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EXPERIMENTAL STUDY ON THE CYCLIC PRESSURES OF UNTREATED AND TREATED MARINE CLAY USING PHOSPHOGYPSUM AND LIME AS SUBGRADE FOR FLEXIBLE PAVEMENTS

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Abstract: India has large coastline exceeding 7,517kms. The marine clay is found widely along the coastal corridor and it causes expensive solutions in the construction of coastal highways and building foundations. Hence, the marine clay should be stabilized to increase its strength to meet the requirements for the construction of highways and building foundations. In this paper, phosphogypsum is used as an admixture and lime is used as additive to stabilize the marine clay, thereby improving its strength, deformation and swell characteristics. Systematic and methodological process was followed involving experimentation in the laboratory under controlled conditions to study the cyclic pressures of untreated and treated marine clay as subgrade for flexible pavements.

Keywords: -Marine Clay, MDD, OMC, Load carrying capacity, Cyclic pressures, Phosphogypsum, Lime.

I. INTRODUCTION

Marine clays are problematic soils having poor strength and bearing capacity. Engineers face many problems while constructing on such soils. Effects of marine clay have appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, canal and reservoir linings. The estimated damage was very expensive to the pavements running over the marine clay sub grades. They do not possess sufficient strength to support the loads of the structure coming on them during construction or service life of the structure. So considerable changes have to be made in the construction of various coastal and offshore structures. In order to improve the engineering behavior of these soils, several improvement techniques are available in geotechnical engineering practice. The selection of any of these methods to overcome any problem can be proved to be efficient only after the comparison of that with other techniques, then it can be said that the particular method is well suited for a specific system.

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 the soft clay sub grade. In the present work, the phosphogypsum and are used as stabilizing agents to improve the engineering properties of marine clay.

II. REVIEW OF LITERATURE

Hyde AL et.al (1993) presented Engg properties and stability criteria of MC under cyclic pressures. Oh,E.Y.N et.al (2006), presented marine clay properties and characterization for road embankment design. Dr. D. Koteswara Rao et.al (2011), Field studies on the marine clay foundation soil beds treated with lime, GBFS and reinforcement technique, IJEST, Vol.3, No.4, April 2011. "Performance of Hemihydrate PhosphoGypsum in Road Construction", Sam Akly, PE, AIChE Clearwater, 1986. www.aiche-cf.org /Paper # 86.2.4.pdf. K.Ramu, R.D.Babu et al. (2015) a study on the swelling behavior of marine clay treated with VPW and Lime, IGC, Pune. Dr. D. Koteswara Rao and k. Pradeep Varma (2018), presented improving the properties of the marine clay using phosphogypsum and lime as subgrade for flexible pavements, IJTIMES, vol. 4, issue.08, August 2018.

III. OBJECTIVES OF STUDY

The objectives of present experimental study are

- To evaluate the performance of marine clay when stabilized with phosphogypsum as an admixtures and lime as an additives to their suitability for pavement sub grade.
- To study the cyclic plate load characteristics of marine clay when stabilized with optimum mix of phosphogypsum and lime.

- To study the performance of treated marine clay with single geotextile (as reinforcement and separator) as sub grade for flexible pavements under cyclic pressures.

IV. MATERIALS USED

A. Marine clay (MC)

Marine clay sample was collected from Kakinada, sea port at a depth of 0.5-1m below the sea water level. The Index & Engineering properties of marine clay are determined as per IS code of practice.

B. Phosphogypsum (PG)

The production of phosphoric acid from natural phosphate rock by means of the wet process gives rise to an industrial by-product named phosphogypsum (PG). World PG generation is estimated to be around 100-280 million tonnes/year. In this study, PG finer than 75 micron, IS sieve, was used as an admixture. The specific gravity of PG was determined as 2.48, in accordance with BIS code.

TABLE I

CHEMICAL COMPOSITION OF PHOSPHOGYPSUM

SI.No	Parameter	Composition(%)
1	H_2O	18.0
2	SO_2	43.6
3	CaO	32.0
4	MgO	0.40
5	Al_2O_3+ Fe_2O_3	1.82
6	Sio_2	1.64
7	P_2O_5	1.03
8	F	0.76
9	Organic matter	0.26
10	Na_2O_5	0.36

Courtesy to Jijo James, P. KasinathaPandian Anna University Tagore Engineering CollegeDepartment of Civil EngineeringChennai, India

C. Lime

Lime chemically known as, Calcium oxide (CaO), commonly known as quick lime or burnt lime, is widely used chemical compound. It is a white, caustic, alkaline crystal solid at room temperature. It is useful for stabilization of clayey soil compound.

D. 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 60.00kN/m for warp and 45.00kN/m for weft.

E. Aggregates

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

F. Gravel

The Gravel used in this study is collected from Surampalem, East Godavari District, Andhra Pradesh, India. The gravel was classified as well graded gravel and was used in this study as a gravel sub base course on untreated, treated & reinforced marine clay subgrade in all model flexible pavements.

TABLE II
PROPERTIES OF GRAVEL

Sl. No	Property	Values
1	Specific gravity	2.65
2	Grain size Distribution	
	Gravel (%)	63
	Sand (%)	28
	Silt &soil (%)	9
3	Compaction properties	
	Maximum dry density (g/cc)	19.96
	OMC (%)	11.48
4	Atterberg limits	
	Liquid limit (%)	28
	Plastic limit (%)	16
	Plasticity index (%)	6
5	CBR (Soaked) (%)	16

V. LABORATORY TEST RESULTS

TABLE III
OMC & MDD VALUES OF TREATED & UNTREATED MARINE CLAY WITH % VARIATION OF PHOSPHOGYPSUM

Marine clay treated with percentage variation of phosphogypsum	MDD	OMC
Soil	1.47	37.32
Soil + 2%PG	1.522	34.88
Soil + 4%PG	1.528	34.76
Soil + 6%PG	1.541	33.98
Soil + 8%PG	1.512	35.78

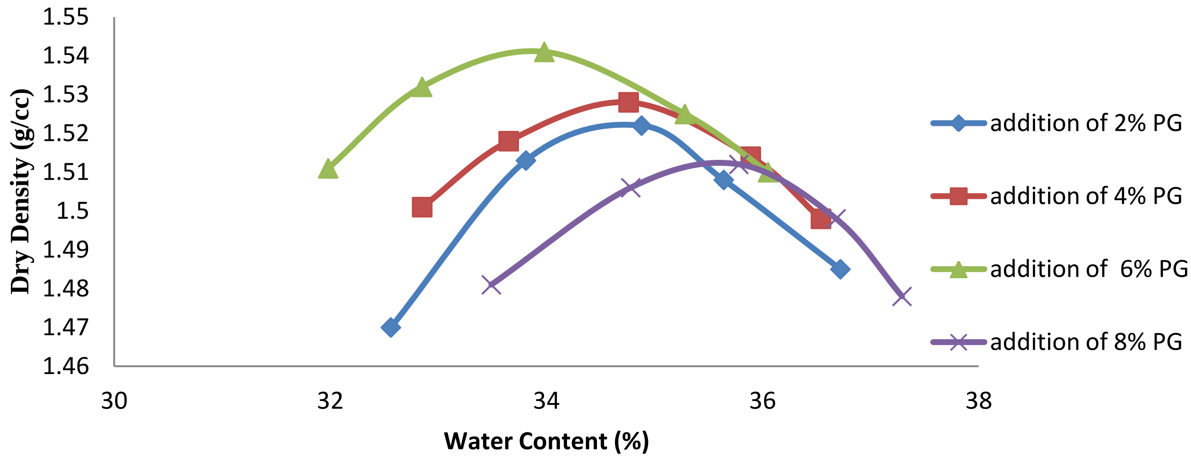

Fig. 1MDD values of marine clay treated with % variation of PG

TABLE IV
CBR VALUES OF MARINE CLAY TREATED WITH % VARIATION OF PHOSPHOGYPSUM

SI.No	Marine clay treated withpercentage variation of phosphogypsum	CBR Value
1	Soil	1.792
2	Soil+2%PG	1.915
3	Soil+4%PG	2.24
4	Soil + 6%PG	3.137
5	Soil+8%PG	2.835

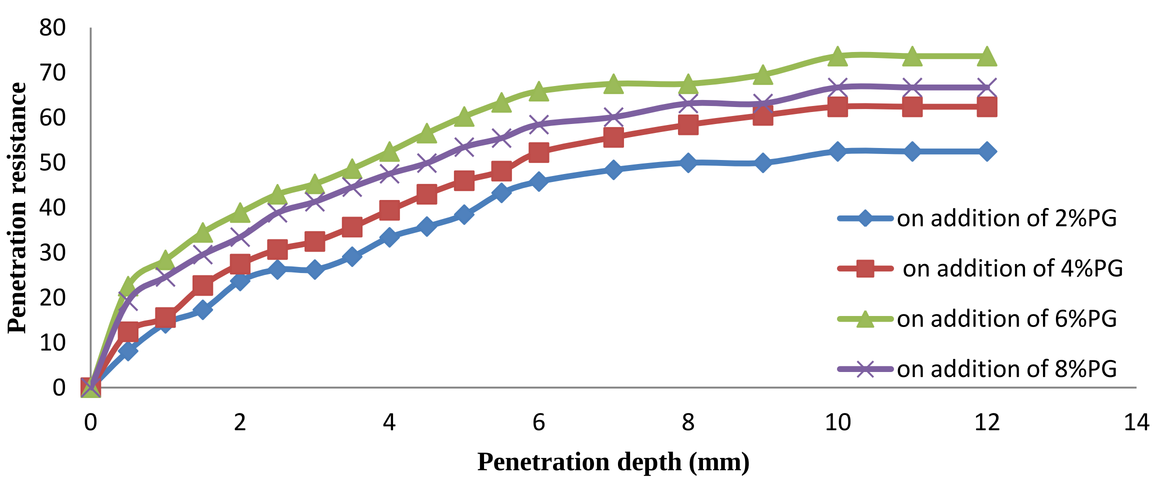

Fig. 2CBR values of marine clay treated with % variation of PG

TABLE V

OMC & MDD VALUES OF MC TREATED WITH AN OPTIMUM OF 6% PG UPON ADDING PERCENTAGE VARIATION OF LIME

Phosphogypsum treated marine clay with percentage variation of lime	OMC	MDD
5%	32.45	1.567
6%	31.41	1.591
7%	31.21	1.621
8%	31.29	1.597

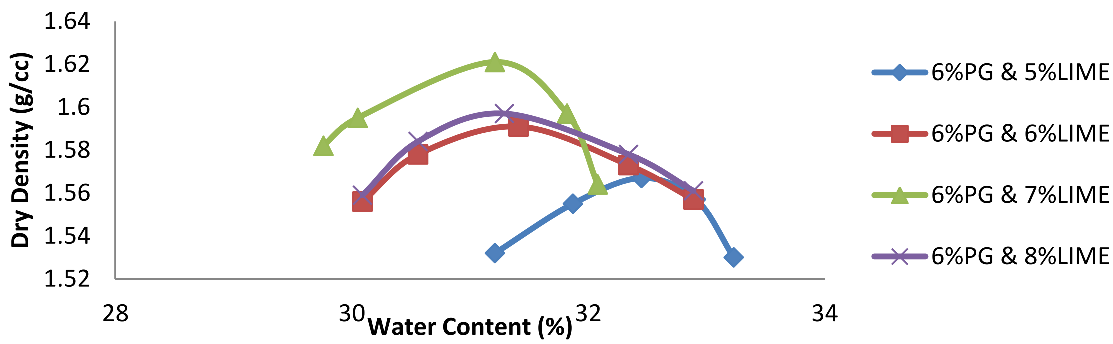

Fig. 3MDD values of marine clay treated with an optimum of 6% PG upon adding percentage variation of lime

TABLE VI

CBR VALUES OF MARINE CLAY TREATED WITH AN OPTIMUM OF 6% PG UPON ADDING PERCENTAGE VARIATION OF LIME

SI.No	Phosphogypsum treated marine clay with % variation of lime	CBR value
1	5%	5.37
2	6%	6.2
3	7%	8.17
4	8%	6.78

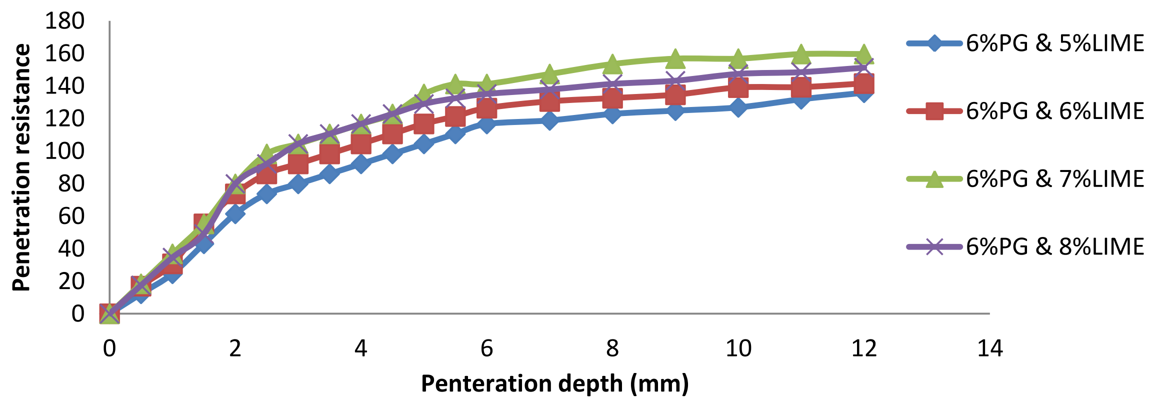

Fig. 4 CBR test results of marine clay treated with an optimum of PG upon adding percentage variation of lime

TABLE VII

LABORATORY TEST RESULTS OF THE UNTREATED AND TREATED MARINE CLAY

SI.No	Property	Symbol	Untreated marine clay	Marine clay treated with 6% phosphogypsum	Marine clay treated with an optimum of 6% PG &7% Lime
1	Liquid limit (%)	W_L	76	61.4	42.4
2	Plastic limit (%)	W_P	34.33	36.67	40.23
3	Plasticity index (%)	I_P	41.69	32.03	21.86

4	Specific gravity	G	2.42	2.61	2.69
5	Optimum moisture content (%)	OMC	37.32	33.98	31.21
6	Maximum dry density (g/cc)	MDD	1.47	1.541	1.621
7	Cohesion (kg/cm^2)	C	0.74	0.61	0.42
8	Angle of shear resistance (^{o})	Φ	3.71^0	8^0	17^0
9	CBR (%)		1.792	3.137	8.17
10	Differential free swell	DFS	110	60	35

VI. 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 marine clay subgrade flexible pavements using model tank.

MODEL TANK

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 marine clay as subgrade of 20cm thickness over which 5cm thick gravel sub base and 5 cm WBM-III is provided as base course with suitable degree of compaction.

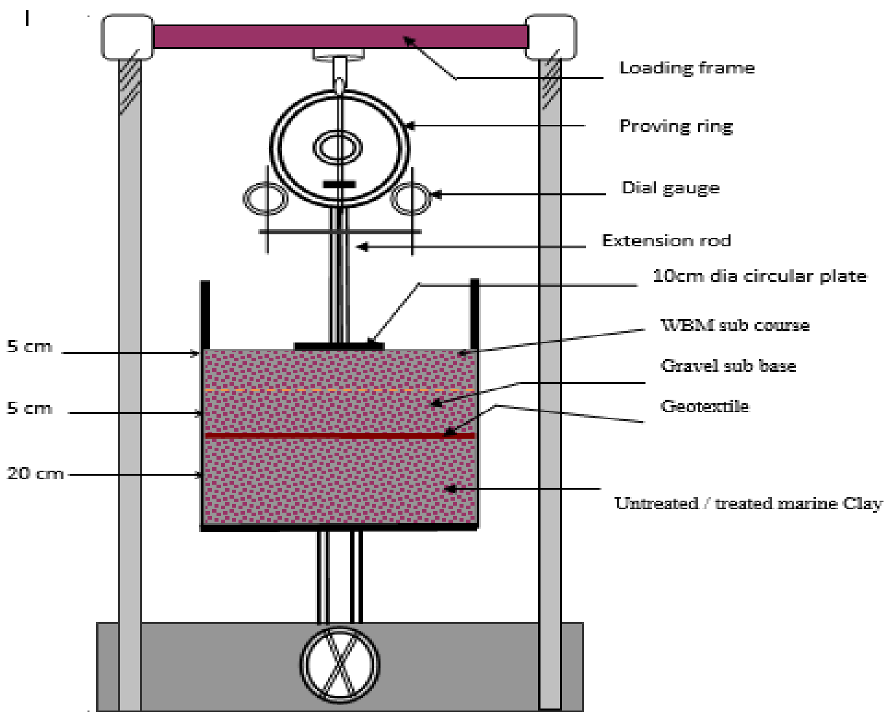

Plate 1 Experimental Setup for Conducting the Cyclic Plate Load Test

5.1 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 marine clay flexible pavement conditions.
5.1.1 Preparation of Subgrade

The marine clay 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 marine clay as subgrade for model flexible pavement.To the untreated marine clay, water was mixed directly with the soil corresponding to the OMC of the natural marine clay. And for the phosphogypsum treated marine clay the weights of the dry mixes were taken corresponding to the M.D.D of marine clay and marine clay is compacted at O.M.C without any lumps.For further treatments, the required quantity of phosphogypsum was spread on the pulverized soil and mixed thoroughly, until there was uniform mix of phosphogypsum with the soil without any lumps. Further, the required quantity of Limewas mixed thoroughly with already mixed soil-phosphogypsum mix at OMC corresponding to the untreatedmarine clay.

5.1.2 Preparation of Sub Base

On the prepared marine clay 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 the gravel.

5.1.3 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 was 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 tonne capacity is placed on the metal plate. In singly reinforced system a woven geotextile is used as reinforcement and separator between subgrade and subbase course. In case of doubly reinforced flexible pavement first layer is provided as reinforcement and separator between subgrade and subbase and the second layer was provided as separator & reinforcement in between the subbase and base course for offering more pressures on the reinforcement flexible pavement system.Cyclic plate load was carried out on untreated and treated marine clay 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 theconsecutive cycles. The test is continued until the failure to record the ultimate pressure of untreated and treated flexible pavement.

a). Table 8 and Fig. 5 Present the laboratory cyclic plate load test results of Marine Clay. The Marine clay alone has exhibited the ultimate cyclic load of 70kPa with the deformation of 2.98mm at OMC.

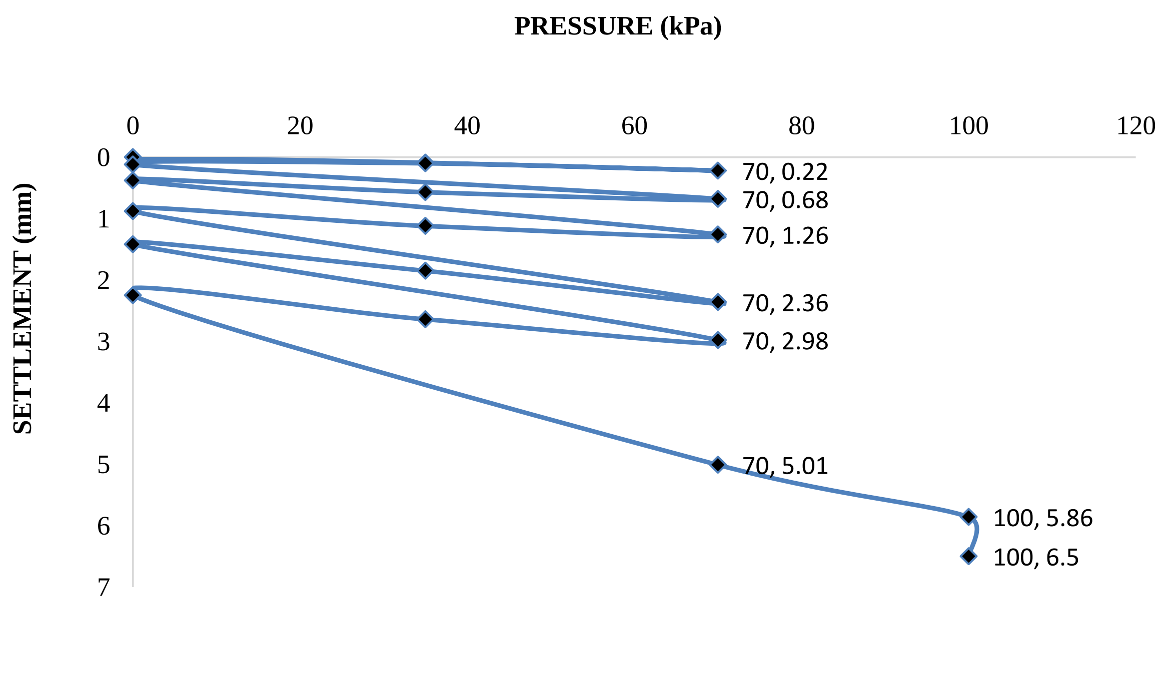

Fig. 5 cyclic plate load test results of Marine Clay subgrade flexible pavement

b). Table 8 and Fig. 6 Present the load carrying capacity of the untreated marine clay subgrade flexible pavement under cyclic pressures. The untreated marine clay subgrade flexible pavement has exhibited the load carrying capacity of 700kPa at 2.51mm settlement.

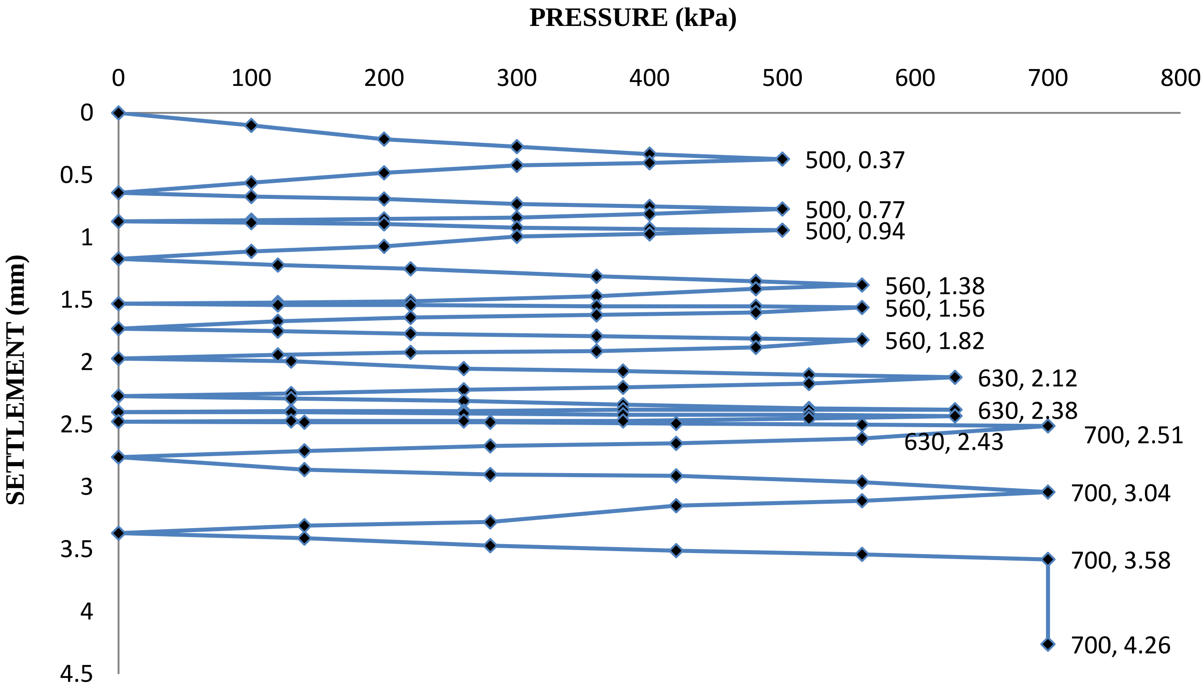

Fig. 6 Cyclic Plate Load test results of Un-treated Marine clay subgrade flexible pavement

c). Table 8 and Fig. 7 present the load carrying capacity of the treated marine clay subgrade flexible pavement under cyclic pressures. The treated marine clay subgrade flexible pavement has exhibited the load carrying capacity of 1000kPa at 2.32mm settlement

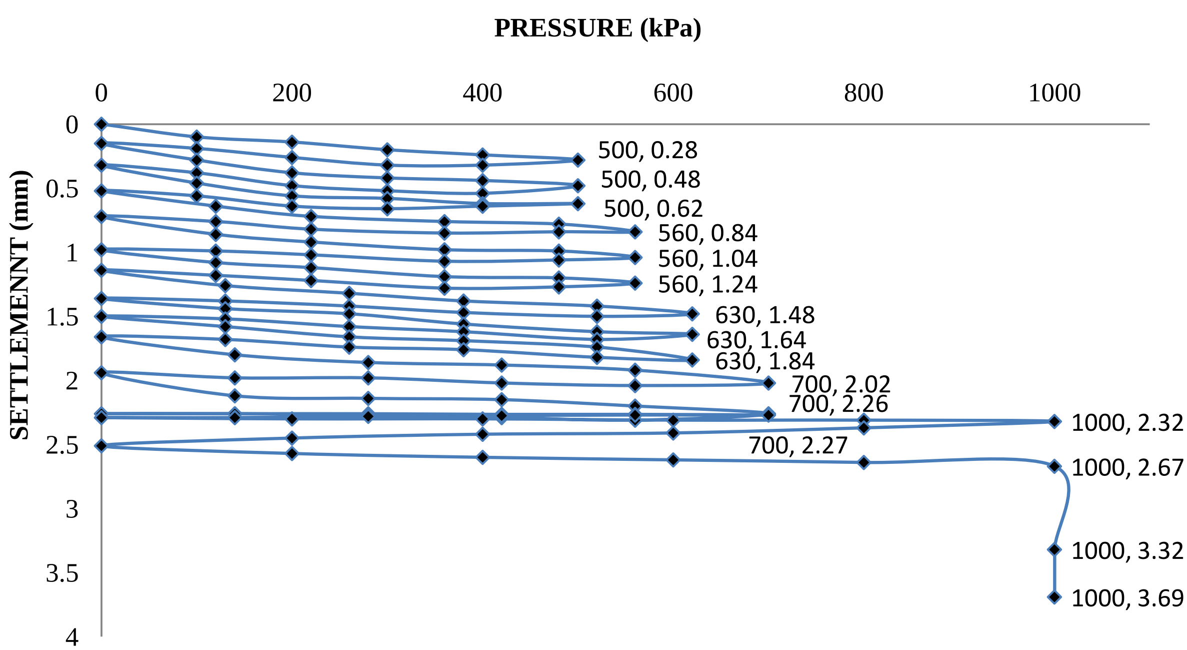

Fig. 7 Cyclic plate load test results of Treated Marine clay subgrade flexible pavement

d). Table 8 and Fig. 8 present the result of singly (geotextile) reinforced treated marine clay subgrade flexible pavement, exhibited the ultimate cyclic pressure of 1650kPa at 1.92mm settlement.

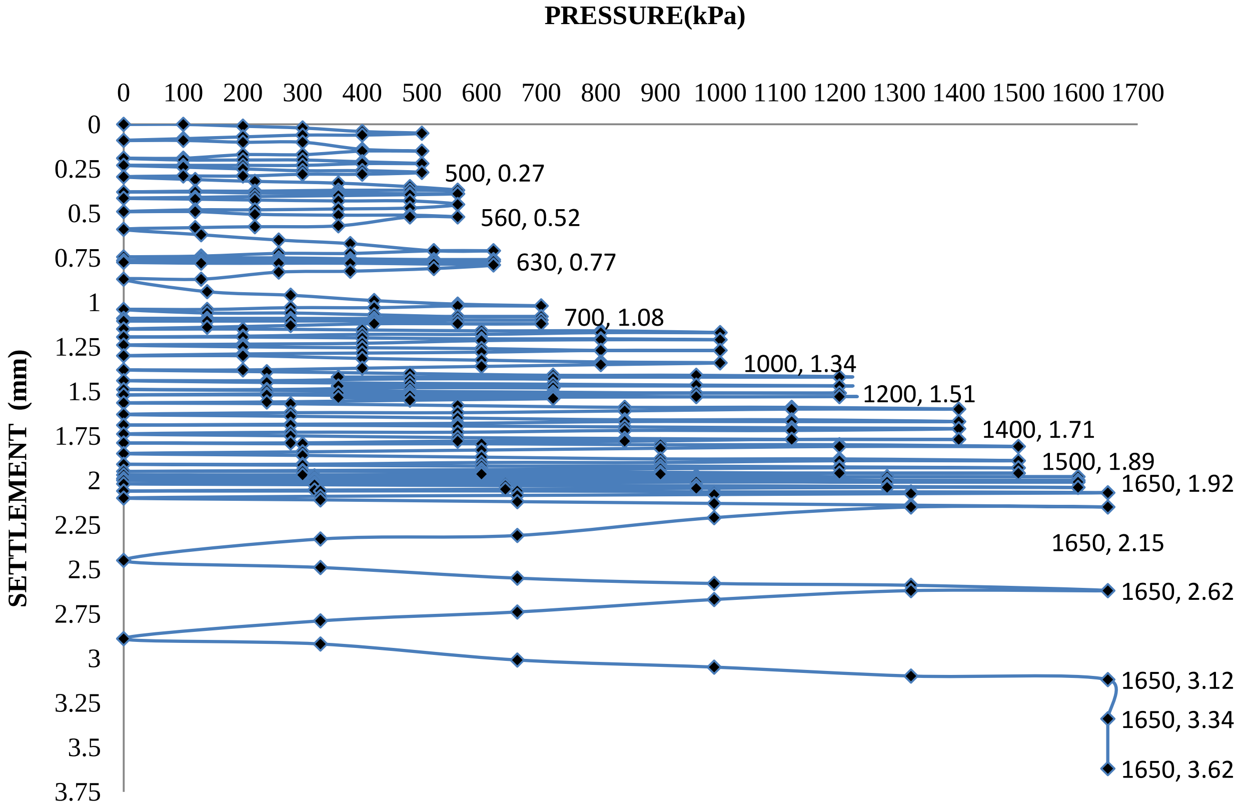

Fig. 8 Cyclic plate load test results of Treated marine clay subgrade flexible pavement reinforced with single layer of Geotextile

TABLE VIII
CYCLIC PLATE LOAD TEST RESULTS OF UN-TREATED AND TREATED MARINE CLAY SUBGRADE FLEXIBLE PAVEMENTS UNDER CYCLIC PRESSURES

SI.No	Type of Subgrade	Sub-Base	Base course	Pressure (kPa)	Settlement (mm)
1	Untreated marine clay	----	----	70	2.98
2	Untreated marine clay subgrade flexible pavement	Gravel	WBM-III	700	2.51
3	6% phosphogypsum and 7% lime treated marine clay subgrade flexible pavement	Gravel	WBM-III	1000	2.32
4	Treated marine clay subgrade flexible pavement with geotextile as reinforcement (singly reinforced) & separator in between subgrade and sub base	Gravel	WBM-III	1650	1.92

VII. CONCLUSIONS

1) It is noticed from the laboratory investigations of the cyclic plate load test results that, the ultimate cyclic pressure of treated marine clay subgrade flexible pavement has been improved by 700kPa to 1650kPa when compared with untreated marine clay.
2) It is noticed from the laboratory investigations of the cyclic plate load test results that, the total deformations of treated marine clay subgrade flexible pavement with single geotextile has been improved by 23.5% when compared with untreated marine clay.

The soaked CBR value of treated marine clay is 8.17% and it is satisfying standard specificationsas per IS-2720 (Part-16) and IRC: 37-2012, pp: 10. It is concluded from the above test results that the stabilized marine clay is suitable to use as subgrade material for the pavement construction and also for various foundations of buildings.

VIII. REFERENCES

[1] Kagawa T (1993), Moduli and Damping Factors of Soft Marine Clays J. Geotech. Eng. ASCE 118(9):1360-1375.

[2] Anandarajah. A and Chu. J (1997), Laboratory Determination of shear strength parameters for marine clay, Journal of the Institution of Engineers, SINGAPORE, VOL.14, NO.3, PP 39-46.

[3] Narasimha Rao, S and Swamy, K. K. R (1984), Geotechnical Properties of Indian Marine Clays, Ind. Geo-tech conf., Calcutta, Dec 84, Vol.1

[4] Basack and Purkayastha (2009), Engineering properties of Marine Clays from the eastern coast of India. Journal of Engineering and Technology Research Vol.1 (6), pp. 109-114, September, 2009..

[5] N. Degirmenci, A. Okucu, A. Turabi, Application of phosphogypsum in soil stabilization, Building. Environ. 42 (9) (2007) 3393-3398.

[6] "Performance of Hemihydrate PhosphoGypsum in Road Construction", Sam Akly, PE, AIChE Clearwater, 1986. www.aiche-cf.org /Paper # 86.2.4.pdf.

[7] Dr. D. Koteswara Roa (2013), "A laboratoryInvestigation on the affect of vitrified Polish Waste for improving the properties of marine clay", International Journal of Engineering and Innovative Technology (IJEIT),vol.- 2, Issue-11, May 2013,pp 37-41.

[8] Dr. D. Koteswara Rao et.al (2011), the affect of reinforcement on GBFS and lime treated marine clay for foundation soil beds, IJEST, Vol.3, No.3, March 2011.

[9] Dr. D. Koteswara Rao et.al (2012), A laboratory study in the affect of rice husk ash & lime on the properties of marine clay, IJEIT, ISO 9001:2008,ISSN :2277-3754, Vol. 2, Issue 1, July 2012.

[10] K.Ramu, R.D.Babu et al. (2015) "A study on the swelling behavior of marine clay treated with VPW and Lime", IGC, Pune.

[11] Dr. D. Koteswara Rao and k. Pradeep Varma (2018), presented improving the properties of the marine clay using phosphogypsum and lime as subgrade for flexible pavements, IJTIMES, vol. 4, issue.08, August 2018.

[12] Dr. D. Koteswara Rao and Ch. AjayKumar (2018), presented a laboratory investigation on the efficiency of marine clay treated with phosphogypsum and lime as subgrade for flexible pavements, IJTIMES, vol. 4, issue.08, August 2018.

[13] Dr. D. Koteswara Rao and M.T.Ramesh Naidu (2018), presented a laboratory study on the improving the strength characteristics of marine clay using phosphogypsum and calcium chloride as subgrade for flexible pavements, IJTIMES, vol. 4, issue.08, August 2018.

[14] IS 2720-Part II,1973 Methods of test for soils.

[15] IS: 2720-Part III, Section I, 1980, Determination of Specific Gravity.

[16] IS: 2720-Part IV, 1975, Determination of Grain Size Distribution.

[17] IS: 2720-Part V, 1970, Determination of Liquid Limit and Plastic Limit.

[18] IS: 2720-Part VI, 1974, Determination ofDry density and Optimum moisture content.

[19] IS: 2720-Part XVI, (1979), Determination of Californiabearing ratio.

[20] IS: 2720 part-40, (1977), Determination of Free Swell Index.

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