An Experimental Study on Stabilisation of Expansive Soil Using Polyethylene Waste And Ferric Chloride

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Abstract- *Black Cotton soils are also known as expansive soils with high potential for swelling and shrinking as a result of water content changes. These expansive soils are distributed in India all most all in all states. The latest trends of soil stabilization can be effectively used to contact the challenges of society, to minimize the amount of waste, producing useful material from non-useful waste materials. Since the use of plastic in diversified forms such as chairs, bottles, polythene bags, etc., has been advancing speedily and its disposal has been a problem all the time regarding the environmental concern. The utilization of chemical are also now a days a new techniques for strengthening the expansive soils. Thus, the present investigation aims to explore the performance of different percentages polyethylene (0.2%, 0.4%, 0.6% & 0.8%) material reinforced with expansive soil and ferric chloride (0.2%, 0.6%, 1.0% and 1.4%) also a binding material and compared with unreinforced soil and conducting different laboratory experiments. It was observed that the optimum value of polyethylene and ferric chloride at 0.6% and 1.0% and tested the modal foundation beds by plate load test using different composition.*

Keywords- Expansive soil, chemical, polyethylene, Shear Strength parameters, CBR and Plate Load test

I. EXPANSIVE SOILS

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 200,000 square miles and thus form about 20% of the total area of India. The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them.

Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are identified in a project. 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, calcium chloride, rice husk, fly ash 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. The effect of the additives and the optimum amount of additives to be used are dependent mainly on the mineralogical composition of the soils. The paper focuses about the various stabilization techniques that are in practice for improving the expansive soil for reducing its swelling potential and the limitations of the method of stabilization there on.

In India, the area covered by expansive soil is nearly 20% of the total area. The expansive soils normally spread over a depth of 2 to 20m. In rainy season, they undergo heave and lose weight. In summer, they shrink and gain density and become hard. This alternate swelling and shrinkage damage the structures severely. This is more severe for the light structures.

II. REVIEW LITERATURE

Chebet (2014) et al, did laboratory investigations to determine the increase in shear strength and bearing capacity of locally available sand due to random mixing of strips of HDPE (high density polyethylene) material from plastic shopping bags. A visual inspection of the plastic material after tests and analysis indicates that the increased strength for the reinforced soil is due to tensile stresses mobilised in the reinforcements. The factors identified to have an influence on the efficiency of reinforcement material were the plastic properties (concentration, length, width of the strips) and the soil properties (gradation, particle size, shape).

Dhatrak (2015) et al, after reviewing performance of plastic waste mixed soil as a geotechnical material, it was observed that for construction of flexible pavement to improve the sub grade soil of pavement using waste plastic bottles chips is an alternative method. In his paper a series of experiments are done on soil mixed with different percentages of plastic (0.5%, 1%, 1.5%, 2%, 2.5%) to calculate CBR. On the basis of experiment that he conducted using plastic waste strips will improve the soil strength and can be used as sub grade. It is economical and eco-friendly method to dispose waste plastic because there is scarcity of good quality soil for embankments and fills.

Achmad Fauzi (2016) et al, calculated the engineering properties by mixing waste plastic High Density Polyethylene (HDPE) and waste crushed glass as reinforcement for sub grade improvement. The chemical element was investigated by Integrated Electron Microscope and Energy-Dispersive X-Ray Spectroscopy (SEM-EDS). The engineering properties PI, C, OMC values were decreased and ϕ, MDD, CBR values were increased when content of waste HDPE and Glass were increased.

Chemical (Ferric Chloride):

Rao and SubbaRao (1994) recommended 5% $FeCl_3$ solution to treat the caustic soda contaminated ground of an industrial building in Bangalore.

A group of researchers (Chen, 1988; Chu and Mou, 1973; Chen and Ma, 1987; SubbaRao and Satya Das, 1987; Subbarao, 1999) have subjected remoulded clay specimens to full swelling and then to desiccate them to their initial water content. They reported that the soil shows the sign of fatigue after each cycle of wetting and drying up to few cycles.

Nordquist and Bauman (1967), Obermier (1973) and Popescu (1980) have established that swelling ability increases with number of drying and wetting cycles.

Tutumluer and Barksdalt (1995) revealed that cement stabilized subbase is effective in bridging over a weak subgrade and the cement treated section has lower vertical stress on the subgrade than the other sections of the test track.

Polyethylene waste:

Binici (2014) et al, Recently, plastic waste is one component of municipal solid waste which is becoming a major research issue to study the possibility of disposal the waste in mass concrete especially in self-compacting concrete, light weight concrete, and in pavements. It can be used as a component of a composite construction material, as an inorganic filling material, and aggregate of concrete.

Kumavat (2014) et al, Recycling of plastic waste in concrete has advantages since it is widely used and has a long service life, which means that the waste is being removed from the waste stream for a long period. Moreover, using of post-consumer plastic waste in concrete will not only be its safe disposal method but may improve the concrete properties like tensile strength, chemical resistance, drying shrinkage and creep on short and long term basis

Patil (2015) et al, One of the environmental issues in the most region of Iraq is the large number of package made from polyethylene materials such as shampoo sachets, carry–bags, nitro packs, milk and water pouches, and vegetable packages etc., which are deposited in domestic waste and landfills.

III. MATERIALS & METHODOLOGY

Materials

Soil

The black cotton soil collected from '**Mummidivaram**' village near Amalapuram, East Godavari District in India. The properties of the soil are given in Table 4.1

Plate 4.1 Black Cotton Soil

Table4.1. Properties of Expansive Soil

S.No	Property	Value
1	**Grain size distribution** Sand (%) Silt (%) Clay (%)	 3 18 79
2	**Atterberg'S limits** Liquid limit (%) Plastic limit (%) Plasticity index (%) Shrinkage limit (%)	 79 38 41 12
3	**Compaction properties** Optimum Moisture Content, O.M.C. (%) Maximum Dry Density, M.D.D (g/cc)	 23.20 1.40
4	Specific Gravity (G)	2.71
5	IS Classification	CH
6	Soaked C.B.R (%)	2.1
7	Differential free swell (%)	134
8	Permeability (cm/sec)	1.829×10^{-7}
9	**Shear Strength Parameters** Cohesion (C) (Kg/cm²) Angle of internal friction (ø)	 0.46 2°

4.1.3 Polyethylene waste:

Plastic fibres were obtained from waste plastic cover (milk and curd packets). After proper cleaning and air drying, the plastic covers were shred into fibers each of average thickness of 2mm. These plastic covers are usually considered to be waste materials.

Plate 4.2Polyethylene waste

4.2. Laboratory Experimentation

4.2.1 Atterberg Limits

- **4.2.1.1 Liquid Limit**

Different percentages of chemical ranging from 0-1.5% by dry weight are mixed with the soil and the liquid limit were determined as per IS: 2720 (part-5)-1985.

Plate 4.3 Author Conducting Liquid Limit Test

Plastic Limit

Different percentages of chemical ranging from 0-1.5% by dry weight are mixed with the soil and the plastic limit were determined as per IS: 2720.

Plate 4.4 Author Conducting Plastic Limit Test

Shrinkage limit

Different percentages of chemical ranging from 0-1.5% by dry weight are mixed with the soil and the shrinkage limit were determined as per IS: 2720 (part-6)-1972.

Compaction test

Optimum moisture content and maximum dry density of the Expansive soil were evaluated as per IS Heavy weight compaction test (IS: 2720 part-8, 1983).

- **4.2.1.5. Differential Free Swell (DFS)**

The DFS test for all the combinations has been conducted as per IS code of practice (IS: 2720-part XL-1977

Plate 4.6 Author Conducting Differential Free Swell Test

4.3. Strength Tests

Tri-axial test, California bearing ratio & Unconfined Compressive Strength values were found for all the soil combinations, as presented below.

California Bearing Ratio Test

The California bearing ratio tests (as per IS: 2720 (part-16)-1979) were conducted on all the combinations listed in table. . At the end of the curing period (all the samples were cured for 3 days and later soaked for 4 days).

Plate 4.7 Author Conducting Modified Proctor Compaction Test

Sample Preparation

Both treated and untreated samples were prepared by compacting different mixes to the maximum dry density of the soil. The initial moisture content for these samples was maintained at optimum moisture content of the untreated soil. The amount of chemical to be added to the amount of water was arrived at based on the optimum moisture content of the natural soil and the chemical solution was prepared. This solution was added to the dry soil and the mixture was thoroughly mixed.

Plate 4.8 Test Setup for CBR
Plate 4.9 Sample after Test

- **4.3.2. Tri-Axial test**

The tri-axial tests (as per) were conducted on all the combinations listed in table. At the end of the respective curing period (the samples were cured for 1 day, 7 days, and 14 days after preparation).

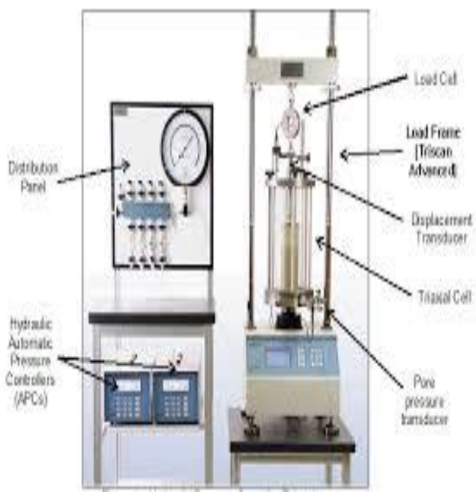


Plate 4.10 Tri axial Test Set

- **4.3.3 Static Plate Load Test**

These tests were conducted on soil foundation systems in a circular steel tank of diameter 60cm. the loading was done through a circular metal plate of diameter laid on the model foundation bed system. The steel tank was placed on the pedestal of the compression testing machine. Two dial gauges of least count 0.01mm were arranged for obtaining deformations. A 5ton capacity hydraulic jack was placed on the loading.

Plate load test is a field test, which is performed to determine the ultimate bearing capacity of soil and the probable settlement under a given load. This test is very popular for selection and design of shallow foundation.

For performing this test, the plate is placed at the desired depth, then the load is applied gradually and the settlement for each increment of load is recorded. At one point a settlement occurs at a rapid rate, the total load up to that point is calculated and divided by the area of the plate to determine the ultimate bearing capacity of soil at that depth.

Plate 4.11 Test Setup for plate load test

IV. TESTS ON FOUNDATION BEDS

Construction Procedure

The steel tank was placed at the centre of the loading frame. Expansive soil which used as a sub grade is pulverized and the material passing through 4.75mm is used in this study. The expansive soil is to be compacted in 2cm thickness, at its OMC and MDD, to a total compacted thickness of 20cm.

For untreated expansive Clay, water was mixed directly with the soil corresponding to the optimum moisture content of the natural expansive Clay.

For the "expansive Clay + polyethylene" mix, the water content corresponding to OMC of same mix was taken and the required quantity of ferric chloride mixed with it.

For the "expansive Clay+ polyethylene + ferric chloride" mix, the water content corresponding to the OMC of the same mix was taken. For the "expansive Clay+ polyethylene + ferric chloride'' mixes, the weights of the dry mixes corresponding to the MDD of the same mix were taken and compacted at OMC of the same mix. Provide the thickness of the treated expansive clay of 20cm. provide a gravel cushion of 10cm. For the tests conducted on the saturated condition, to absorb the water providing 10cm thin sand layer at the bottom and also through vertical sand drains. Static load tests were carried out in saturated state in the same manner of OMC.

Table 4.3 Construction Details of Untreated and Treated Expansive Clay Sub Grade Model Foundation Beds

S.no	Foundation Soil Bed	Cushion
1	Untreated expansive Clay	----
2	Untreated expansive Clay	Gravel
3	Optimum polyethylene waste treated expansive Clay with ferric chloride	Gravel
4	Optimum polyethylene waste treated expansive Clay with ferric chloride using Geo textile as separator & reinforcement	Gravel

V. DISCUSSIONS ON TEST RESULT

5.2.1 General

In the laboratory, index tests, swell tests, strength tests were conducted by using different percentages of polyethylene waste and ferric chloride with a view to determine the optimum percentages of polyethylene waste and ferric chloride and strength Properties are discussed in the following sections.

Additives	Percentage
Polyethylene waste	0.2%, 0.4%, 0.6% & 0.8%
Ferric chloride	0.2%, 0.6%, 1.0% and 1.4%

5.1 Effect of polyethylene waste and ferric chloride on Atterberg's limits

	Expansive Soil	Expansive Soil + 0.2% polyethylene waste + 0.2% $FeCl_3$	Expansive Soil + 0.4% polyethylene waste + 0.6% $FeCl_3$	Expansive Soil + 0.6% polyethylene waste + 1.0% $FeCl_3$	Expansive Soil + 0.8% polyethylene waste + 1.2% $FeCl_3$
Liquid Limit	79	65	57	52	47
Plastic Limit	34	35	38	41	40
Plasticity Index	45	30	19	11	9
Shrinkage Limit	12	15	17	18	18

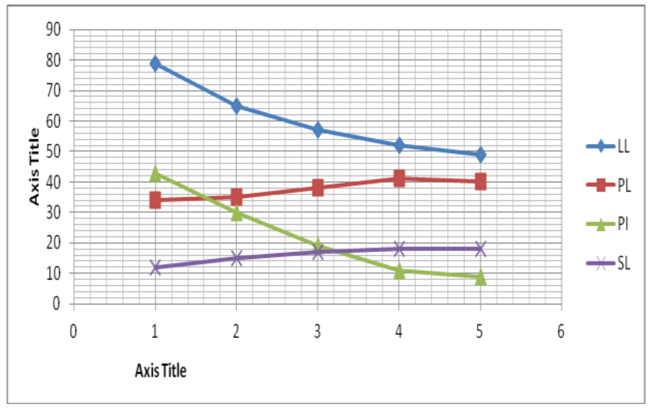
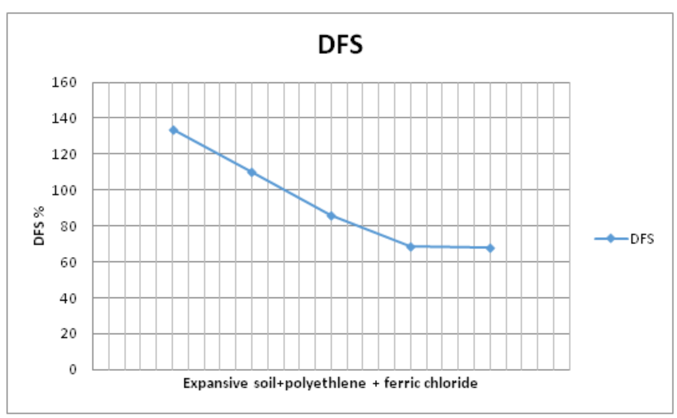


Figure 5.1 Variation On Atterberg's Limits

table 5.2: Effect of polyethylene and ferric chloride on DFS of Expansive Soil

	Expansive Soil	Expansive Soil + 0.2% polyethylene waste + 0.2% $FeCl_3$	Expansive Soil + 0.4% polyethylene waste + 0.6% $FeCl_3$	Expansive Soil + 0.6% polyethylene waste + 1.0% $FeCl_3$	Expansive Soil + 0.8% polyethylene waste + 1.2% $FeCl_3$
DFS	134	110	86	69	68



Graph:3 Shows the variation of DFS with the expansive soil

The static plate load tests were conducted on untreated and treated expansive soil sub grade foundation beds.

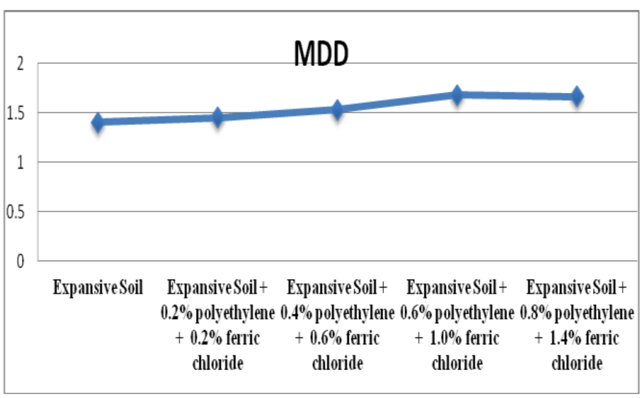
The effect of addition of polyethylene waste and ferric chloride to the expansive soil, on compaction, CBR properties, Atterberg's limits, swell properties, and strength properties, were discussed in detail in the following sections. The optimum percentages of different individual additives observed during the laboratory experimentation were summarized and presented in the following table.

The Optimum Percentages of are Presented in the Following

Additives	Optimum Percentage
Polyethylene waste Ferric chloride	0.6% 1.0%

Table 5.3: Effect of polyethylene and ferric chloride on MDD&OMC of expansive soil

Particular	MDD(g/cc)	OMC (%)
Expansive Soil	1.40	23.20
Expansive Soil + 0.2% polyethylene + 0.2% ferric chloride	1.45	20.30
Expansive Soil + 0.4% polyethylene + 0.6% ferric chloride	1.53	17.22
Expansive Soil + 0.6% polyethylene + 1.0% ferric chloride	1.68	14.23
Expansive Soil + 0.8% polyethylene + 1.4% ferric chloride	1.66	15.20



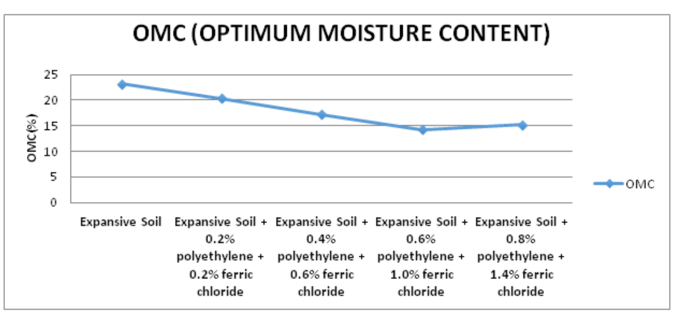
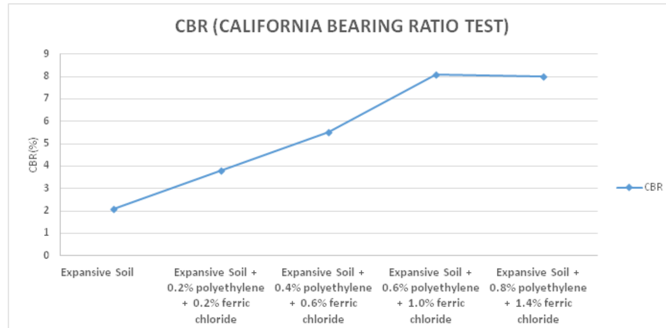


Table 5.4: Effect of polyethylene and ferric chloride on CBR of expansive soil

Particular	CBR (%) (soaked)
Expansive Soil	2.1
Expansive Soil + 0.2% polyethylene + 0.2% ferric chloride	3.8
Expansive Soil + 0.4% polyethylene + 0.6% ferric chloride	5.5
Expansive Soil + 0.6% polyethylene + 1.0% ferric chloride	8.1
Expansive Soil + 0.8% polyethylene + 1.4% ferric chloride	8.0



Graph 6. Effect of polyethylene and ferric chloride on CBR of expansive soil

Table 5.5: Variation of Shear strength parameters with the addition of polyethylene and ferric chloride to the expansive soil

Particular	Shear Strength Parameters (KPa)					
	1 day		7 days		14days	
	Cohesion, C_u (kg/cm²)	Angle of internal friction, ϕ, (Deg.)	Cohesion, C_u (kg/cm²)	Angle of internal friction, ϕ, (Deg.)	Cohesion, C_u (kg/cm²)	Angle of internal friction, ϕ, (Deg.)
Expansive Soil	0.56	2^0	--	--	--	--
Expansive Soil + 0.2% polyethylene + 0.2% ferric chloride	0.98	6^0	1.46	3^0	1.53	2^0
Expansive Soil + 0.4% polyethylene + 0.6% ferric chloride	1.28	4^0	1.75	2^0	1.85	2^0
Expansive Soil + 0.6% polyethylene + 1.0% ferric chloride	1.48	3^0	1.98	2^0	2.2	1^0
Expansive Soil + 0.8% polyethylene + 1.4% ferric chloride	1.47	3^0	1.98	2^0	2.1	1^0

5.3 Laboratory Static Plate Load Tests on Untreated and Treated Expansive soil soil Foundation Beds Using Model Tanks

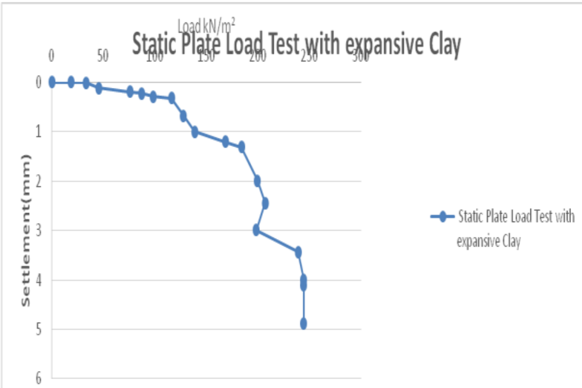
5.3.1 General

Static plate load tests were carried out on untreated and treated expansive soil foundation bed in separate model tanks and woven Geotextile was used as reinforcement & separator between the treated and gravel of model Foundation under pressures. Tests were conducted until the expansive soil model foundation beds fails at OMC conditions.

5.3.2 Laboratory Static Plate Load Test Results

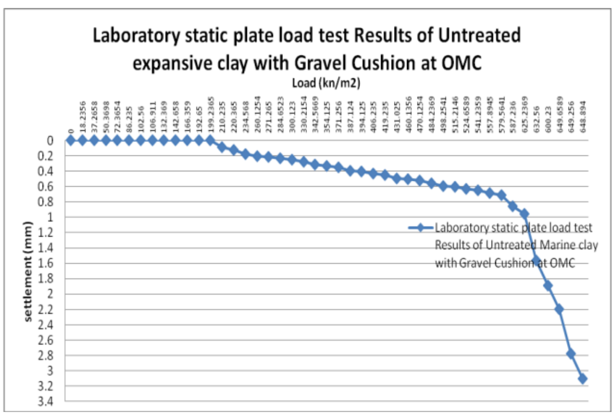
The static plate load tests were conducted on untreated and treated expansive soilclay sub grade foundation beds.

The table 5.6 and the Fig 4.1 show the laboratory static plate load test results of Expansive Clay. The expansive soilclay alone has exhibited the ultimate static load of **206.9856 KN/m²** with the deformation of **2.45mm** at OMC



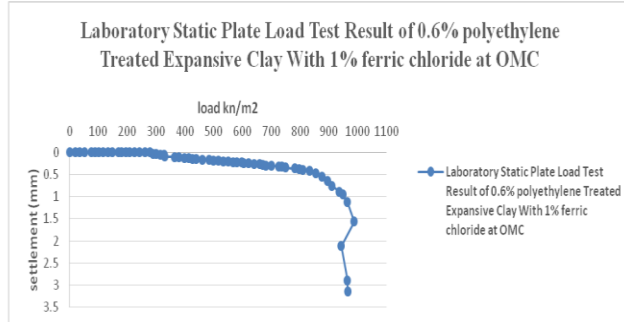
Graph 7: Static Plate Load Test With Expansive soil

4.5 and the Fig 4.2 show the laboratory static plate load test results of Expansive soil. The Expansive soil with gravel cushion has exhibited the ultimate static load of **632.56kN/m²** with the deformation of **1.56 mm** at OMC



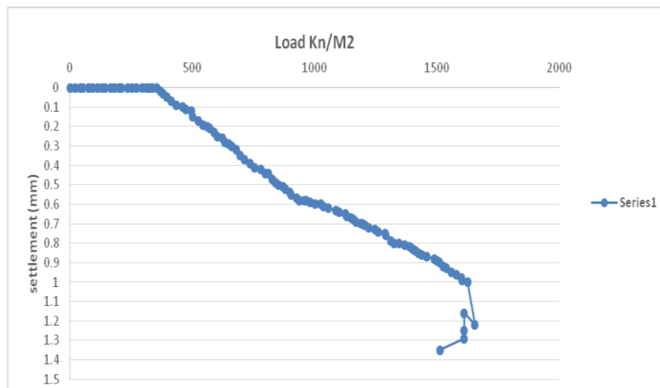
Graph 8 Laboratory static plate load test Results of Untreated expansive soil with Gravel Cushion at OMC

The table 5.6 and the Fig 4.3 show the laboratory static plate load test results of Expansive soil. The polyethylene treated expansive soil with 1% ferric chloride with gravel cushion has exhibited the ultimate static load of **987.235 kN/m²** with the deformation of **1.26mm** at OMC



Graph 9. Laboratory Static Plate Load Test Result of 0.6% polyethylene Treated Expansive soil With 1% ferric chloride at OMC

The table 4.7 and the Fig 4.4 show the laboratory static plate load test results of Expansive Clay. The polyethylene treated expansive soil with 1.0% ferric chloride with gravel cushion with geo textile as separator and reinforcement has exhibited the ultimate static load of **1610.22kN/m²** with the deformation of **1.16mm** at OMC



Graph 10s.

Table 5.9 Laboratory Static Plate Load Test Results of Untreated and Treated expansive soil Model Foundation Bed at OMC.

S. No	Foundation Bed	Cushion	Load Bearing Capacity(kN/m²)	Settlement (mm)
			OMC	OMC
1	Expansive soil	----	206.9856	2.45
2	Untreated Expansive soil	Gravel	632.56	1.56
3	Treated Expansive soil (0.6% Polyethylene +1% ferric chloride)	Gravel	987.235	1.26
4	Treated expansive soil (0.6% polyethylene +1% ferric chloride) and Geotextile provided as reinforcement & separator between Foundation Bed and Gravel Cushion.	Gravel	1610.22	1.16

VI. CONCLUSIONS

1. The Significant change in un-drained cohesion and marginal change in angle of internal friction is observed with addition of polyethylene and ferric chloride to the expansive soil.
2. It was noticed that when the expansive Clay was treated with 0.6% polyethylene +1% ferric chloride the CBR values are increased by 175.71% respectively when compared with untreated expansive soil.
3. It was noticed that when the expansive Clay was treated with 0.6% polyethylene +1% ferric chloride the MDD values are increased by 20% respectively when compared with untreated Expansive soil
4. It was noticed from laboratory plate load test that the total deformations at ultimate load carrying capacity of treated model foundation bed has decreased by 52.65% at OMC when compared to the untreated expansive soil.
5. It was noticed from laboratory plate load test that ultimate load bearing capacity of the treated expansive soil has increased by 681.55% when compared to the un treated expansive soil soil at OMC when compared to the untreated expansive soil.

VII. FURTHER SCOPE OF WORK

The following areas are identified as the scope of further work in this direction, based on the experience of present work.

1. Similar work can be done using other additives and also admixtures to arrive the optimum combination used in construction of foundation beds on expansive soil.
2. The reinforcement Technique can be adopted for higher load bearing capacity of the foundation beds.
3. The technique can also be done with a combination of chemicals like potassium chloride, ferric chloride, calcium chloride and some other fibres etc.
4. Advanced cyclic Tri axial tests may be conducted for further confirmation of test results.

REFERENCES

[1] Anandakrishnan, M.and Dhaliwal, S.S. (1966): "Effect of Various constructions of sodium chloride and Calcium Chloride on the pore pressure parameters and on strength parameters of Black Cotton Soil", Research Report, Dept. of Civil Eng., IIT, Kanpur, India.

[2] Bansal, R.K., Pandey, P.K. and Singh, S.K (1996): "Improvement of a Typical Clay for Road Subgrades with Hydrated Lime", Proc. of National Conf. on Problematic Subsoil Conditions, Terzaghi-96, Kakinada, India, pp193-197.

[3] Bell, F.G. (1993): "Eng. Treatment of Soils", E&FN Spon Pub. Co.

[4] Bhattacharya, P. and Bhattacharya, A. (1989): "Stabilization of Bed banks of Railway Track by Lime Slurry Pressure Injection Technique", Proc. of IGC-89, Visakhapatnam, Vol. 1, pp. 315-319.

[5] CBRI. (1978): "Handbook on Under-reamed and Bored Compaction Pile Foundation", Jain Printing Press, Roorkee, India.

[6] Chandrasekhar, B.P., Prasada Raju, G.V.R., Ramana Murthy, V. and Hari krishna, P. (1999): "Relative Performance of Lime and Calcium Chloride on properties of Expansive soil for pavement subgrades", Proc. of IGC-99, Calcutta, pp 279-282.

[7] Chen, F.H. (1988): "Foundations on Expansive Soils", Elsevier publications Co., Amsterdam.

[8] Chen, F.H and Ma, G.S. (1987): "Swelling and Shrinkage Behavior of expansive clays", Proc. of 6th Int. Conf. on expansive soils, Vol1, New Delhi, pp. 127-129.

[9] Chu. T.Y. AND Mou, C.H. (1973): "Volume Change Characteristics of expansive soils determined by controlled suction tests", Proc. of 3rd Int. Conf on expansive soils, Haifa, Israel, Vol 1, pp 177-185.

[10] Chummar, A.V. (1987): "Treatment of Expansive Soil below Existing Structures with Sand – Lime Piles", Proc. of sixth Int. Conf. on expansive soils, New Delhi, pp. 451-452.

[11] CRRI. (1991): "Report on Base Paper on Test Track Research", CRRI, New Delhi.

[12] Davidson, L.K., Demirel, T. and Handy, R.L (1965): "Soil Pulverization and Lime Migration in Soil-Lime stabilization", Highway Research Record-92, pp 103-126.