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Stabilization of Expansive Soil Using Aluminum Chloride and Flyash

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Abstract: *Expansive soils are basically susceptible to detrimental volume changes with the changes in moisture content. Expansive soils are chemically active, their nature and behavior can be controlled through the application of chemical agents with may be either occurred naturally, manufactured or waste products of manufacturing processes. Application of stabilization technique consists of either introducing the chemical (AlCl3) into the soil or through mixing of flyash with the expansive soil to form a homogeneous stabilized sub grade layer. The main objective of this study is to investigate the effectiveness of homogeneous layer formed by mixing the flyash and Aluminum Chloride chemical (AlCl3) with the expansive soil. In this paper, the test results such as Atterberg limits, compaction, California Bearing Ratio, and Differential Free Swell obtained on expansive soils mixed with Aluminum Chloride ($AlCl_3$) in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of the expansive soil and at each percentage of chemical, addition of flyash in percentages of 5%, 10%, 15%, 20%. From the results, it is observed that at optimum percentage, i.e., 1.0% $ALCL_3$ and 10% Flyash, there is a marked improvement in the strength of soil.*

Keywords: *Expansive soil, Flyash, $ALCL_3$,Atterberg limits, DFS,Soaked CBR*

I. Introduction

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. World over, problem of expansive soils has appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, sewer lines, canal and reservoir linings. 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.

The losses due to extensive damage to highways running over expansive soil sub-grades are estimated to be in billions of dollars all over the world. The remedial measures can be different for planning and designing stages and post construction stages. Many stabilization techniques are in practice for improving the expansive soils in which the characteristics of the soils are altered or the problematic soils are removed and replaced which can be used alone or in conjunction with specific design alternatives. Additives such as lime, cement, Aluminum chloride, rice husk, flyash etc. are also used to alter the characteristics of the expansive soils. The characteristics that are of concern to the design engineers are permeability, compressibility and durability.

Flyash and Aluminum Chloride can be used best for various construction purposes like sub grade, foundation base and embankments. Flyash and Aluminum Chloride exhibits high shear strength which is highly beneficial for its use as a geotechnical material.

II. Review Of Literature

Black Cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. Black Cotton soil has a high percentage of clays, which is predominantly montmorillonite in structure and black or blackish grey in color. Because of its high swelling and shrinkage characteristics, the Black Cotton soil has been a challenge to geotechnical and highway engineers. The soil is very hard when dry, but loses its strength completely when in wet condition (Balasubramaniam, et al., 1989). The wetting and drying process causes vertical movement in the soil mass which leads to failure of a pavement, in the failure of a pavement, in the form of settlement, heavy depression, cracking and unevenness. It also forms clods which cannot be easily pulverized as treatment for its use in road construction (Holtz & Gibbs, 1956). With the seasonal variation, polygonal cracks appear at the surface during the summer, which may extend to a depth of about 2m indicating the active zone in which volume change occurs called as active zone. The depth of active zone defined as the thickness of the soil below the ground surface within which moisture content variations and hence volume changes do take place with the variation of seasons. Sustained efforts are being made all over the world on highway research field to evolve more promising treatment methods for proper design and construction of pavements running over expansive soil sub grade.

In the present work, an attempt was made by using $ALCL_3$ and Flyash as stabilization material in expansive soil. In this investigation different laboratory experiments like Atterberg limits, differential free swell, soaked CBR tests conducted on stabilized expansive soil with Aluminum Chloride in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of to the expansive soil and at each percentage of chemical, addition of flyash in percentages of 5%, 10%, 15%, 20%.

III. Materials Used

Black Cotton Soil

The soil used was a typical black cotton soil collected from 'ODALAREV' near Amalapuram, in East Godavari District, Andhra Pradesh State, India. The black cotton soil was collected by method of disturbed sampling after removing the top soil at 150mm depth and transported to the laboratory. The soil was air dried and sieved with is sieve 4.75mm as required for laboratory test as shown in fig.1. The soil properties are WL=85.25%, WP=29.2%, PI=56.12, WS=12%, I.S. Classification=CH (Clay of high compressibility), OMC=25.70, MDD=1.55g/cc, Differential free swell = 140 %, Soaked CBR=2.12%, Specific Gravity=2.85.

Flyash

Flyash was used in this study as shown in fig.2. Flyash is mixing in varying percentages of 5%, 10%, 15%, 20% of the expansive soil. The flyash collected from Vijayawada thermal power station, Vijayawada was used as a subbase course in this work. The properties of flyash are MDD=13.24 kN/m3, OMC=24%, Soaked CBR=4.0%.

Aluminum Chloride ($ALCL_3$)

Commercial grade Aluminum chloride was used in this study. Aluminum Chloride ($AlCl_3$) in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of the expansive soil. The quantity of Aluminum chloride was varied from 0 to 2% by dry weight of soil as shown in fig.3.

Fig.1 Expansive Soil

Fig. 2 Flyash

Fig.3Aluminum Chloride

IV. Experimental Investigation

To find the effectiveness of Aluminum Chloride and flyash i.e. Aluminum Chloride ($AlCl_3$) is added separately in varying percentages 0.5%. 1.0%, 1.5%, 2.0% to the expansive soil and at each percentage of chemical, addition of flyash in percentages of 5%, 10%, 15%, and 20% was investigated. The Liquid Limit & Plastic Limit tests were conducted as per IS:2720 (Part 5) – 1985, Heavy compaction testing IS2720 (Part 8) – 1983, Free Swell Index Testing IS:2720 (Part XL) – 1977 and California Bearing Ratio (CBR) Testing IS:2720 (Part 16) – 1987.

Testing is conducted with a view to find the gradual variation of different engineering properties by increasing the quantity of chemical and flyash and finally to determine the optimum percentage of chemical and flyash i.e. at which the properties are reaching a definite improved value.

V. Results And Discussions

`The variation of different Atterberg limits with the addition of different additives is presented in this article. The influence of chemical and flyash combinations on the index properties observed during the laboratory testing is shown in Figs.4 to 7. The decrease is significant up to the addition of 1% chemical+10% flyash combination and nominal afterwards. The percentage reduction in liquid limit values for 1% addition of chemical is 27% for $AlCl_3$. The reduction is very nominal beyond 1% addition of chemical. The liquid limit values further could be reduced by the addition of flyash to the above soil and chemical mixture. The percentage reduction is 37% for the addition of 1% $AlCl_3$+10% flyash combinations. A slight increase in the plastic limit values was observed with the increase in the percentage chemical. The increase in the plastic limit values and the reduction in the liquid limit values cause a net reduction in the values of plasticity index. For 1% chemical, it is observed that, the reduction in plasticity index value is of the order of 42% for $AlCl_3$ treatment in comparison to the untreated soil. The Plasticity Index values further could be reduced by the addition of flyash to the above soil and chemical mixture. The percentage reduction is 60% for the addition of 1% $AlCl_3$+10% flyash combinations. It can be seen from the graph, the $AlCl_3$ treatment has effectively controlled the plasticity index. Variation of Shrinkage Limit values for different soil mixes is shown Fig. 7. It may be observed that the shrinkage limit values are increased by 20% for 1% $AlCl_3$ treatment and the values are further increased with the addition of flyash. For 1% $AlCl_3$+10% flyash combinations the percentage increase in shrinkage limit is 37%.

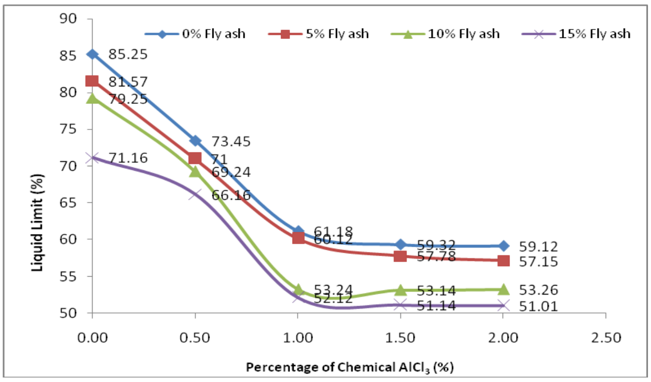

Fig. 4 Variation of Liquid Limit for Expansive Soil with Different Percentages of $AlCl_3$ and Flyash Mixes.

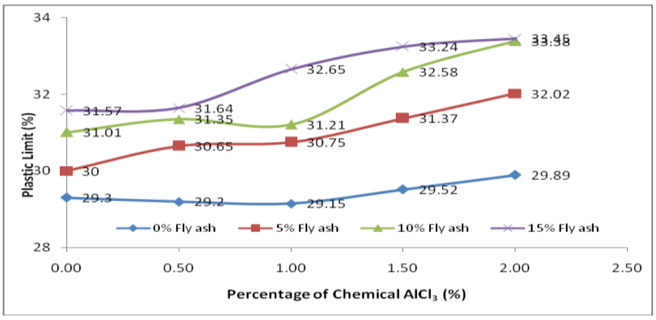

Fig.5 Variation of Plastic Limit for Expansive Soil with Different Percentages of $AlCl_3$ and Flyash Mixes.

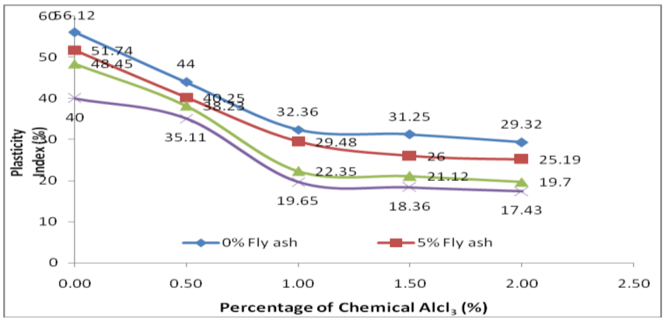

Fig. 6 Variation of Plasticity index for Expansive Soil with Different Percentages of $AlCl_3$ and Flyash Mixes.

Effect of Additives on Differential Free Swell

The variation of Differential Free Swell for different percentages of Aluminum Chloride and flyash mixed in expansive soil as shown in Fig 8. There is a significant decrease in D.F.S. values up to 1% of the chemical, after that the reduction of DFS values is very less. The percentage reduction in the values of D.F.S. at 1% chemical are of the order 46% and 54% for flyash and $AlCl_3$ treatments. The values are further reduced with the addition of the flyash. The decrease is significant up to the addition of 1% chemical+10% flyash combination and nominal afterwards.

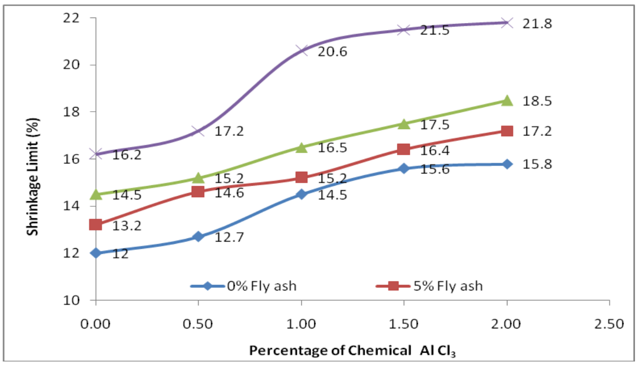

Fig. 7 Variation of Shrinkage Limit for Expansive Soil with Different Percentages of $AlCl_3$ and Flyash Mixes.

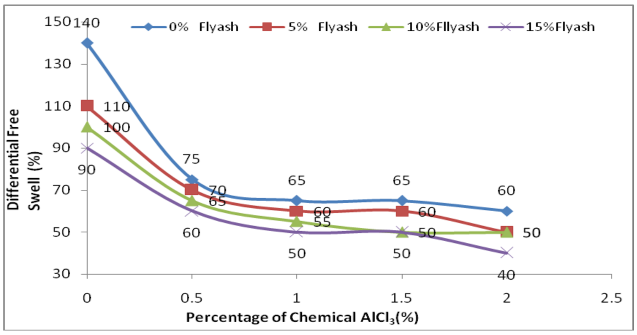

Fig. 8 Variation of Differential Free Swell for Expansive Soil with Different % of $AlCl_3$ and Flyash Mixes.

Compaction Test Results

IS heavy compaction tests were conducted as per IS: 2720 (Part VIII). All the expansive soil samples are mixed with different percentages of flyash and Aluminum Chloride. Graphs are drawn between OMC and MDD for each percentage of flyash and Aluminum Chloride mixing in the expansive soil. From the test results Optimum Moisture content increases and Maximum Dry Density values are decreases presented below in the Figs.9&10.

California Bearing Ratio Test Results

Soaked CBR test was carried on a specimen prepared at Modified Proctors maximum dry density and optimum water content. Fig 11shows the variation of soaked CBR values with increasing percentages of chemical $AlCl_3$ and flyash. Soaked CBR value of original expansive soil is 2.12. It is observed that the flattening of the curve at 1% addition of chemical indicates nominal improvement with the addition of further chemical. Increase in percentage of CBR with the addition of 1% chemical is of the order 114% for $AlCl_3$ respectively. The values are further increased with the addition of the flyash. The increase is significant up to the addition of 1% chemical+10% flyash combination and afterwards it is nominal. The CBR values are increased to 9.58 for the addition of 1% $AlCl_3$+10% flyash combination.

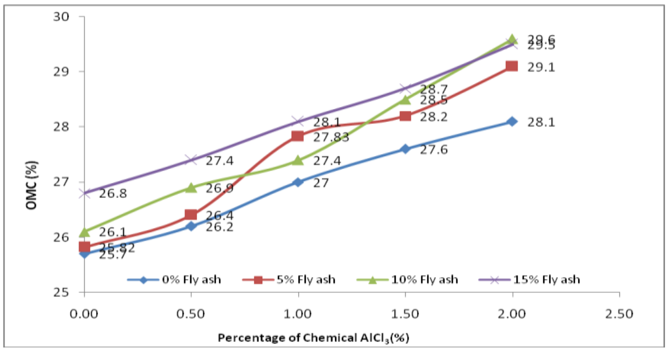

Fig. 9 Variation of Optimum Moisture Content for Expansive Soil with Different % of $AlCl_3$ and Flyash Mixes.

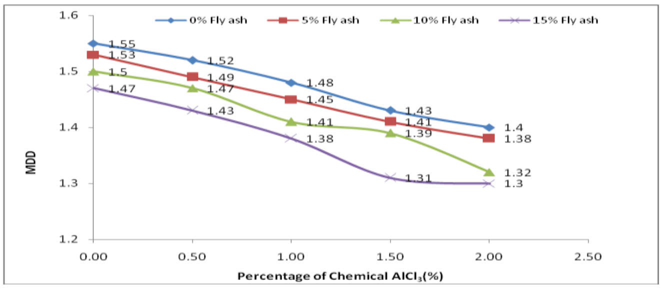

Fig. 10 Variation of Maximum Dry Density for Expansive Soil with Different % of $AlCl_3$ and Flyash Mixes.

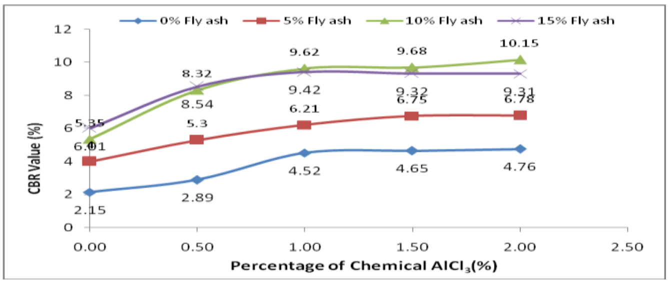

Fig. 11 Variation of California Bearing Ratio for Expansive Soil with Different % of $AlCl_3$ and Flyash.

VI. Conclusions

1. From the laboratory studies, it is observed that the percentage reduction in liquid limit values are of the order of 27% for 1% addition of $AlCl_3$ and further addition of flyash up to 10% made the liquid limit values reduced to 37% .
2. Decrease in the values of Liquid Limit followed by slight increase in the Plastic Limit causes a net reduction in the Plasticity Index. The percentage reduction in Plasticity Index values are 42% with the addition of 1% $AlCl_3$ and 60% with the addition of 1% $AlCl_3$ + 10% flyash combination.
3. The Shrinkage Limit values increased by 37% for 1% + 10% addition chemical ($AlCl_3$) and flyash combination.
4. The Differential Free Swell reduces by 54% for 1% addition of $AlCl_3$ respectively and reduction up to 61% is made possible with further addition of 10% flyash.
5. Atterberg Limits and DFS values reached a definite improved value with the addition of different combinations of chemical and flyash and there after the improvement is insignificant.
6. CBR value of the untreated expansive soil observed as 2.12 only, but with the treatment of $AlCl_3$ values reached to 4.54 i.e. increase is 114% to the initial value. But further addition of flyash up to 10%, the CBR values reached to 9.58.

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