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Swelling Properties of Expansive Soils Treated with Chemicals and Flyash

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***Abstract*: -** Expansive soil shows recurrent volume changes with the changes moisture content, causing serious problems to the civil engineering structures such as road pavements resting on them. Several attempts are being made all over the world to control the swell shrink behavior of expansive soils. Flexible Pavements constructed on these soil shows signs of damage continuously during the service life of the pavement causes an increase in the maintenance costs. Numerous methods are available in the stabilization of expansive subgrade soil. Many researchers have made an attempt with the chemical stabilization technique, it has gained prominence due to its easy applicability and adaptability. Flyash is freely available waste product which has little cementing property can be used for altering the characteristics of expansive soil. The main objective of this work is to study the swelling properties of the expansive subgrade soil treated with chemicals like Magnesium Chloride ($MgCl_2$), Aluminum Chloride ($AlCl_3$) and also by adding flyash in varying percentages. The swelling properties of the collected expansive soil samples were determined based on the parameters like Free Swell Index, Swell Potential and Swell Pressure. The results obtained from the experimental study indicate that the measured Free Swell, Swell Potential and Swelling Pressure are reduced substantially with the increasing percent of chemicals and flyash and remain stable after reaching certain concentration. This paper discusses the results of the testing.

***Keywords*: -** *Expansive soil, Swell Pressure, Swell Potential, Chloride Compound Chemicals, Flyash*

I. INTRODUCTION

Expansive soils generally called as Black Cotton Soils covers nearly twenty percent of the geographical area in India. Differential Thermal Analysis and X-ray diffraction pattern analysis have shown that montmorillonite mineral is predominant in expansive soil [1]. These soils contain high percentages of clay with predominant montmorillonite mineral in it causing the soil to swell and shrink during drying and wetting. The nature of these soils creating a problem to the civil engineering structures particularly flexible pavements constructed on them. Many Highway agencies, private organizations and researchers are doing extensive studies on this problem and its remedial measures. Calcium based stabilizers such as lime is used widely throughout the world for the treatment of expansive soils [2]. Chemicals like Potassium Chloride (KCl), Calcium Chloride($CaCl_2$) and Ferric Chloride($FeCl_3$) can be used effectively in place of lime, because these chemicals are dissolvable in water making it to mix easily with soil and supply adequate cations [3] [4]. There is an increase in strength and reduction in swelling is observed with the addition of CaCl2 & KOH to the expansive soil [5]. The properties of black cotton soils in place can be altered by treating with aqueous solution of KOH [6]. There is a hypothesis that if the aluminum is introduced into the soil it will precipitate into the pore space, thus strengthening the soil [7] [8]. CBR, UCS and indirect tensile strength of expansive soil are greatly improved with the addition of Sodium Chloride (NaCl) as a stabilizer [9]. When ammonium chloride is added to the expansive soil, it removes ionized water and draws the lattice together, but the ammonium ions reduces the capillarity in the soil requiring more thorough mixing of the soil [10]. Increase in max dry density and the corresponding reduction in Optimum Moisture Content values were observed with the addition of varying percentages of Magnesium Chloride ($MgCl_2$) and Sodium Chloride (NaCl) chemicals [11]. Oedometer free swell tests conducted on the flyash mixed specimens, confirmed that the plasticity index, activity and swelling potential of the samples decreased with the increasing percent stabilizer and curing time and the optimum content of flyash in decreasing the swell potential was found to be 20% [12]. The variation of CBR of flyash and black cotton soil mixes can be attributed to the relative contribution of frictional or cohesive resistance from flyash or black cotton soil respectively {13]. The undrained shear strength of of the expansive soil blended with flyash increases with the increase in the flyash content [14]. The tests carried out with different proportions of flyash added with the soil having high plasticity indicated that the workability is maximum and the dry density observed is maximum with the addition of 25% flyash [15]. Keeping in view of the influence of various chemicals and flyash in the stabilization of expansive soil an attempt is made in this work to study the swelling properties of the expansive soil with the addition of chemicals like Magnesium Chloride ($MgCl_2$), Aluminum Chloride ($AlCl_3$) and flyash in varying percentages.

II. MATERIALS AND METHODS

Expansive Soil: In this study expansive soil sample having high degree of swelling and shrinkage is collected from Komaragiripatnam village, Amalapuram mandal of Andhra Pradesh, India. Soil is collected at a depth of 1.5 mt below the ground level. The color of the soil is black and when tested in the laboratory it has a Differential Free Swell of 140%. The soil lies above the A-line of Unified Soil Classification System (USCS) and is classified as Inorganic Clay of High Plasticity. Hydrometer analysis indicates that the clay content is very high of nearly 70%. The Properties of the soil are presented in Table 1.

Chemicals: Chloride Compound Chemicals chosen in the present study are Magnesium Chloride ($MgCl_2$) and Aluminum Chloride ($AlCl_3$). These chemicals are easily soluble in water and uniform mixing can be easily achieved. These chemicals are added to the expansive soil samples in varying percentages of 0.5%, 1.0%, 1.5%, 2.0% of dry weight of soil.

Flyash: The Flyash used in this work is collected from Thermal Power Station, Vijayawada, A.P., India. The properties obtained from the laboratory testing are furnished in the Table 2.

Experimental Study: Laboratory experimentation is carried out as per the procedures given in the Indian Standard Codes. Free Swell Index as per IS2720(Part XL)–1977, Max Dry Density & OMC as per IS2720(Part 7&8)-1983, Swell Pressure Testing as per IS2720(Part XLI)-1977.

Free Swell Index: The determination of free swell index also known as differential free swell of soil helps to identify the potential of a soil to swell which might need further detailed investigation regarding swelling and swelling pressures under different field conditions. In this method 10 grams of oven-dried soil sample passing through 425 Micron sieve is poured in two graduated cylinders of 100 ml capacity. One cylinder shall then be filled with kerosene oil and the other with distilled writer up to the 100 ml mark. After removal of entrapped air by stirring with glass rod, the soils in both the cylinders shall be allowed to settle. Sufficient time (not less than 24 hours) shall be allowed for the soil sample to attain equilibrium state of volume.

Free Swell Index = $[(V_d – V_k)/V_k] \times 100$

Where V_d and V_k are the final volumes of soil sample in water and kerosene.

Swell Potential: Swell Potential of a soil specimen is the ratio of the increase in thickness to the original thickness of a soil specimen compacted at OMC in a consolidation ring, soaked under a surcharge load of 7 KPa and is expressed as a percentage.

Swelling Pressure: Swelling Pressure is the pressure at which the expansive soil exerts if the soil is not allowed to swell or the volume change of the soil is arrested. In this study it is determined as per IS2720 (Part XLI)-1977 using the Consolidometer method. Samples of diameter of 60mm and thickness 20 mm are used. Samples are prepared at Max Dry Density and Optimum Moisture Content. During testing sample was kept always submerged in water. Free swell of the sample is allowed for 6 days under the seating load of 5 KPa. The swollen sample shall then be subjected to consolidation under different pressures till the specimen attains its original volume. A plot of change in thickness of expanded specimen as ordinate and applied consolidation pressure as abscissa in semi-logarithmic scale shall be made. The swelling pressure exerted by the soil specimen under zero swelling condition shall be obtained by interpolation and is expressed in KPa.

III. RESULTS AND DISCUSSION

Effect of Additives on Differential Free Swell:

The influence of additives on the values of Differential Free Swell is shown in Fig 1 & 2. Untreated soil sample is having a DFS value of nearly 140 which shows that the potential of soil for free swell is very high and the soil can be treated as highly expansive. With the addition of chemicals Magnesium Chloride (MgCl2) and Aluminum Chloride (AlCl3) separately, it is observed that there is a considerable reduction in the DFS values. For both the chemicals the reduction is significant up to the addition of 1% chemical and is nominal afterwards. The reduction in the value of DFS at 1% chemical and 0% flyash are of the order of 54% and 46% for AlCl3, MgCl2 respectively. Whereas the reduction in the values of DFS at 1% chemical+10% flyash are of the order of 64% and 54% for $AlCl_3$ and $MgCl_2$ treatments respectively.

Effect of Additives on Swell Potential:

The variation of the swell potential with the addition of the chemicals and flyash is shown in Fig 3 & 4. Samples are prepared at max dry density and optimum moisture content. Untrated sample is having a swell potential of 20.6% and is gradually reduced to 9.4% and 10.5% with the addition of 2% $AlCl_3$, $MgCl_2$ respectively. And addition of flyash has its effect in reducing the swell potential. Addition of 1% chemical and 10% flyash is considered as optimum and the swell potential reduced to 6.5% and 7.6% for $AlCl_3$, $MgCl_2$ respectively.

Effect of Additives on Swell Pressure:

Swell pressure testing is carried out on the samples prepared at Max Dry Density of 1.551 g/cc and Optimum Moisture Content of 24.70%. Consolidometer method of testing is used. Samples are allowed to swell under a seating load of 5 KPa and then the swollen sample is subjected to consolidation under different pressures. Fig 5 & 6 depict the variation of Swell Pressure with the addition of increasing percent of chemicals and flyash to the expansive soil samples. It is observed that the swell pressure values are reduce by 44% and 52% with the treatment of 1% $MgCl_2$, and $AlCl_3$ respectively. Similarly these values reduced to 69% and 73% with addition of 1% chemical and 10% flyash for $MgCl_2$ and $AlCl_3$ respectively and are considered as the most approving combination.

IV. FIGURES AND TABLES

Table 1:Properties of Expansive Soil

Field Data	
Field Moisture Content (%)	46.40 %
Field Bulk Density (g/cc)	1.820 g/cc
Field Dry Density (g/cc)	1.243 g/cc
Specific Gravity	2.613
Differential Free Swell (%)	140 %
Sieve Analysis	
Fine Sand	2 %
Silt	28 %
Clay	70 %
Consistency Limits	
Liquid Limit (LL)	85.23%
Plastic Limit (PL)	33.10%
Plasticity Index (PI)	52.13%
Shrinkage Limit (SL)	12.00%
Compaction Properties	
Max Dry Density (γd)	1.551 g/cc
Optimum Moisture Content	24.70 %
Unconfined Compressive Strength	94 KPa
Cohesion (c)	0.32
Angle of Internal Friction (φ)	$3^0 40'$
CBR (soaked)	2.02
Swell Pressure	295 KPa
Soil Classification	CH

Table 2:Properties of Flyash

Specific Gravity	1.950
Liquid Limit (LL)	25%
Max Dry Density (γd)	1.35 g/cc
Optimum Moisture Content	24.20 %
CBR (soaked)	8
Sieve Analysis	
Fine Sand	25 %
Silt	70 %
Clay	5 %

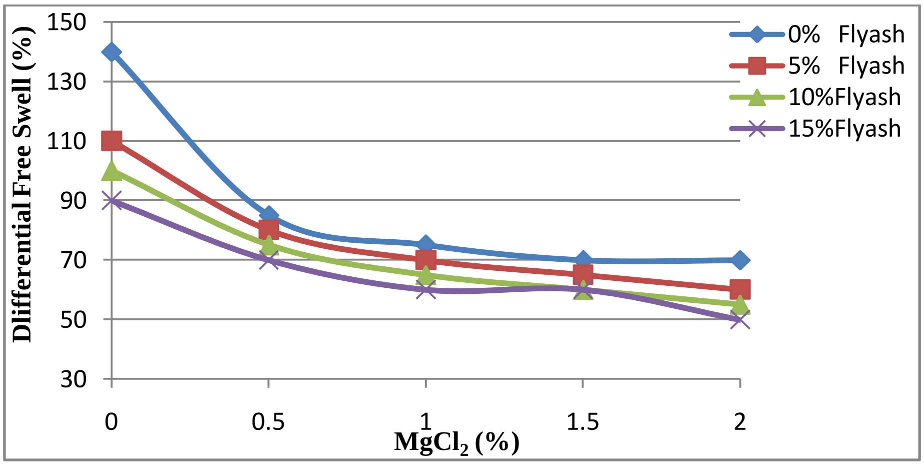

Fig.1 Variation of DFS for Soil+MgCl2+Flyash Mixes.

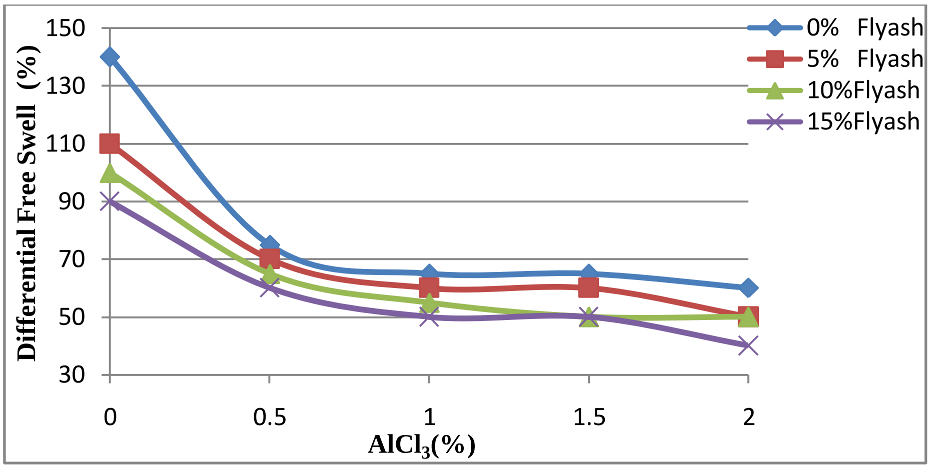

Fig.2 Variation of DFS for Soil+AlCl3+Flyash Mixes

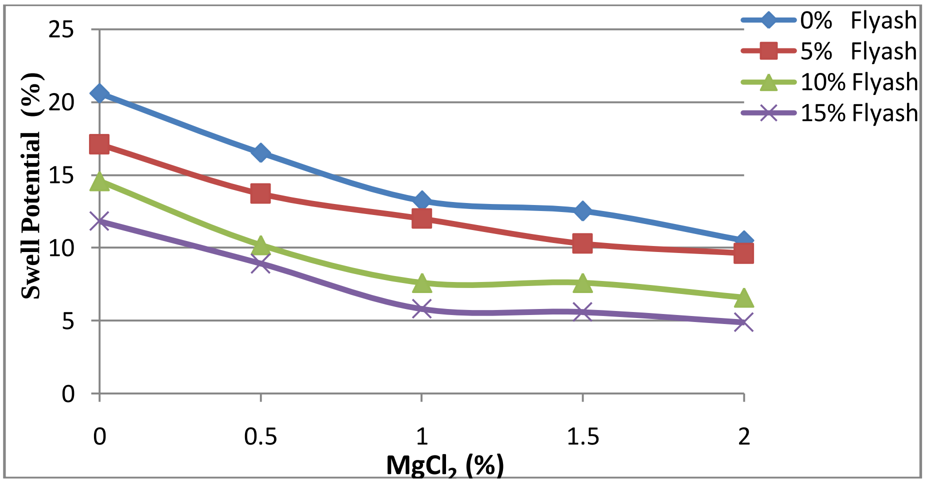

Fig.3 Variation of Swell Potential for Soil+$MgCl_2$+Flyash Mixes.

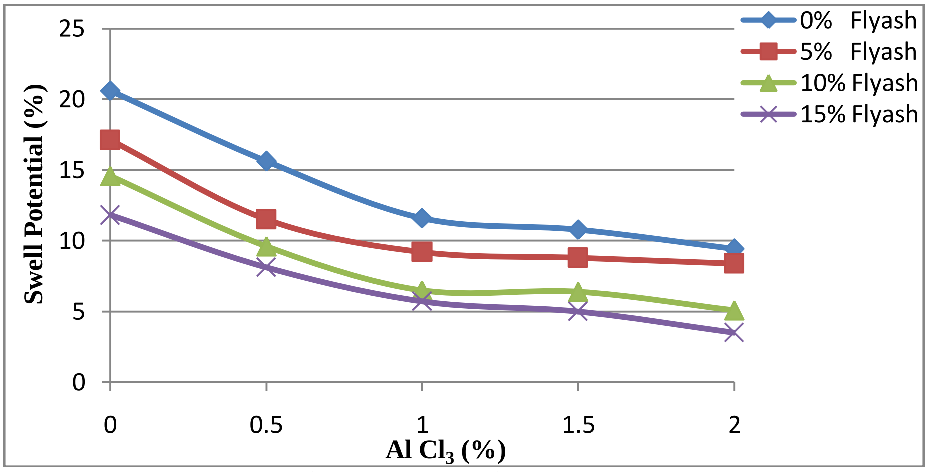

Fig.4 Variation of Swell Potential for Soil+$AlCl_3$+Flyash Mixes

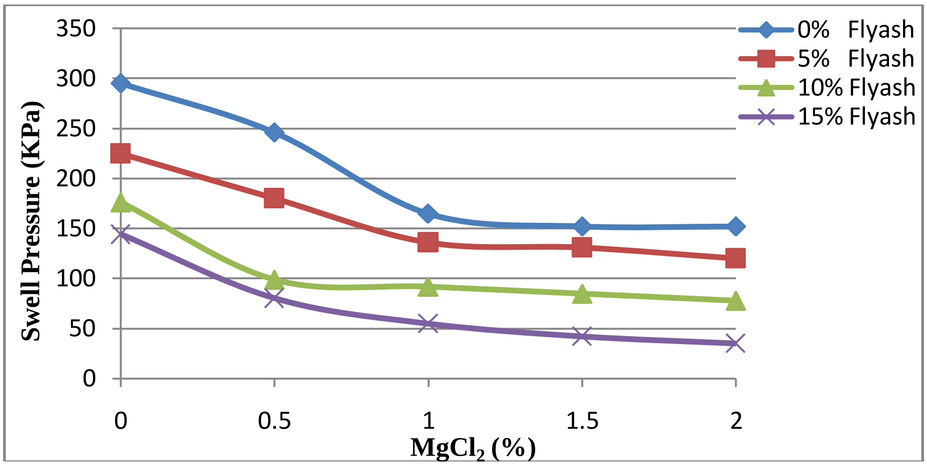

Fig.5 Variation of Swell Pressure for Soil+$MgCl_2$+Flyash Mixes.

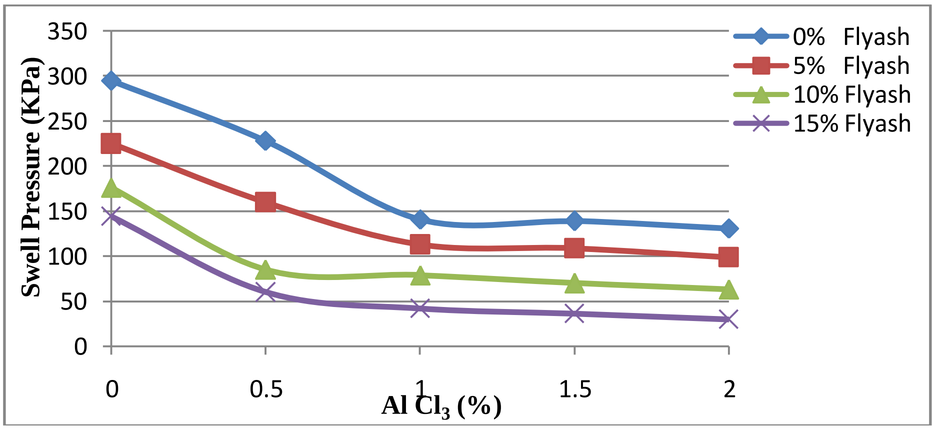

Fig.6 Variation of Swell Pressure for Soil+$AlCl_3$+Flyash Mixes

V. CONCLUSIONS

The following conclusions are drawn based on the present laboratory study. Engineering Properties of the collected expansive soil samples indicate that soil samples comes under CH group. The Differential Free Swell value of the soil is 140%, indicating that the soil is highly expansive. Consistency limits indicate that the soil is high plasticity. The Swelling Pressure value is very high of the order of 295 KPa. From the experimental study it is observed that the treatment of the expansive soil with Aluminum Chloride ($AlCl_3$) and flyash at 1% and 10% respectively is more effective than the other. There is a steep reduction in the DFS value of the expansive soil in the beginning, up to 1% addition of chemicals and is nominal afterwards. The percentage reduction in DFS value for the addition of 1% chemical and 10% flyash is 54% and 64% respectively for $MgCl_2$

and $AlCl_3$ chemicals. The reduction in swell potential and swell pressure is significant upto the addition of 1% chemical and 10% flyash. The percentage reduction in swell potential is 63%, 68% and swell pressure is 69%, 73% respectively for $MgCl_2$, $AlCl_3$ chemicals with flyash. Finally a conclusion can be made that the selected chemical and flyash combination is very effective in reducing the swell pressure, swell potential of the expansive soil considered.

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