economical for use in the road construction. Steel slag is easily available and has higher CBR value than fly ash hence saving is excess than fly ash use. The optimum mix was reported as 15% steel slag mix in sub grade and in sub base for road construction.

MEENU PRAKASH, REKHA RAVEENDRAN (2011) exposed the possibilities of paper sludge and rice husk ash in soil improvement and comparison of the results. Both paper sludge and rice husk ash are waste materials which cannot be disposed easily. The main objective of this paper is to check which stabilizing agent will give more strength. This paper involves the detailed study with various tests such as initial soil properties and to check the strength achievement through unconfined compression test. Soil stabilization is the alteration of property of locally available soil to improve its engineering performance. Stabilization can increase the shear strength of soil and control shrink – swell properties of soil, thus improving the load bearing capacity of a sub grade to support the pavements and foundation.

T.K. ROY , B.C. CHATTOPADHYAY , S.K. ROY (2009) explained that Procurement of conventional materials in huge quantity required for construction of subgrade of road is becoming very difficult in many locations due to various problems. On the other hand, due to increasing economic growth and industrialization, a huge quantity of waste materials generated needs land for disposal and from that generally creates problems for public health and ecology. So need has arisen for proper disposal of the waste materials. Utilizing these materials in the area of road construction after improving their characteristics suitably can provide useful solution of this problem. So keeping this in view, an experimental study was undertaken to explore the possibility of utilization of the alternative materials like rice husk ash by mixing with local alluvial soil by adding small percentage of lime for the construction of road subgrade as cost effective mix.

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 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 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 Magnesium Chloride ($MgCl_2$), 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, 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 4.1 Properties of expansive soil

S. No	Property	Value
1	Specific gravity	2.63
2	Differential free swell Index (%)	98
3	Atterberg's Limits	
	i) Liquid limit (%)	69.5
	ii) Plastic limit (%)	24.2
	iii) Plasticity index (%)	45.3
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)	1.38
	ii) Optimum Moisture Content (%)	26.7
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.4
	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 CEMENT

Cement 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. Cement is used to stabilize a wide range of soils. Numerous types of cement are available in the market such as ordinary Portland cement, blast furnace cement, sulfate resistant cement and high alumina cement. Usually the choice of cement depends on type of soil to be treated and desired final strength. Normally the amount of cement used is small but sufficient to improve the engineering properties of the soil and further improved cation exchange of clay. Cement can be used to modify and improve the quality of the soil or to transform the soil into a cemented mass with increased strength and durability

4.3 MAGNESIUM CHLORIDE (MgCl2)

Magnesium Chloride (MgCl2) It is white or colorless crystalline solid. It is most commonly used for dust control and road stabilization. When magnesium 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 MgCl2 solution on the characteristics of dispersibility and swelling potential of clay soils were investigated. Below Fig shows the photograph of magnesium chloride used.

4.4 FLY ASH

Class "F" fly ash is produced from burning harder, older anthracite and bituminous coal. This kind of fly ash contains less than 20%lime and thus glasey silica and alumina are the only pozzolans present in sufficient quantities soil stabilization using fly ash class "F" will be feasible only it additives such as Portland cement and quick lime, or hydrated cement added, when fly ash blended with water, result in the products that bind soil grains or increases the strength in the soil matrix.

The extent of leaching and harmfulness to humans of fly ash leachate is still not entirely known but is being investigated. Unlike soil stabilization using fly ash, environmentally, safe solutions are created by global road technology. The fly ash used as a filler material was procured in a 1 kg bag were purchased from National Thermal Power Corporation (NTPC), Visakhapatnam and stored in a dry place away from weather effects.

Fig.4.1: Fly ash

V. 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

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 Cement 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.

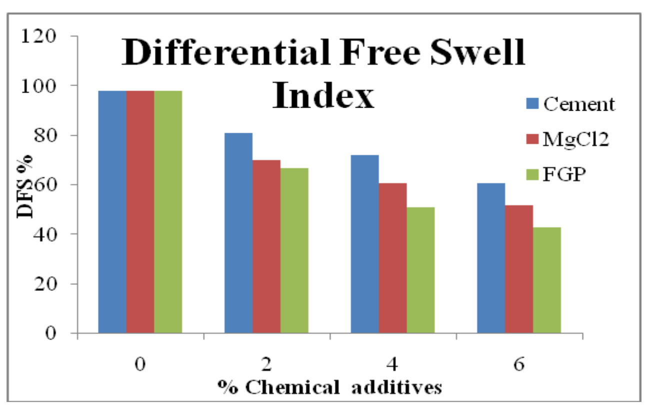

Fig 6.1 Variation of DFSI with percentage addition of chemical additives

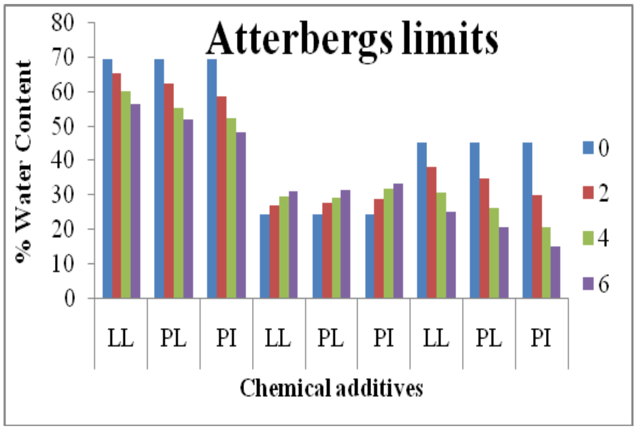

Fig 6.2 Variation Atterberg limits with percentage addition of chemical additives

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

Table 6.3, Figures 6.3 and 6.4 shows the variation of compaction parameters like MDD, OMC for addition of different chemical additives like Cement. $MgCl_2$, FGP. 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.

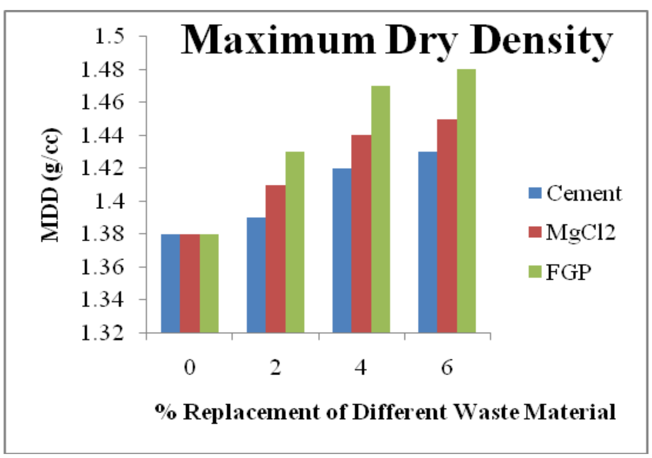

Fig. 6.3 Plot showing the variation of maximum dry density with % addition of chemical additives to Expansive soil.

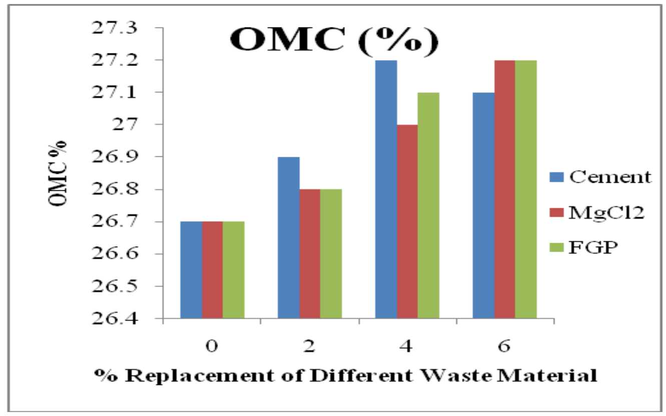

Fig. 6.4 Plot showing the variation of Optimum Moisture Content with % addition of chemical additives to Expansive soil.

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

Table 6.4, Figure 6.5 shows the variation of penetration parameters for unsoaked CBR for addition of different chemical additives like Cement. $MgCl_2$, FGP. 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 Cement, MgCl2 and FGP Respectively and for 6% addition the CBR value increased about 70%, 88%, and 111% for Cement, $MgCl_2$ and FGP Respectively.

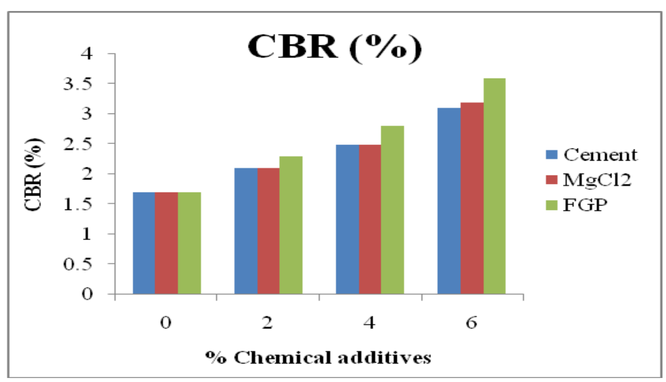

Fig. 6.5 Plot showing the variation of soaked CBR values with % addition of chemical additives to Expansive soil**.**

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

Table 6.5, Figure 6.6 shows the variation of strength parameters for UCS for addition of different chemical additives like Cement. $MgCl_2$, FGP. 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 Cement, $MgCl_2$ and FGP Respectively and for 6% addition the UCS value increased about 35%, 43%, and 74% for Cement, $MgCl_2$ and FGP Respectively.

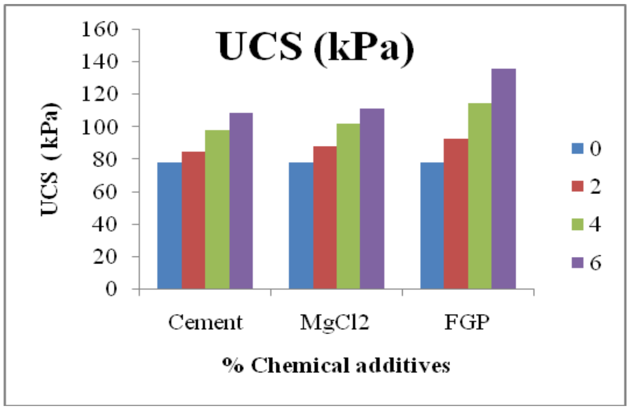

Fig. 6.6 Plot showing the variation of UCS with % addition of chemical additives to Expansive soil.

6.5 DURABILITY STUDIES - (CURING)

Table 6.6, Figure 6.7 shows the variation of soaked CBR values for addition of different chemical additives like Cement. $MgCl_2$, FGP. 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.

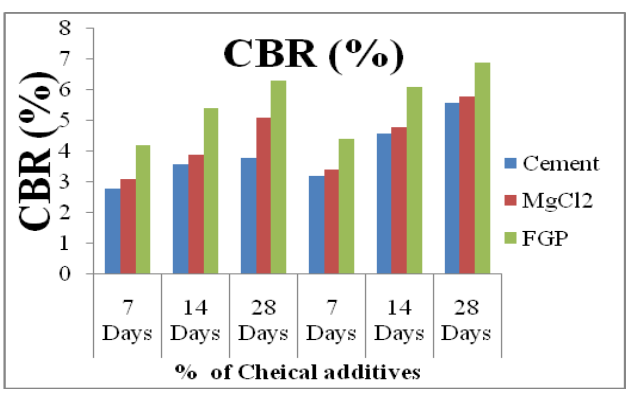

Fig 6.7 Shows the soaked CBR for different curing periods

Table 6.7, Figure 6.8 shows the variation of UCS values for addition of different chemical additives like Cement. MgCl2, FGP. 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.

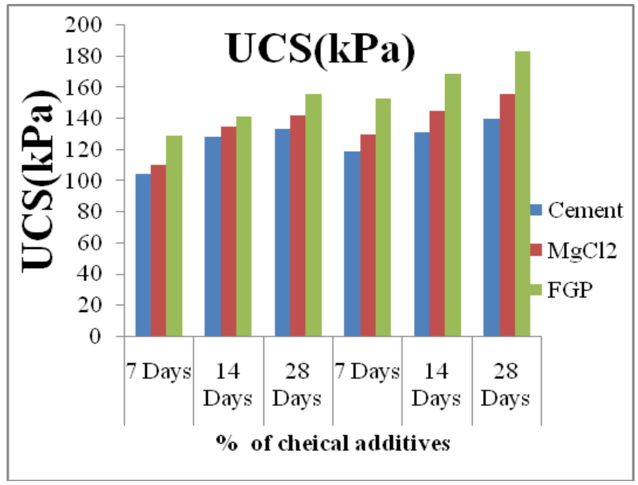

Fig 6.8 shows the UCS (kPa) for different curing periods

VII. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- The soil used for the present study was an expansive soil with IS classification as CH. 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 expansive soil treated with chemical additives has moderately improved the expansive soil.
- The reduction in plasticity index was about 78% when replaced with 6 % cement and reduction of about 125% and 200% for $MgCl_2$ and FGP respectively. This may be due to the replacement of plastic soil with a non plastic waste material.
- There is improvement in compaction parameters. The maximum dry density with an increment in the % addition up to 6% with an improvement of about 2% and it was about 107% increases for fly ash based Geopolymer.
- There is an improvement in CBR values 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%.

- There is an improvement in UCS values 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%.
- Further durability studies were done on the 4% and 6% addition of different chemical additives. The laboratory result shows that 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.
- 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.

Finally it can be summarized that the chemical additives like Cement MgCl2 and FGP 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 Cement and MgCl2

REFERENCES

[1] **Mitchell, J. K. and Soga, K**., Fundamentals of Soil Behavior, 3rd Edition, John Wiley and Sons Inc., New York, 2005.

[2] **Mitchell, J. K**., Fundamentals of Soil Behavior, John Wiley and Sons Inc., New York, 1976

[3] **Mitchell, J.K. and Hooper, D.R.(1961):** Influence of time between mixing and compaction on properties of a Cement stabilized expansive clay bulletin 304, highway research board, Washington.

[4] **Nelson, J.D. and Miller, D.J**., Expansive Soils, Problems and Practice in Foundation and Pavement Engineering, John Wiley and Sons Inc., New York, 1992.

[5] **Oweis, I. S., Khera, R. P**., Geotechnology of Waste Management, 2nd Edition, PWS Publishing Company, Boston, 1998.

[6] **Popescu, M.E., (1986),** "A Comparison between the Behaviour of Swelling and of Collapsing Soils", Engineering Geology, Vol. 23, pp. 145-163.

[7] **Terzaghi, K., Peak R.B. and Mesri, G**., Soil Mechanics in Engineering Practice, 3rd Edition, John Wiley and Sons Inc., New York, 1996.

[8] **Uppal, Dr. I.S Kewal krishan.(1973):** Effect of aging of the engineering properties of Cement stabilized soil-institu of military engineers seminar.

[9] **Uppal, H.L. and Bhatia, H.S(1958).:** Stabilization of Black cotton soil for use in road construction, road research bulletin No.5, Indian roads congress, New Delhi.

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

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

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

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

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

[15] 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).