

A LABORATORY STUDY ON THE EFFICIENCY OF COPPER SLAG AND LIME ON IMPROVING THE PROPERTIES OF EXPANSIVE SOIL FOR SUBGRADE IN FLEXIBLE PAVEMENTS

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ABSTRACT

The problem with expansive soils has been recorded all over the world. In monsoon they imbibe water and swell and in summer they shrink on evaporation of water there from. Because of this alternative swelling and shrinkage, lightly loaded civil engineering structures like residential buildings, pavements and canal linings are severely damaged. This paper investigates the improvement in the properties of clayey soils stabilized with copper slag and lime. Laboratory tests were carried out on expansive soils, stabilized with copper slag and lime at varying percentages to determine the strength characteristics. Copper slag and lime are used at varying percentages ranging strength properties of expansive soils improved with increase in percentages of copper slag and lime and the maximum strength is obtained at 19% copper slag and 8% lime.

Keywords— *Copper slag, Expansive Soils, Lime, OMC, MDD, CBR, Cyclic Pressures, Deformation, Atterberg Limits, Grain Size distribution.*

I INTRODUCTION

Expansive soils which contain montmorillonite minerals are having a tendency to swelling and shrinking with variation of moisture content. Several attempts had been made by (Sangita P. Lajurkar et al; 2013, Pankaj daipuria and Dr.M.K Trivedi; 2016) to decrease swelling potential. It leads to damages in structures and pavements. Mainly sites with clayey soil will cause more failures like settlement in foundation and structures. This settlement is not a problem as long as it is uniform or not great enough to damage the foundation. In order to overcome these problems, the soil should be stabilized. Soil stabilization is one of the geotechnical methods for improving the index properties of expansive soils (Aditya Chansoria and R K Yadav 2016) for enable their strength and durability with the addition of a modifier a soil before the construction. A variety of techniques are currently used to improve or stabilize the ground such that it improves the shear strength (K.Mukherjee et al

2015, Mohamadreza mahmoudi et al; 2014), reduces the differential settlement (K. Vijay Kiran et al 2015), reduces hydraulic conductivity.

Soil stabilization techniques are adopted to stabilize the clayey soils like cement (Upma and J. Sudheer Kumar), lime (Dr.D Koteswara Rao. et al; 2012,), fly ash (Prof.J.M. Raut et al; 2014, S. Bhuvaneshwari et al; 2005) etc... But these techniques became expensive so recently adopting the special additives to stabilize the soil like copper slag (R C Gupta et al; 2012, P. Rajendra kumar et al; 2017, A. Mohan Chand et al; 2017). Copper slag is the waste product which is obtained in large quantity from copper industries.

Copper is the basic chemical elements which are a soft and ductile metal, known for its high thermal and electrical conductivity and a reddish orange surface in its pure state. It is generally used in electrical, construction and transportation industries pure copper is rarely found in nature, but is commonly combined with other chemicals in the form of copper ores. Copper slag,

mixing with soil, can be used as an effective stabilizing agent for the improvement of problematic soils for use in the sub-grades and sub-base courses. When lime and water are mixed with soil, particularly expansive soils like block cotton soil, both physical and chemical properties changes, resulting in beneficial alterations of soil engineering behaviour.

Expansive soils are poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to the structures if not adequately treated. The disadvantages of clay can be overcome by stabilizing with suitable material. This research was done on the efficiency of copper slag and lime on improving the properties of expansive soil for subgrade in flexible pavements.

II. OBJECTIVE OF STUDY

The Objectives of present experimental study are

- To determine the properties of the Expansive Soil.
- To evaluate the performance of Expansive Soil when treated with Copper Slag as an admixture and lime as an additive.
- To study the performance of un-treated and treated Expansive Soil sub grade flexible pavements under cyclic pressures.

III MATERIALS

The experiments work was undertaken to achieve the objectives of the study. Laboratory tests were conducted on nature soil and after treatment with copper slag and lime.

A. SOIL

The Expansive soil used in this study was collected from Godilanka near Amalapuram, East Godavari District, A. P, India.

B. Copper slag

Copper slag is a by-product formed during the copper smelting process. The countermined copper slag has to be properly treated or washed to meet certain recycling criteria before it can be further used for other applications. The production of one-ton Copper generates, approximately 2-3 tons of Copper Slag. Copper Slag is the toxic for environment because it contains large amount of heavy metals in their oxides. We can solve an important problem for environment by utilization of Copper Slag in soil stabilization. The copper slag used in this study was obtained from the Nellore in Andhra Pradesh. The chemical compositions are given bellow table1.



Plate 3.1 Copper slag

Table-3.1: Chemical composition of copper slag

SI. No.	Constituent elements	Percent Content (%)
1	Silica as SiO ₂	35
2	Iron oxide as Fe ₂ O ₃	44
3	Alumina as Al ₂ O ₃	6.0
4	Calcium as CaO	1.5
5	Magnesium as MgO	2.0
6	Copper as Cu	0.9
7	Zinc as Zn	0.3
8	Cobalt as Co	0.13
9	Lead as Pb	0.04
10	Nickel as Ni	0.03
Physical composition		
1	Physical appearance	Back in color
2	Specific gravity	3.8

courtesy to Hindustan Copper Limited, Jharkand, India

C. Lime

Lime stabilization is done by adding lime to soil. It is useful for stabilization of clayey soils. When lime reacts with soil there is an exchange of cations in the adsorbed water layer and a decrease in plasticity of the soil occurs. The resulting material is more friable than the original clay, and is, therefore more suitable as sub grade. The lime is used in this study is a high quality hydrated lime produced locally and satisfies the general requirements for the construction purpose.



Plate 3.2 Lime

Table-3.3: Chemical composition of lime

Sl. NO.	Constituent elements	Percent Content (%)
1	SiO ₂	2.5
2	Al ₂ O ₃	1.5
3	Fe ₂ O ₃	2
4	CaO	84
5	MgO	1.5
6	Na ₂ O	0.5
7	C ₂ O	5

Courtesy to GRR Associates, Vizag

D. Aggregates

Road aggregate of size between 40-20 mm, confirming WBM-III standards was used for the preparation of the base course in the investigation of the modal flexible pavements.

E. Gravel

For the present investigation, the gravel was collected from Surampalem, East Godavari District, and Andhra Pradesh State, India. The gravel was classified as well graded gravel and was used in this investigation as a gravel cushion on untreated, treated & reinforced expansive soil foundation soil bed and also as a sub-base course in all model flexible pavements.

F. Geotextile

The geotextile used in this study is PP woven geotextile-GWF-40-220, manufactured by GARWARE –WALL ROPES LTD, Pune, India. The tensile strength of woven Geotextile is 62.00kN/m for warp and 46.00kN/m for weft.

IV RESULTS AND DISCUSSION

Table-4.1: properties of the expansive soils

Sl. NO.	Property	value
1	Specific gravity	2.64
2	Free swell	120
3	Soil classification	CH
Grain Size Distribution		
4	Gravel (%)	0
5	Sand (%)	8
6	Silt (%)	27
7	Clay (%)	61
Atterberg Limits		
8	Liquid limit (%)	69
9	Plastic limit (%)	27
10	Plasticity index (%)	42
Compaction properties		
11	Optimum moisture Content (%)	27.15
12	Maximum Dry Density (g/cc)	1.542

Strength properties		
13	Unsoaked CBR (%)	2.79
14	Soaked CBR (%)	1.78

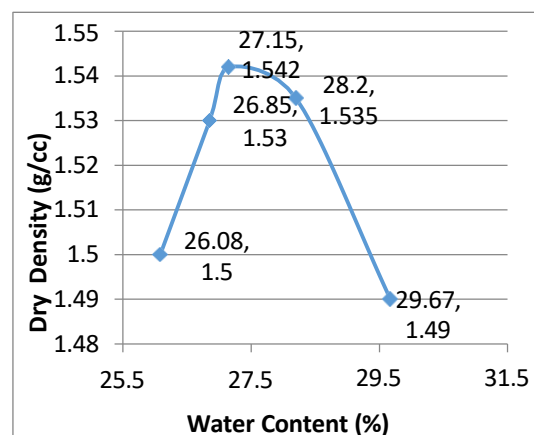


Fig 4.1 Compaction curve of Untreated Expansive soil

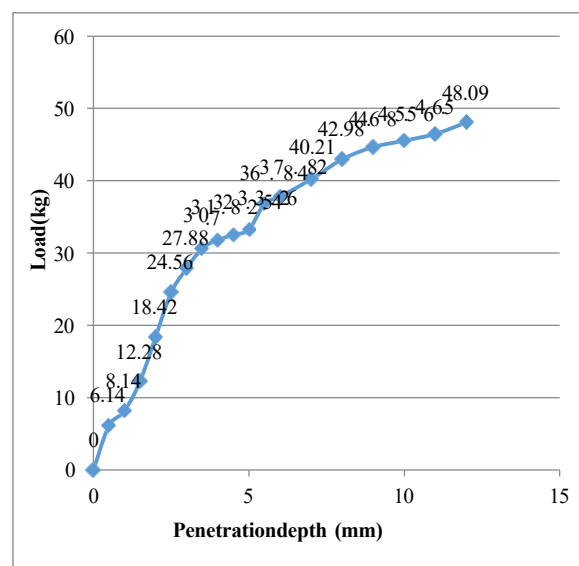


Fig 4.2 CBR curve for Untreated Expansive soil

Table 4.2: MDD and OMC results of different % of copper slag

Sl. NO.	Soil and admixture proportions	MDD (g/cc)	OMC (%)
1	100%soil	1.54	27.15
2	82%Soil+18% of CS	1.68	24.82
3	81%Soil+19% of CS	1.75	22.40
4	80%Soil+20% of CS	1.84	22.83
5	79%Soil+21% of CS	1.813	21.34
6	78%Soil+22% of CS	1.789	21.24

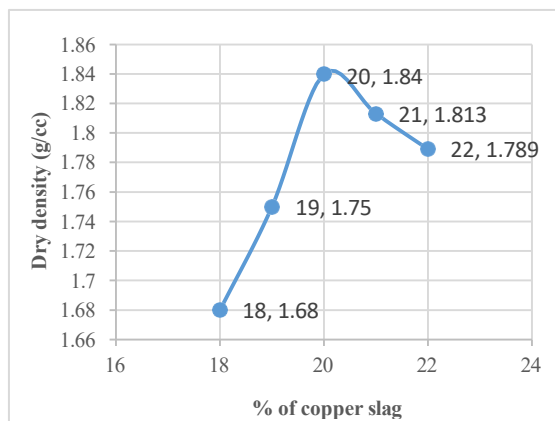


Fig 4.3 Curve showing variation of MDD with % variation of Copper Slag

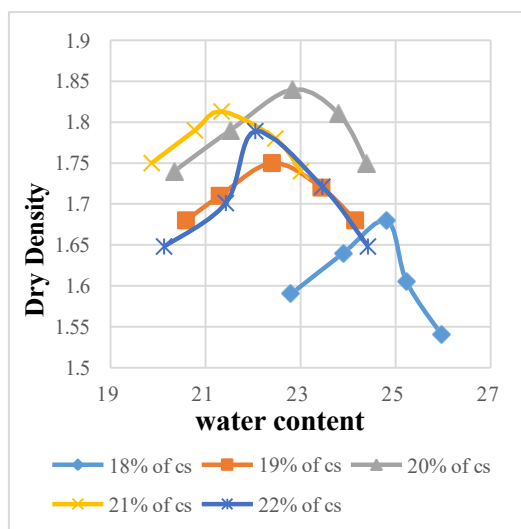


Fig 4.4 Composite graph of OMC and MDD values of Expansive soil treated with different % of copper slag

Table 4.3: Soaked CBR test results of Expansive soil treated with different % of copper Slag

Sl.NO.	Soil + admixture proportions	CBR (%)
1	100% soil	1.78
2	82% Soil+ 18% CS	4.06
3	81% Soil +19% CS	4.66
4	80% Soil + 20% CS	3.94
5	79% Soil +21% CS	3.12

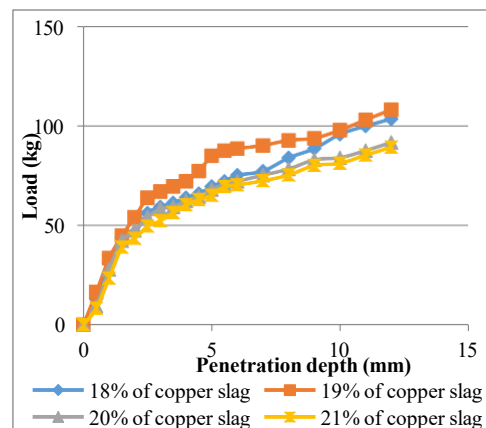


Fig 4.5 Composite graph of CBR values of expansive soil treated with different % of CS

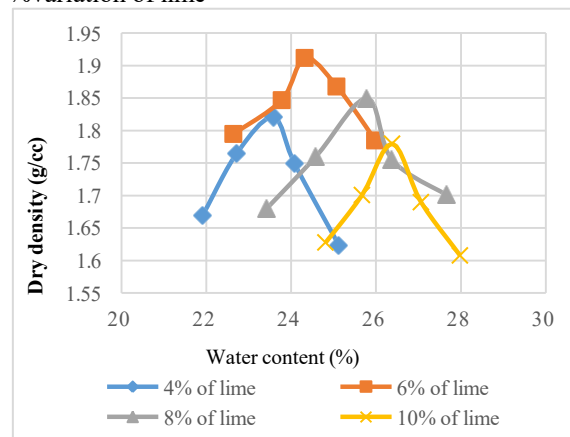
Discussion-1

As per IRC 37-2001,2012 the subgrade soil should possess the minimum CBR value of 6%. In the present study Copper Slag treated Expansive Soil has exhibited the CBR value of 4.66% which is less as per codes of practice. To achieve required CBR value as per codes of practice, an attempt has been taken to improve the CBR of Copper Slag treated Expansive Soil with the percentage variation of lime to suite it as subgrade for flexible pavements.

Table 4.4: variation of MDD and OMC values of Lime(%) with Copper Slag treated Expansive soil

Sl. NO.	Soil and admixture proportions	MDD (g/cc)	OMC (%)
1	Soil+19% of CS and 4% lime	1.821	23.58
2	Soil+19% of CS and 6% lime	1.912	24.32
3	Soil+19% of CS and 8% lime	1.85	25.78
4	Soil+19% of CS and 10% lime	1.78	26.38

Fig 4.6 Curve showing MDD values with %variation of lime



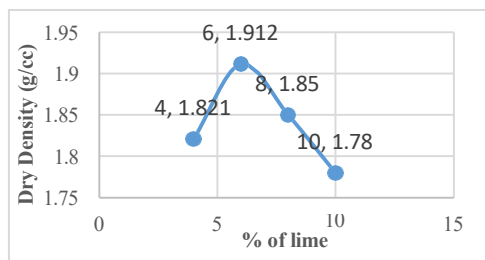


Fig 4.7 Composite graph of OMC and MDD values of Expansive soil treated with 19% of copper slag and different % of lime

Table 4.5: Soaked CBR test results of Expansive soil treated with 19% of CS and different % of lime

SL.NO	Soil + admixture proportions	CBR (%)
1	Soil+19% of CS and 4% lime	6.89
2	Soil+19% of CS and 6% lime	7.35
3	Soil+19% of CS and 8% lime	10.72
4	Soil+19% of CS and 10% lime	8.58

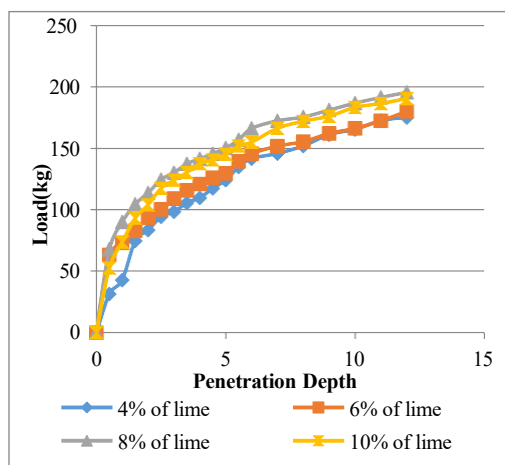


Fig 4.8 Composite graph of CBR values of expansive soil treated with 19 % of CS and different % of lime

Discussion-2

From the above study, 19% Copper Slag treated Expansive Soil has exhibited the CBR value of 10.72% on addition of 8% lime as an optimum. Hence this treated Expansive Soil is suitable as subgrade for flexible pavements as per IRC 37-2001,2012 codes of practice.

Table 4.6 Properties of Treated and Untreated Expansive Soil

SI. NO	Properties	Exp soil	Exp soil+19 % CS	Exp soil+19 % CS+8% lime
1	Liquid limit (%)	69	49.75	41.23
2	Plastic limit(%)	27	18.63	22.3
3	Plasticity index(%)	42	31.2	18.93
4	Soil classification	CH	CH	CH
5	Specific gravity	2.64	2.927	3.14
6	OMC (%)	22	21.2	25.78
7	MDD (g/cc)	1.54	1.75	1.85
8	CBR (%)	1.78	4.66	10.72

V. CYCLIC PLATE LOAD TEST

Cyclic plate load tests are more significant for determining the ultimate load carrying capacity of the pavements.

Cyclic plate load tests were conducted in the laboratory on untreated and treated Expansive Soil subgrade flexible pavements using model tanks.

MODEL TANK

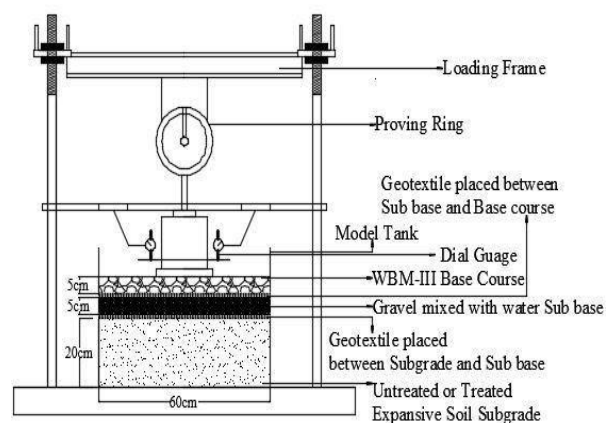


fig 5.1 Experimental set up for conducting cyclic plate load test

A circular model tank made of steel with a diameter of 60cm and height of 50 cm is used in this study. In this study a model flexible pavement is prepared with treated and untreated Expansive Soil as subgrade of 20cm thickness over which

5cm thick gravel sub base and 5 cm WBM-III is provided with suitable degree of compaction.

TEST PROCEDURE

A model flexible pavement is prepared in the model tank by providing 3 layers viz. subgrade, sub base, and base course for untreated and treated Expansive Soil flexible pavement conditions.

PREPARATION OF SUBGRADE

The Expansive Soil passing through 4.75 mm IS Sieve was used and compacted in layers of 2cm thickness at O.M.C to a total compacted thickness of 20cm for untreated and treated Expansive Soil model flexible pavement.

For the untreated Expansive Soil, water was mixed directly with the soil corresponding to the OMC of the natural Expansive Soil. For the Copper Slag treated Expansive Soil the weight of the dry mixes were taken corresponding to the M.D.D of Expansive Soil is compacted at O.M.C without any lumps.

For further treatments, the required quantity of Copper Slag was spread on the pulverized soil and mixed thoroughly, until there was uniform mix of Copper Slag with the soil without any lumps. Further, the required quantity of lime was mixed thoroughly with already mixed soil-Copper Slag mix at OMC corresponding to the untreated Expansive Soil.

PREPARATION OF SUB BASE

On the prepared Expansive Soil subgrade, the gravel mixed with water at OMC was laid in layers of 2.5 cm compacted thickness to a total thickness of 5cm. The sub base layer was compacted to MDD and OMC of gravel.

PREPARATION OF BASE COURSE

On the prepared sub base, two layers of WBM-III each of 2.5 cm compacted thickness, was laid to a total thickness of 5 cm and the gravel used as a binding material the spreading of WBM-III as base course for the model flexible pavement.

Prepared Flexible pavement is placed at the center of the loading frame of compression testing machine. A metal plate of 10 cm diameter is placed on the Model flexible pavement through which loading is done. Two dial gauges of least count 0.01mm were arranged to obtain deformations. A hydraulic jack of 5 tone capacity is placed on the metal plate.

In Singly reinforced system a woven geotextile is used as reinforcement and separator

between subgrade and sub base course. In case of doubly reinforced flexible pavement first layer is provided as reinforcement and separator between sub grade and sub base for offering more pressures on the reinforcement flexible pavement system.

Cyclic plate load was carried out on untreated and treated Expansive Soil model flexible pavements corresponding to tire pressures of, 500kPa, 560kPa, 630kPa, 700kPa, 1000kPa at O.M.C as per IRC codes of practice.

Each pressure increment was applied until there is no further change in deformations in between the consecutive cycles. The test is continued until the failure to record the ultimate pressure of untreated and treated flexible pavement.



plate 5.1 Author is conducting cyclic plate load test

Plate load test results

1. Table 5.1 and Fig 5.2 Present the load carrying capacity of the Expansive Soil under cyclic pressures. The Expansive Soil has exhibited the load carrying capacity of 180kPa at 2.85mm settlement.

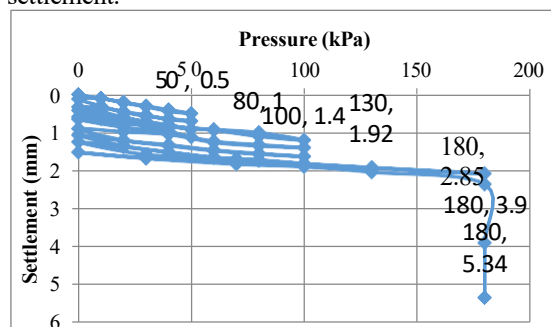


Fig 5.2 Cyclic Plate Load test results of Expansive Soil

2. Table 5.1 and Fig 5.3 show the results of untreated Expansive Soil subgrade flexible pavement has exhibited the load carrying capacity of 650kPa at 2.75mm settlement.

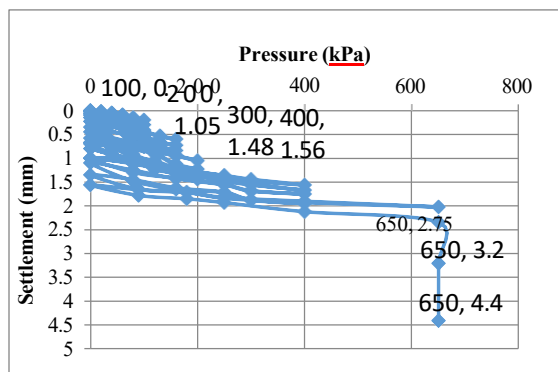


Fig 5.3 Cyclic Plate Load test results of Un-treated Expansive Soil subgrade flexible pavement

3. Table 5.1 and Fig 5.4 present The results of treated Expansive Soil subgrade flexible pavement has exhibited the load carrying capacity of 1600kPa at 2.22mm settlement

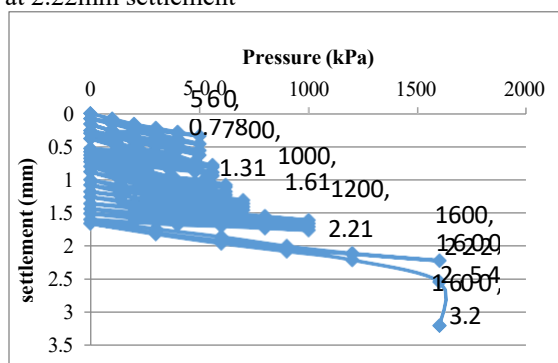


Fig 5.4 Cyclic plate load test results of Treated Expansive Soil subgrade flexible pavement

4. Table 5.1 and Fig 5.5 show the result of geotextile reinforced treated Expansive Soil subgrade flexible pavement, exhibited the ultimate cyclic pressure of 2250kPa at 1.69mm settlement.

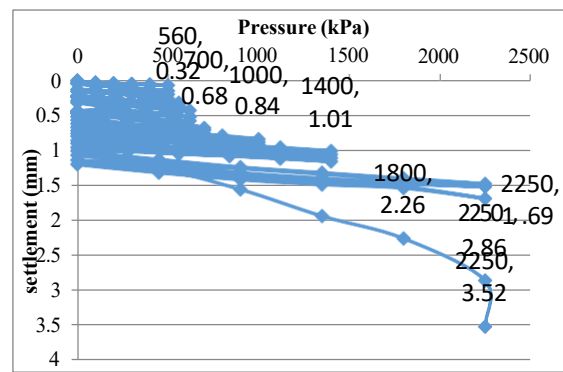


Fig 5.5 Cyclic plate load test results of Treated Expansive Soil subgrade flexible pavement reinforced with single geotextile

5. Table 5.1 and Fig 5.6 show the result of doubly reinforced treated Expansive Soil subgrade flexible pavement, exhibited the ultimate cyclic pressure of 3200kPa at 1.61mm settlement. In this experiment the two layers of geotextiles has been provided viz. the first layer has been provided subgrade and sub base and the second one provided in between sub base and base course.

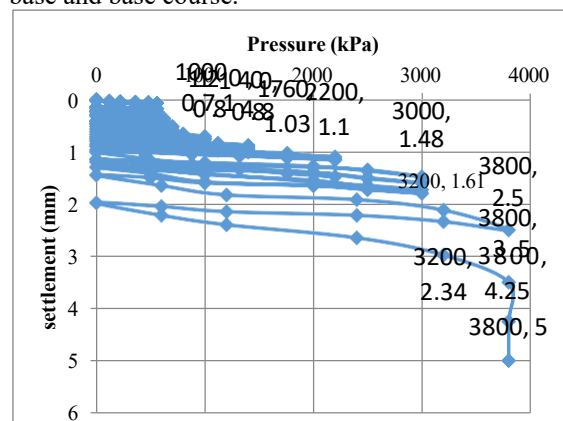


Fig 5.6 Cyclic plate load test results of treated Expansive Soil subgrade flexible pavement reinforced with double geotextile

Table 5.1 Results of Cyclic Plate Load Test of Un-treated and treated Expansive Soil Subgrade Flexible Pavements under cyclic pressures

Sl.No	Type of Subgrade	Sub-Base	Base course	Pressure (kPa)	Settlement (mm)
1	Expansive Soil	-----	-----	180	2.85
2	Untreated Expansive Soil subgrade flexible pavement	Gravel	WBM-III	650	2.75
3	19% Copper Slag and 8% lime treated Expansive Soil subgrade flexible pavement	Gravel	WBM-III	1600	2.22
4	Treated Expansive Soil subgrade flexible pavement with geotextile as reinforcement(singly reinforced) & separator in between subgrade and sub base	Gravel	WBM-III	2250	1.69
5	Double geotextile reinforced Treated Expansive Soil subgrade flexible pavement.	Gravel	WBM-III	3200	1.61

Discussion 3

It has been observed from the laboratory cyclic plate load test results that the doubly reinforced flexible pavement has exhibited maximum cyclic

pressure than the remaining untreated and treated flexible pavements.

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Dr. D. Koteswara Rao, Professor & Director (FDC), University College of Engineering, JNTUK KAKINADA, East Godavari District, Andhra Pradesh, India.

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VII. CONCLUSION

- It was observed from laboratory test results that the liquid limit and plasticity index of the expansive soil has been decreased by 40% and 55% respectively with the addition of 19% Copper slag and 8% lime as an optimum when compared with untreated expansive soil.
- It was noticed from the laboratory test results that the maximum dry density of 19% Copper slag & 8% Lime treated expansive soil has been increased by 20% when compared with untreated expansive soil.
- It was observed that the CBR value of treated Expansive Soil increased by 502% when compared with untreated expansive soil on addition of 19% Copper Slag and 8% lime as an optimum.
- It was observed from the laboratory cyclic load test results that the load carrying capacity of the treated expansive soil subgrade flexible pavement has been improved by 392% when compared with untreated expansive soil subgrade flexible pavement.
- It was observed from the laboratory cyclic plate test results that the deformation of the reinforced and treated expansive soil subgrade flexible pavement has been improved by 39% when compared with untreated expansive soil subgrade flexible pavement.

REFERENCES

- [1]. S. Bhuvaneshwari, R. G. Robinson, S. R. Gandhi (2005) " Stabilization Of Expansive Soils Using Flyash "
- [2]. Dr. D. koteswara Rao, Pranav. P.R.T, Anusha M (2011) " Stabilization Of Expansive Soil with Rice Husk Ash, Lime And gypsum—An Experimental Study " Vol.3 ISSN : 0975-5462.
- [3]. R C Gupta1, Blessen Skariah Thomas, Prachi Gupta , Lintu Rajan and Dayanand Thagriya (2012) " An Experimental Study Of Clayey Soil Stabilized By Copper Slag " Vol.3, ISSN 2319 – 6009.
- [4]. Sangita P. Lajurkar, Shantanu R. Khandeshwar , Rajesh M. Dhoble, Rashmi G. Bade (2013)" Experimental Study On Shrink- Swell Behaviour Of Expansive Soil" Vol. 2, Issue 6, ISSN: 2319-8753.
- [5]. Prof.J.M. Raut, Dr. S.P.Bajad, Dr. S.R.Khadeshwar (2014) " Stabilization of Expansive Soils Using Flyash and Murrum " Vol.3, Issue 6, ISSN: 2319-8753.
- [6]. Mohamadreza Mahmoudi, Hamed Niroumand, Khairul Anaur Kassim (2014) "A Systematic Literature Review On Performance Of Fly Ash On The Strength Parameters In Cohesive Soils "
- [7]. K.Mukherjee1, A.K.Mishra2, Balaji Mudaliyar.A (2015) "A review on consolidation and strength behaviour of fiber reinforced expansive soil "
- [8]. K. Vijay Kiran, M. R. Madhav, M. Padmavathi (2015) " Settlements Of Single Granular Pile At Different Depths "
- [9]. Upma, J. Sudheer Kumar (2015) " Effect of Cement Kiln Dust and Chemical Additive on Expansive Soil at Subgrade Level " Vol. 4, Issue 5, ISSN: 2347-6710.
- [10]. Pankaj Daipuria, Dr. M.K Trivedi (2016) " Improvement Of Swelling Properties Of Expansive Soil Blending With Sand And Cement" *Volume 5, Issue 6, ISSN: 2278 – 7798.*
- [11]. Aditya Chansoria , R K Yadav (2016) " Effect of Quarry Dust on Index Properties of Black Cotton Soil " Vol. 4, Issue 02, 2016 | ISSN (online): 2321-0613.
- [12]. P.Rajendra Kumar, P.Suresh Praveen Kumar, G.Maheswari (2017) " Laboratory Study of Black Cotton Soil Blended With Copper Slag and Fly-Ash " Vol 6, Issue 2 , ISSN (Print) : 2347-6710.
- [13]. A. Mohan chand, V. Ramesh babu, B. Ramesh Babu3 and K. Niveditha (2017) " Behavior Of Black Cotton Soil With Addition Of Copper Slag And Steel Slag " Vol.4 ,Issue 01, p-ISSN: 2395-0072, e-ISSN: 2395 -0056.