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Effect of Polymeric Resins on Geotechnical Properties of Black Cotton Soil

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Abstract*: *Stabilization of black cotton soil is a challenging task for geotechnical engineers since such soil is highly vulnerable to expansive characteristics when the moisture content is increased. Due to its expansive nature, it is also called as swelling or expansive soils. Among the clay minerals, Montmorillonite is mainly responsible for such expansive characteristics. Bore log profile has a cluster of soil specimens including black cotton soil also which is unavoidable. Soil engineers have a serious concern about such expansive soil since it is treacherous for foundation of buildings. To overcome such deficiencies it becomes essential to stabilize the soil conditions. The commonly employed methods to decrease the expansive behaviour are: Chemical stabilization, Mechanical stabilization and installation of moisture barriers. In this paper, chemical stabilization method is adopted. Soil stabilizers, namely, sodium silicate, epoxy resin and polyvinyl alcohol are chosen and are mixed with black cotton soil in varying proportions of 5%, 10% and 15% to study the changes in geotechnical properties. From the results it is evident that polymer treated soils reduce plasticity characteristics and shows better results in geotechnical properties.

Index Terms*: *Black cotton soil, Soil stabilization technique, Soil stabilizers, Polymeric Resins, Geotechnical properties.

I. INTRODUCTION

Expansive soils are problematic soils since it has volume change behaviour (swelling & shrinkage) characteristics. Intensive research activities are carried out by many geotechnical investigators to decrease such plasticity nature of soil. The plasticity characteristics of clays are due to unusual molecular structure of water in soil deposits and adsorbed water. Such plasticity nature can be reduced effectively by polymers than traditional soil stabilizers such as cement and lime. Various literature reviews and previous studies reveal that promising results are achieved by adopting polymer impregnation of soils as soil stabilization technique.

Expansive soils cause significant damage to structures and roadways by cyclically shrinking and swelling within the active zone. Conventionally the volume change behaviour of soil is measured either by using shrinkage characteristics or swelling characteristics. [1]. Stabilization of highly expansive clay is, in particular an area of major interest to the construction community due to excess swelling and shrinkage experienced by this clay upon changes in moisture content [2].

Polymer based binders are attractive stabilization candidates when compared to traditionally used binder, namely, Portland cement. Polymer stabilized soil samples displayed a more ductile behaviour while undergoing deformation. This attribute is especially desirable in pavement design and construction. Increase of strength resulting from polymer stabilization, the increase in toughness indicates that the polymer stabilized soil will have higher resistance to crack propagation. Increase in total energy is an indication of flexibility and ductility that the polymer adds to the soil and thus makes it less susceptible to abrupt damage under repeated loads [3].

Compared to traditional cement, geo-polymer is an environmental-friendly cementitious material for self-solidification/ stabilization of heavy metal wastes [4]. Polymer addition to surface aggregate leads to stabilization of existing aggregates and improved bonding between adjacent aggregates mainly through their adsorption on the outer surface of soil particles. Use of synthetic organic polymer as soil conditioners started as early as 1950 [5]. Chemicals as a soil stabilizer has been used to improve the strength due to low cost and relatively wide applicability compared to standard stabilizers [6]. Stabilization of expansive soil by the addition of lime is an ancient art and age old practice [7]. Stabilization with lime was only marginally effective in improving its properties [8]. With lime treatment, plasticity index of expansive soil decreases from approximately 400 to just 50%. This substantial reduction in plasticity index suggests that the soil itself changed. Lime generally improves the engineering performance of soils. However in some cases lime has been reported to have an adverse effect. [9]. Cement stabilization is not effective in certain types of organic soils, soils rich with sulphates and chlorides [10].

These findings confirm that there is great potential for polymers in stabilization of black cotton soils than routine soil conditioners, namely, cement and lime. In this paper an attempt is made to assess the effect of Polymeric resins such as sodium silicate, epoxy resin and polyvinyl alcohol on geotechnical properties of black cotton soil.

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II. MATERIALS AND METHODS

In the present study, black cotton soil is chosen as the soil medium and polymeric resins have been used for the purpose of stabilization. Brief details of the materials are presented in the following.

A. Black Cotton Soil

Black cotton soil used in this study was collected from Sriperumbudur, near Chennai. The soil was black in colour and the basic properties are enlisted in Table 1.

Table.1 Basic properties of soil

S.No	Soil property	Values
1	Specific gravity	2.55
2	Liquid limit	56%
3	Plastic limit	31%
4	Plasticity Index	25%
5	Swelling potential	5.56
6	Differential free swell	70%
7	Grading: a) Silt b) Clay c) Total Fine Content	 25% 54% 79%
8	GBR (Unsoaked pit) a) 2.55mm b) 5 mm	 5.2% 4.89%

B. Polymeric Resins

The polymeric resins used in this study were Epoxy resin, Sodium silicate and Polyvinyl alcohol in varying proportions of 5%, 10% and 15%. Positive influence of polymeric resins chosen in this paper in terms of enhancements in both index and engineering properties of soil and better interactive mechanism with expansive soil made it as a professional alternative to traditional stabilizers.

Table.2 Basic properties of Polymeric resins

Properties	Sodium Silicate	Epoxy Resin	Polyvinyl alcohol
Molecular formula	$(Na_2Sio_2)_nO$	Combination of Epichlorohydrin and Bisphenol A.	[CH2CH(OH)]n
Colour	Colourless or White	Epichlorohydrin : Colourless	White
Odour	Odourless	Pungent, Garlic	Odourless
Solubility	Soluble in water in various amounts.	Moderately soluble in water.	Water soluble synthetic

III. PROCEDURE

Geotechnical properties of untreated and treated soils are determined by relevant current Indian Standards which is indicated below.

A. Specific Gravity

A greater attention must be given for a precise determination of the specific gravity of soil since it is an important factor in computing the soil properties.. Specific gravity values are determined as per IS 2720 Part II – 1980.

B. Atterberg Limits Test (Liquid limit & Plastic limit test)

Consistency limits namely liquid and plastic limit determines the plasticity characteristics of soil. Such limits are determined as per IS : 2720 (PART-5)- 1985.

Plasticity index values are obtained based on mathematical computation i.e, numerical difference between liquid and plastic limit.

C. Swelling Potential

Swelling potential is one of the important parameters of black cotton soil. Plasticity index is used to predict swell percent, SP = $(2.16 \times 10^{-3})\ (PI)^{2.44}$ [11].

D. California Bearing Ratio(CBR) Test

CBR test is conducted for a penetration of 2.5mm and 5mm in unsoaked condition as per IS 2720 (PART16)1987.

IV. RESULTS AND DISSCUSSIONS

The summary of results on the effect of polymeric resins on geotechnical properties of black cotton soil are shown in Table 3.

Table.3 Results on effects of polymeric resins on geotechnical properties of black cotton soil

Soil property	Sample 0% (Untreated)	Soil + Sodium silicate			Soil + Epoxy Resin			Soil + Polyvinyl alcohol		
		5%	10%	15%	5%	10%	15%	5%	10%	15%
Specific gravity	2.55	2.62	2.65	2.66	2.66	2.64	2.68	2.62	2.67	2.68
Liquid limit (%)	56	43	32	27	46	36	24	40	33	27
Plastic limit (%)	31	30	25	25	29	25	24	27	29	25
Plasticity Index (%)	25	13	7	2	17	11	0	13	4	2
Swelling potential (%)	5.56	1.13	0.25	0.01	2.17	0.75	0	1.13	0.06	0.01
CBR (Unsoaked)										
2.5 mm	5.2	7.56	6.03	6.0	7.33	8.04	7.6	5.67	5.8	5.9
5 mm	4.89	7.41	5.6	5.12	7.17	7.6	7.33	5.12	5.4	5.59

A. Effect of Polymeric Resins on Specific Gravity of Soil

Specific gravity of polymer treated specimen in varying proportions of 5% , 10%, 15% are determined in which test reveals that specific gravity values obtained for polymer binded soil is higher than untreated soil specimen. The variation of specific gravity (G) values of soil with various polymeric resins are represented graphically in fig (1). From the results (Table (3)) it is evident that , addition of polymeric resins to the soil yields higher values of specific gravity especially for sodium silicate and poly vinyl alcohol which shows better results at 10% and 15%.

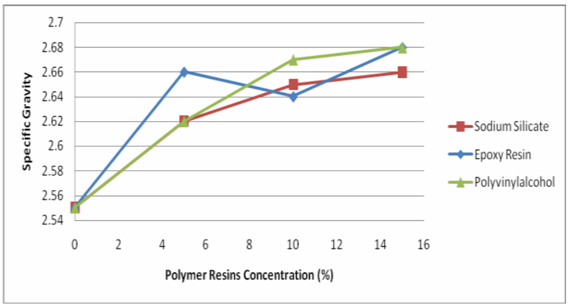

Fig.1 Variation of specific Gravity with Polymeric Resins

Increase in specific gravity values upon addition of polymeric resins namely sodium silicate and polyvinyl alcohol upto 15% is highly contributed to enhanced bonding/linkage between clay soil particles and polymeric resins. Also good binding between expansive soil and polymeric resins clearly illustrates that such stabilizers are appropriate candidates for stabilization mechanism. However, epoxy resin shows significant decrease at 10% which indicates the presence of repulsive nature of inter particle forces present in soil mass.

B. Effect of Polymeric resins on Atterberg limits of soil

Liquid limit values of polymeric resins treated soil specimen are represented graphically in fig (2) and results are tabulated in Table (3). Significant reduction occurred in liquid limit values upto 15% addition of polymeric resins. Reductions in liquid limit values of soil are mainly due to low shear strength, decrease in thickness of diffuse double layer and increase in electrolyte concentration of pore water.

The variation of plastic limit with the addition of polymeric resins are represented graphically in fig (3) and results are tabulated in Table (3). Plastic limit value decreases with increase in polymeric resins concentration. Among the three polymeric resins, epoxy resin exhibits lesser value of plasticity index results in reduction of plasticity characteristics. Significant reduction in plasticity index fig(4) implies that polymeric resins are effective in reduction of plasticity characteristics. Decrease in plastic limit and plasticity index upto 15% with the addition of polymeric resins relies on the concept that polymeric resins curtails the permeation of water into the soil effectively thereby reduces plastic limit and plasticity index value. But in plastic limit test, polyvinyl alcohol shows some increase at 10% and suddenly a fall occurs at 15% which may be due to dominance of cohesive nature of black cotton soil.

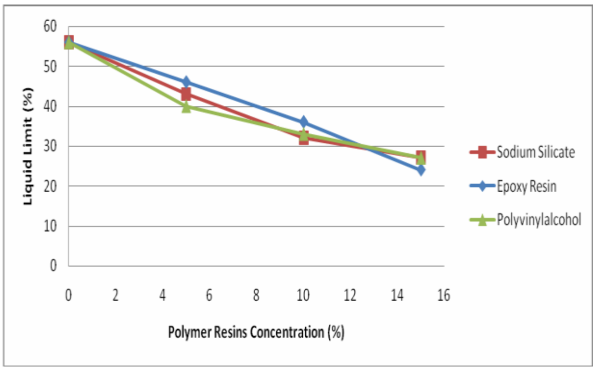

Fig.1 Variation of Liquid limit with Polymeric Resins

C. Effect of Polymeric resins on Swelling potential of soil

Swelling potential of untreated black cotton soil and sample treated with varying proportions of 5%, 10% and 15% are determined by empirical relation :

$SP = (2.16 \text{ X } 10^{-3}) (PI)^{2.44}$ [11]. The graphical results are represented in fig (5) and results are tabulated in Table 3. From the analytical calculations it is concluded that with addition of polymeric resins, swelling potential decreases and for epoxy resin the value of swelling potential at 15% is zero which implies that the soil stabilizer is highly effective for soil stabilization technique. The fall in swelling potential values is mainly due to reduction in water holding capacity of soil by the interaction of polymeric resins with black cotton soil.

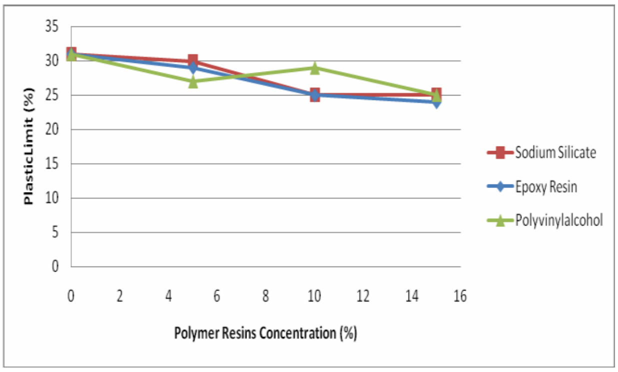

Fig.3 Variation of Plastic limit with Polymeric Resins

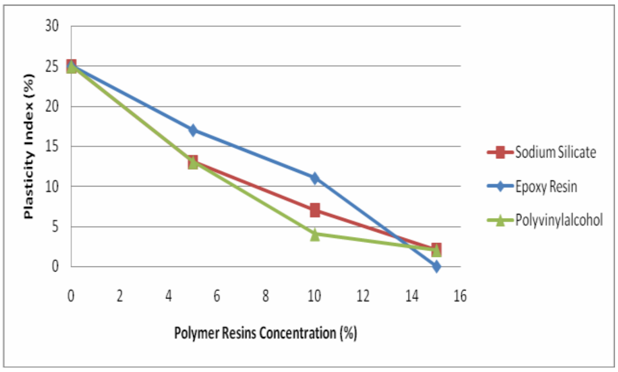

Fig.4 Variation of Plasticity Index with Polymeric Resins

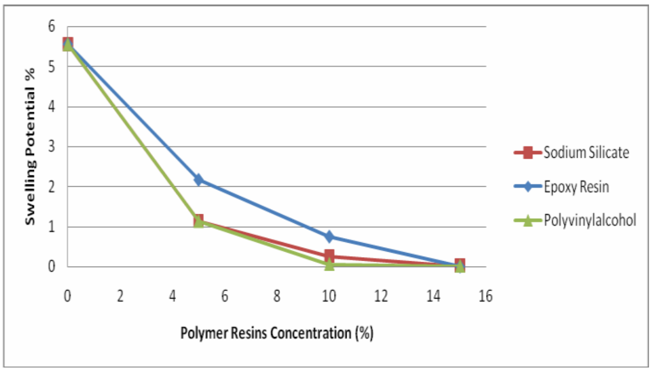

Fig.5 Variation of Swelling Potential with Polymeric Resins

D. Effect of Polymeric resins on swelling potential of soil

California Bearing Ratio value (CBR) test is conducted for soil sample and sample treated with polymeric resins in unsoaked condition.

Fig.6- shows the variation of CBR values in unsoaked condition for a penetration of 2.5mm.

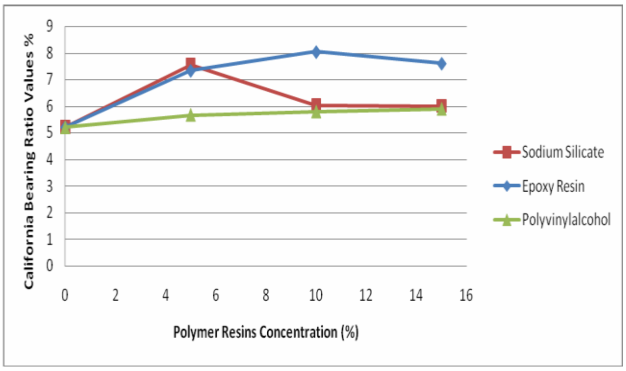

Fig.6 - Variation of CBR Values with Polymeric Resins

Fig.7- shows the variation of CBR values in unsoaked condition for a penetration of 5mm.

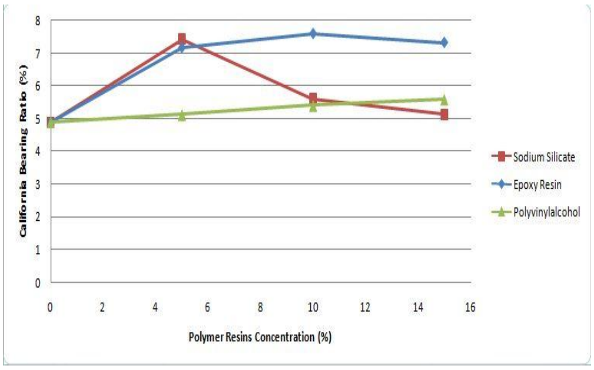

Fig.7 - Variation of CBR Values with Polymeric Resins

Cement kiln dust (CKD) addition to a Na- montmorillonite clay resulted in 150% increase in the 28 days compressive strength (unsoaked) [12]. Fig(6,7) gives the variation of CBR values and results are tabulated in Table(3). Test results shows that addition of polymeric resins results in reduction of CBR values upto 15% for Sodium silicate. CBR value of black cotton soil increases as the polymeric concentration increases especially for polyvinyl alcohol. Black cotton soil and polymeric resin matrix is more rigid by the interlocking of soil grains, which yields resistance to friction, ultimately results in increase in CBR value.

CBR value decreases with addition of sodium silicate upto 15% for penetration of both 2.5mm and 5mm under unsoaked condition due to surface forces present in clay soil particles which exhibits high surface area per unit volume of soil particles. Simultaneously epoxy resin shows considerable decrease at 10%. The reason pertaining to this reduction may be due to random distributive nature of clay soil particles.

V.CONCLUSION

A.Figures and Tables

In this paper, details of an experimental study carried out on the effects of polymeric resins on the geotechnical properties of black cotton soil are presented. Important conclusions drawn from the test results are given below.

1.Addition of polymeric resins to the soil causes increase in specific gravity values. Among the three polymeric resins, epoxy resin and poly vinyl alcohol yields higher value of specific gravity at 15%.

2. Reduction in liquid limit values and plasticity index occurs up to addition of 15% of polymeric resins to the soil hence plasticity characteristics are also reduced and epoxy resin exhibits lesser value of plasticity index than other polymers. So, decrease in plasticity index upon the addition of polymeric resin is a positive approach and attractive phenomenon.

3.Swelling potential is highly reduced with the addition of polymeric resins and specifically Epoxy resin shows nil value i.e, zero at 15%.

4.Polyvinyl alcohol yields higher value of CBR up to addition of 15% to soil.

5.From the test results it is evident that polymeric resins enhances the geotechnical properties of black cotton soil, in such a way that plasticity index and swelling potential are decreased and higher value is recorded by polymeric resins in terms of specific gravity and CBR.

6.Among the three polymeric resins, Epoxy resin found to be effective since it reduces plasticity index and swelling potential to zero at 15% which ultimately leads to reduction of plasticity characteristics of soil.

ABBREVIATIONS	
PI	Plasticity Index
SP	Swelling potential
IS	Indian Standards
CBR	California Bearing Ratio
ECH	Epichlorohydrin

REFERENCES

1. P.K.Jayasree, K. Balan, Leema Peter and K.K. Nisha, "Shrinkage characteristics of expansive soil treated with coir waste," Indian Geotech J, Vol.45, No.3, (2015), pp.360-367.
2. SulaphaPeethamparam, Jan olek, and Jannet Lovell,. "Influence of chemical and physical characteristics of cement kiln dusts (CKDs) on their hydration behaviour and potential suitability for soil stabilization," Cement and concrete research, Vol.38, No.6, (2008), pp 803-815.
3. R.Srinath Iyengar, Eyad Masad, K. Ana Rodriguez, Hassan S. Bazz, Dallas Little, and M. Hanley, "Pavement subgrade stabilization using polymer characterization and performance," Journal of Materials in Civil Engineering, Vol. 25, No.4, (2013), pp 472-483.
4. Xiaolu Guo and Huisheng shi, "Self– solidification/ Stabilization of Heavy metal wastes of class C Fly ash based Geopolymers," Journal of Materials in Civil.Engineering, Vol .25, No.4, (2013), pp 491-496.
5. R.Ellen Graber, Pinchas Fine, J. Guy Levy, "Soil stabilization in semiarid and Arid Land Agriculture," Journal of .Materials in Civil.Engineering, Vol. 18 , No.2, (2006), pp 190-205.
6. B.M. Lekha, A.U.Ravishankar and Gautham sarang., "Fatigue and Engineering properties of chemically stabilized soil for pavements," Indian Geotech J , Vol. 43, No.1, (2013), pp 96-104.
7. S.Bhuvaneshwari , R.G.Robinson and Gandhi S.R. , "Behaviour of lime treated cured expansive soil composites," Indian Geotech J, Vol. 44, No.3, (2014), pp 278 -293.
8. Omar saeed Baghabra, Khaqan khan, and Nasser saban Al kahtani, "Stabilization of a Saudi Calcareous Marl Soil," Construction and Building materials, Vol .24, No.10, (2010), pp 1848 – 1854.
9. Sujit kumar Dash, and Monowar Hussain, " Lime stabilization of soils : Reappraisal," Journal of .Materials in.Civil.Engineering, Vol. 24, No.6, (2012), pp 707- 714.
10. C.N.V. Satyanarayana Reddy and A.C.S.V. Prasad, "Performance studies on cement stabilized gravelly soil exposed to sulfate environment," Indian Geotech J, Vol. 45 , No.2, (2015), pp 217 -224.
11. H.B.Seed, R.J.Woodward and R.Lundgreen, "Prediction of swelling potential for compacted clays," Journal of the Soil mechanics and Foundation Division , Vol. 88, No.3, (1962), pp 53-88.

12. G.A. Miller and S. Azad, "Influence of soil type on stabilization with cement kiln dust," Construction and Building materials, Vol. 14, No.2, (2000), pp 89-97.
13. IS: 1498: 1970. Indian standard Classification and identification of soil for general engineering purposes. Bureau of Indian Standards, NewDelhi.
14. IS: 2720 : 1980. Methods of tests for soils (Part 3). Indian standard specifications for determination of specific gravity of soil, Bureau of Indian Standards, NewDelhi.
15. IS: 2720 : 1985. Methods of tests for soils (Part 4). Indian standard specifications for grain size analysis. Bureau of Indian Standards, NewDelhi.
16. IS: 2720 : 1985. Methods of tests for soils (Part 7). Indian standard specifications for determination of liquid limit and plastic limit of soil. Bureau of Indian Standards, NewDelhi.
17. IS: 2720 : 1980. Methods of tests for soils (Part 3). Indian standard specifications for determination of specific gravity of soil. Bureau of Indian Standards, NewDelhi.
18. IS: 2720 : 1987. Methods of tests for soils (Part 16). Indian standard specifications for laboratory determination of CBR of soil (second revision). Bureau of Indian Standards, NewDelhi.

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Jayaganesh Kuppusamy , currently working as a Assistant Professor of Civil Engineering Department in Aalim Muhammed Salegh College of Engineering, affiliated to Anna University, Chennai. He has done his B.E. from Madras University and M.E. from Anna University in Civil Engineering discipline and currently pursuing his PhD in Civil Engineering at VIT, chennai. In teaching sector as a faculty he has 14.5 years experience. He has teaching experience of 13 years in engineering institutions and 1.5 years in polytechnic institution in Civil Engineering Department. During teaching profession, awarded best teacher for good results produced in Engineering subjects handled for B.E. students. He has published question bank for Civil Engineering Discipline.

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