International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 11, November-2019

A LABORATORY INVESTIGATION ON THE EFFICIENCY OF EXPANSIVE SOIL TREATED WITH PHOSPHOGYPSUM AND CALCIUM CHLORIDE AS SUBGRADE FOR FLEXIBLE PAVEMENTS

Dr. D. Koteswara Rao[1], Sajida Sulthana Mohammed[2], G.Samsonu[3]
[1]*Professor of Civil Engineering, UCEK, JNTUK Kakinada, Andhra Pradesh, India,*
[2]*Assistant professor of civil Engineering, UCEK, JNTUK Kakinada ,Andhra Pradesh, India*
[3]*P.G (SM&FE) Student, Department of Civil Engineering, UCEK, JNTUK Kakinada, A.P, India*

Abstract-- Expansive soils are extensively distributed worldwide, it cover approximately one-sixth of the total area of our country mainly in coastal regions and are a source of great damage to infrastructure, buildings and pavements. Most of the time, large areas are covered with highly plastic and expansive soil which is not suitable for the construction purpose. Expansive soils are basically susceptible to detrimental volumetric changes with variations in moisture content due to seasonal variations. Montmorillonite is present in these type of soils due to this the soil exhibits large swelling and shrinkage. Understanding the behaviour of these Expansive soils and adopting suitable methods to overcome the failures in these problematic soils have become a challenging task for geotechnical engineers. The present study deals with the strength behaviour of the expansive soil collected from Relligadda, nearby Amalapuram, East Godavari district, Andhra Pradesh, India, on adding Phosphogypsum as an admixture and Calcium chloride as a chemical for improving the strength characteristics of the expansive soil. The laboratory tests have been carried out and results were reported in this paper

Key Words—Expansive Soil, Phosphogypsum(PG) , Calcium chloride, Optimum Moisture Content (OMC) & Maximum Dry Density (MDD), CBR

I. INTRODUCTION

Development of roads play important role for transportation, and for freight in India. There is need of safe and good roads for transporting the men and Goods. Almost all the pavements service life depends upon subgrade soil of that pavement. Subgrade is the main constituent earth material of the pavements for carrying the load, so, it is necessary to check the properties required for the subgrade to bear the designed traffic. Otherwise, the pavement service life gets gradually decreases.

The studies are carried out on causes of pavement failures (Sharad.S.Adlinge and Prof.Ankit Gupta, 2004) mainly reported that the subgrade is weak and the subgrade soil cannot take the designed load. By considering this criteria, There is a need of stabilization of black cotton soils as they are covered in major portion of India. Their engineering properties can be improved by adopting suitable stabilization methods. Investigations were carried out for various subgrade soils of pavement such as black cotton soils, marine clays, and soft soils by treating with various additives (Biswas Gourhari et al., 2010) such as fly ash (Baiwara Ramlakhan et al 2013) lime (Kunal Anand et al., 2013; Nadgouda. K.A and Hegde. R.A, 2010) rice husk ash (Dr. D. Koteswara Rao et al., 2012) etc. By the usage of different by products or waste materials, produced by industries can be used for the strengthening of weak Expansive soil and also their disposal problems can be achieved. Phosphogypsum is a solid powder waste by product from processing of phosphate rock. This is also causing a great disposal problems, so it can be utilized as a stabilizing material on improving the weak soils such as expansive soils (K. Divya krishnan et al, 2014) and differnert additives for soft soils and also in soil-cement (K. Purnanandam et al., 2013) and concrete stabilization (M.T.S Lakshmayya and G. Aditya, 2017), here in this study stabilization technique is adopted by the usage of Phosphogypsum for expansive subgrade soil. Optimum dosage of PHOSPHOGYPSUM addition is found by conducting various tests confining to standards of Indian soil testing codes (IS 2720-3-1 (1980), (IS 2720-4 (1985), (IS 2720-8 (1983), (IS 2720-16 (1987), (IS 2720-40 (1977), (IS2720 Part 20-(1992), (IS 2720- Part 10- (1991)) and then in addition to this Calcium chloride is also used to impart additional strength. And then load tests are done on stabilized soil as subgrade according to the standards of Indian road congress (IRC: 37-2012).

Fig.1 Phosphogypsum

Fig.2 Calcium chloride

II.OBJECTIVES OF STUDY

The objectives of the present laboratory investigation are as follows.

- To identify the techniques to overcome the problems associated with expansive soil with a view to adopt suitable methodology through critical review of literature.
- To determine the properties of the expansive soil and Phosphogypsum.
- To evaluate the performance of expansive soil treated with optimum % of Phosphogypsum as an admixture and also on addition of % variation of Calcium Chloride as an additive.

III.MATERIALS USED

A. Expansive Soil (ES)

The soil used in this study is of expansive in nature, collected at a depth of 2.0m from ground level from Rellugadda village which is nearby Amalapuram, East Godavari District, Andhra Pradesh. The engineering and index properties of the expansive soil were determined as per IS codes of practice. The geotechnical properties of the air dried expansive soil such as the differential free swell, specific gravity, liquid limit, plastic limit, compaction, CBR were determined as per IS Codes of Practice and the results were tabulated as follows.

TABLE 1
GEOTECHNICAL PROPERTIES OF THE UNTREATED EXPANSIVE SOIL

S.NO	Property		Expansive Soil
1	Gravel (%)		3
2	Sand (%)		10
3	Fines (%)	silt	24
		clay	63
4	Liquid limit (%)		55.27
5	Plastic limit (%)		29.17
6	Plastic index (%)		26.10
7	Soil classification		CH
8	Specific gravity		2.57
9	Differential Free Swell (%)		132
10	O.M.C (%)		19.88
11	M.D.D (g/cc)		1.585
12	Cohesion (Kg/cm^2)		0.8
13	CBR (%)		1.56
14	Angle of internal friction (^{0})		5.61^0

B. Phosphogypsum

For the present study, the Phosphogypsum was collected from Nagarjuna Fertilizers, Samalkot, A.P, India. It is a waste by product from processing of phosphate rock. In the present study the addition of Phosphogypsum was varied from 1% to 7% for stabilizing the expansive soil. The chemical composition of the Phosphogypsum were shown in table 2.

TABLE2

CHEMICAL COMPOSITION OF PHOSPHOGYPSUM

Chemical composition	**Percentage (%)**
SO_3	42.3
CaO	31.2
Phosphate ,Fluoride	18.49
SiO_2	3.92
P_2O_5	3.6
MgO	0.49

(Courtesy: Nagarjuna Fertilizers ,Samalkot **)**

C. Calcium chloride

For the present study, Calcium chloride was collected from Nagarjuna Fertilisers, Samalkot, A.P, India . Calcium chloride is a salt obtained from natural brines as a byproduct from synthetic soda ash production and can be produced from hydrochloric acid and lime stone. In the present study the addition of Calcium chloride was varied from 0.5% to 3% for further stabilizing the expansive soil. The properties of the calcium chloride were shown in table 3.

TABLE 3
PROPERTIES OF CALCIUM CHLORIDE

Property	**Value**
Molar mass	110.98 $g.mol^{-1}$
Appearance	White powder
Odour	Odourless
Density	2.15g/cm^3
Melting point	772-775°C
Boiling point	1935°C

(Courtesy: Nagarjuna Fertilizers, Samalkot)

IV.LABORATORY INVESTIGATION

The laboratory studies were carried out on the expansive soil, expansive soil with percentage variation of Phosphogypsum for obtaining the optimum mix and also soil with optimum percentage of Phosphogypsum on percentage variation of Calcium chloride.

A. Liquid limit

The liquid limit test was conducted on the expansive soil, the expansive soil treated with an optimum of 5% of Phosphogypsum and also on the expansive soil treated with an optimum of 5% of Phosphogypsum & 2% of Calcium chloride mixes by using Casagrande's liquid limit apparatus as per the procedures given in the IS: 2720 part 4 (1970).

B. Plastic limit

Similarly the Plastic limit test was conducted on the Expansive soil, expansive soil treated with optimum of 5% Phosphogypsum and expansive soil treated with optimum of 5% Phosphogypsum and 2% Calcium chloride as per the specifications given in IS: 2720 part 4 (1970).

C. Differential Free Swell

Differential Free Swell (DFS) is a parameter used for the expansiveness identification of the soil. To determine the free swell of a soil, oven dry soil passing through 425µ size sieve is taken i.e 20g. One sample of l0g is taken into a l00cc capacity graduated cylinder containing kerosene oil , and the other sample of 10g is taken into a l00cc capacity graduated cylinder containing water.

$$\text{Differential Free Swell (\%)} = V_d - V_k / V_k$$

Where,

V_d = volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = volume of soil specimen read from the graduated cylinder containing kerosene.

Kerosene is a non-polar liquid, it does not cause any swell of the soil IS: 2720 (Part III- l980) gives degree of soil expansion depending upon its differential free swell as under.

TABLE 4

RANGE OF DIFFERENTIAL FREE SWELL

S. No	Differential Free Swell	DFS
1	Low	<20%
2	Moderate	20-35%
3	High	35-50%
4	Very High	>50%

(Courtesy: Basic and Applied Soil Mechanics by Gopal Ranjan and A.S.R Rao pp:704)

D. *Proctor Modified compaction Test*

The expansive soil was treated with different percentages of admixture i.e., the Phosphogypsum. Phosphogypsum was replaced with the expansive soil in different percentages varying from 1% to 7% to improve the properties of the expansive soil. Table 5 represents the OMC and MDD values of untreated expansive soil and also treated expansive soil with percentage variation of Phosphogypsum.

E. Specific Gravity Test

Specific gravity is the ratio of the mass of unit volume of soil to the mass of the same volume of gas-free distilled water at a standard temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given soil volume. Specific gravity test was carried out by Pycnometer as per IS 2720 Part 3 (1980).

F. California Bearing Ratio Test

The California bearing ratio test was conducted on the soil sample with 4 varying percentages of Phosphogypsum. Phosphogypsum added to soil in varying percentages of (1%,3%,5%,7%) respectively. CBR value increases up to 5 % addition of Phosphogypsum, by further adding Phosphogypsum the CBR value of soil decreases. The maximum value of CBR for 5 % addition of Phosphogypsum was obtained as 3.12 %. The CBR value showed an Increase from 1.59% to 3.12% at 5% addition of Phosphogypsum. Further on addition of 2% Calcium chloride to soil and 5% Phosphogypsum the CBR increased from 3.12% to 8.2%. The test was conducted under a constant strain rate of 1.25mm/min. The proving ring reading is noted for 50 divisions, and loading was continued until 3 (or) more readings are decreasing (or) constant. The test was conducted at Optimum moisture content. The samples were tested in soaked condition.

G. Compaction Test Results

TABLE 5

OMC AND MDD VALUES OF UNTREATED & TREATED EXPANSIVE SOIL WITH PERCENTAGE VARIATION OF PHOSPHOGYPSUM

Expansive soil Treated with % variation of Phosphogypsum	**MDD (gm/cc)**	**OMC (%)**
Soil	1.585	19.88
Soil+1%PG	1.575	19.72
Soil+3%PG	1.592	18.93
Soil+5%PG	1.662	18.48
Soil+7%PG	1.606	18.15

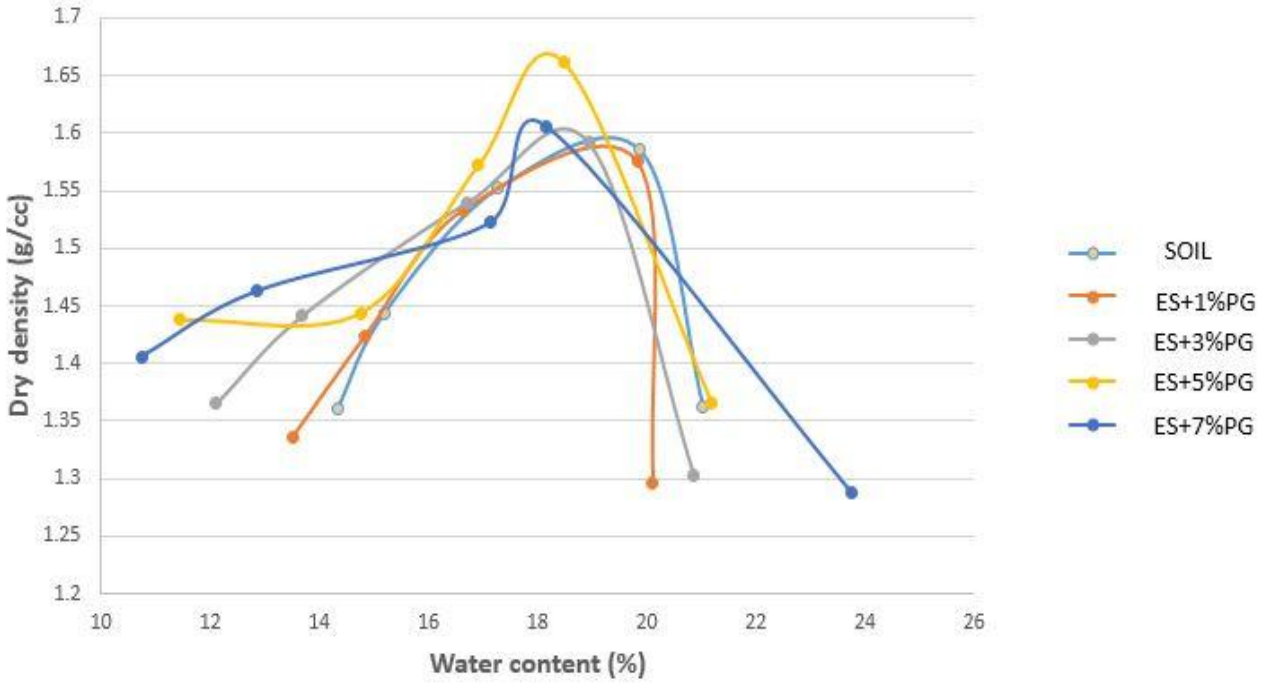

Fig.3 OMC & MDD values of untreated soil & treated with % variation of Phosphogypsum

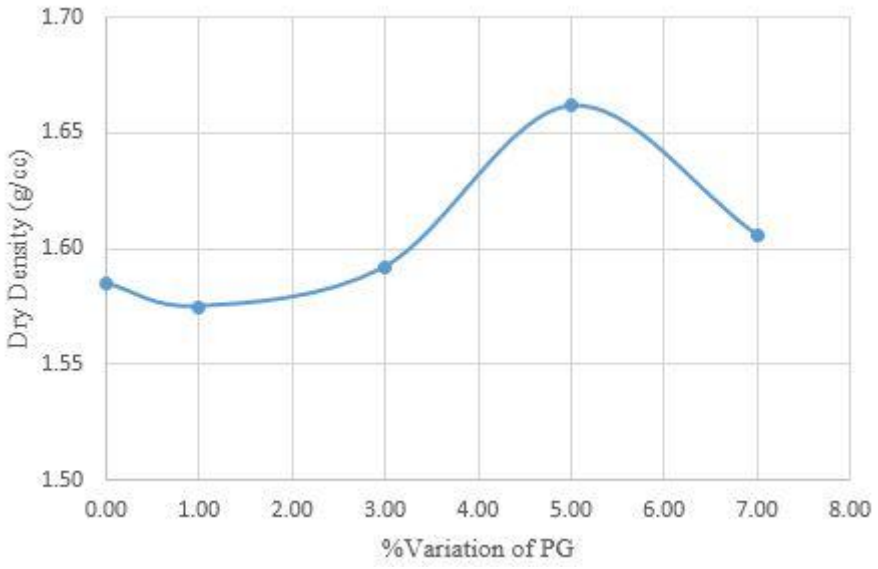

Fig.4 MDD of the soil treated with % variation of Phosphogypsum

H. CBR TEST RESUTLS

The soaked CBR values of various mixes of Expansive Soil and Phosphogypsum using OMC obtained from compaction are determined. The soaked CBR after immersing the sample in water for four days, that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Phosphogypsum is presented.

TABLE 6

CBR VALUES OF UNTREATED SOIL & SOIL TREATED WITH % VARIATION OF PHOSPHOGYPSUM

Soil treated with % variation of Phosphogypsum	Soaked CBR (%)
Soil	1.59
Soil+1%PG	2.23
Soil+3%PG	2.85
Soil+5%PG	**3.12**
Soil+7%PG	2.95

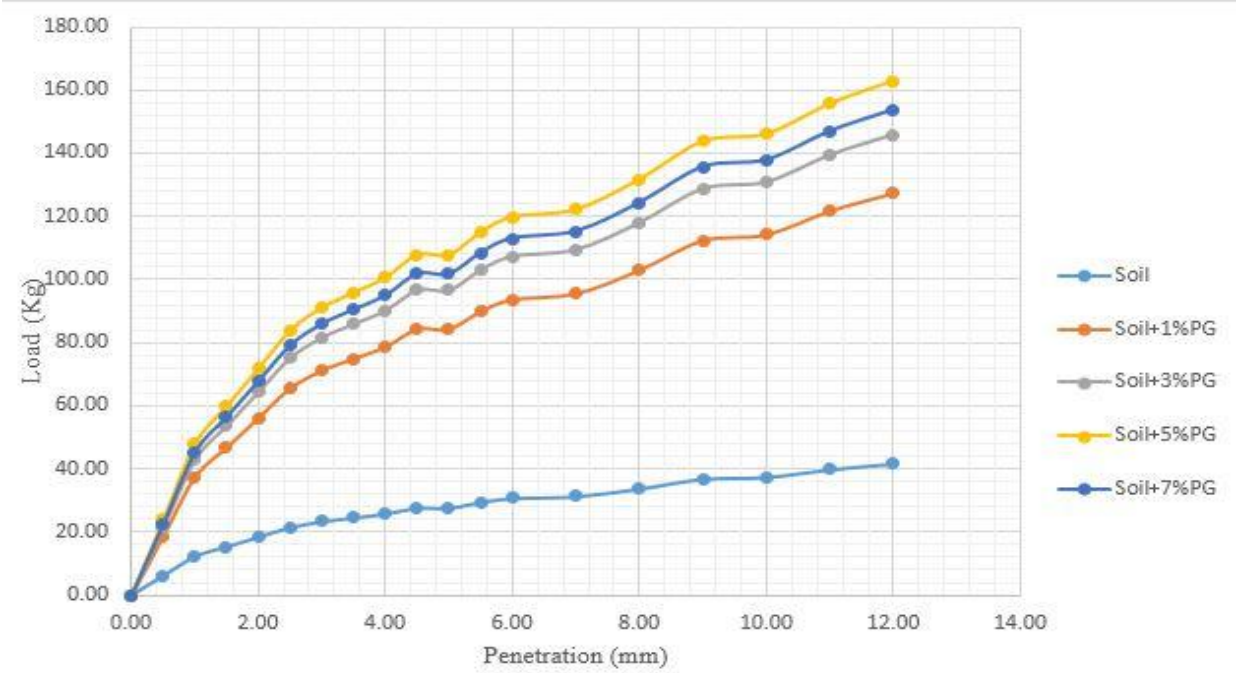

Fig.5 CBR values of untreated & expansive soil treated with % variation of Phosphogypsum

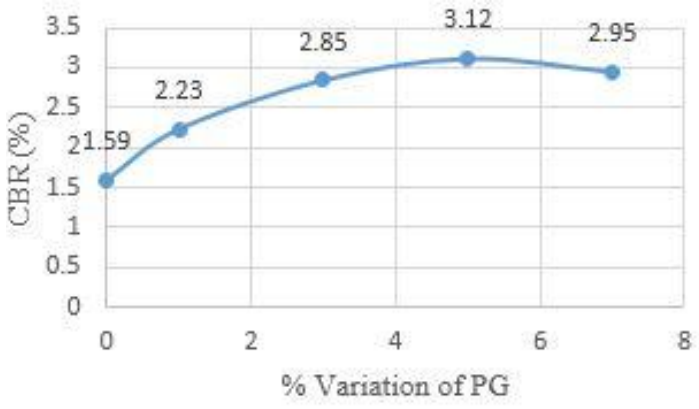

Fig.6 CBR Values of Expansive Soil with % Variation of Phosphogypsum

DISCUSSION-1

It was observed from the laboratory test results that the expansive soil treated with an optimum of 5% of Phosphogypsum has exhibited the CBR value of 3.12%, which is less as per IRC:37-2012, pp:10, to use this treated expansive soil as subgrade for flexible pavements.

Further, it is essential to improve the CBR value of this treated expansive soil to suit it as subgrade for flexible pavement as per IRC codes of practice. For which an attempt has been taken by adding calcium chloride as an additive for improving the CBR value of the expansive soil treated with 5% of Phosphogypsum.

I). Initially, the OMC, MDD and CBR values were determined for the treated expansive soil with percentage variation of Calcium chloride and the results were shown in tables 7&8 respectively.

TABLE 7

OMC & MDD VALUES OF THE EXPANSIVE SOIL TREATED WITH AN OPTIMUM OF 5% PHOSPHOGYPSUM AND ON ADDITION OF PERCENTAGE VARIATION OF CALCIUM CHLORIDE

Phosphogypsum treated expansive soil with percentage variation of Calcium chloride	**MDD (g/cc)**	**OMC (%)**
Soil+5%PG+0.5%$Cacl_2$	1.624	17.56
Soil+5%PG+1% $Cacl_2$	1.656	17.23
Soil+5%PG+2% $Cacl_2$	**1.692**	**16.52**
Soil+5%PG+3% $Cacl_2$	1.642	16.73

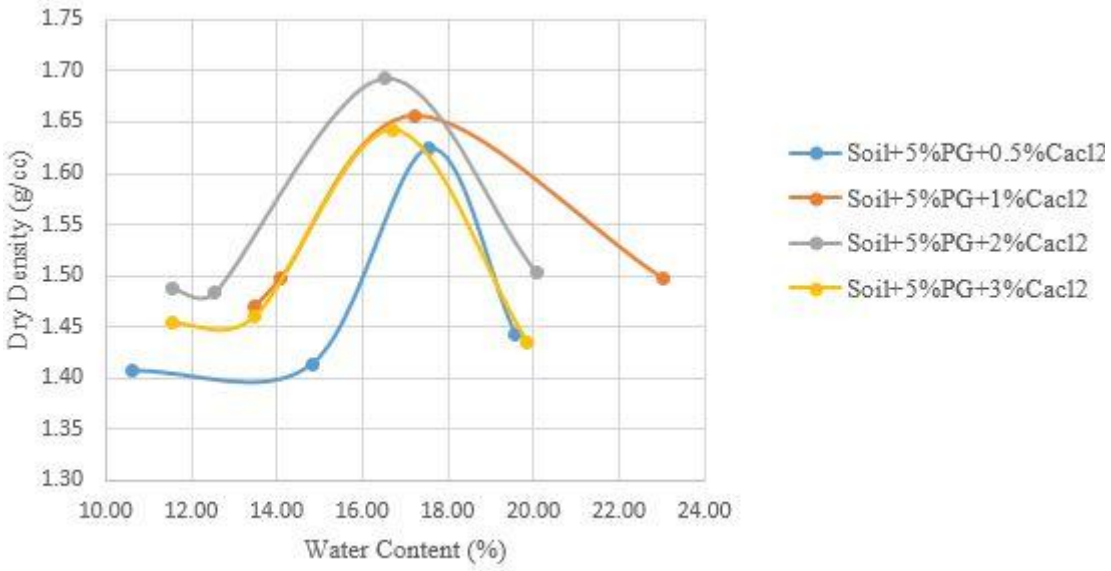

Fig.7 OMC&MDD values of soil treated with an optimum of 5% Phosphogypsum upon adding % variation of Calcium chloride

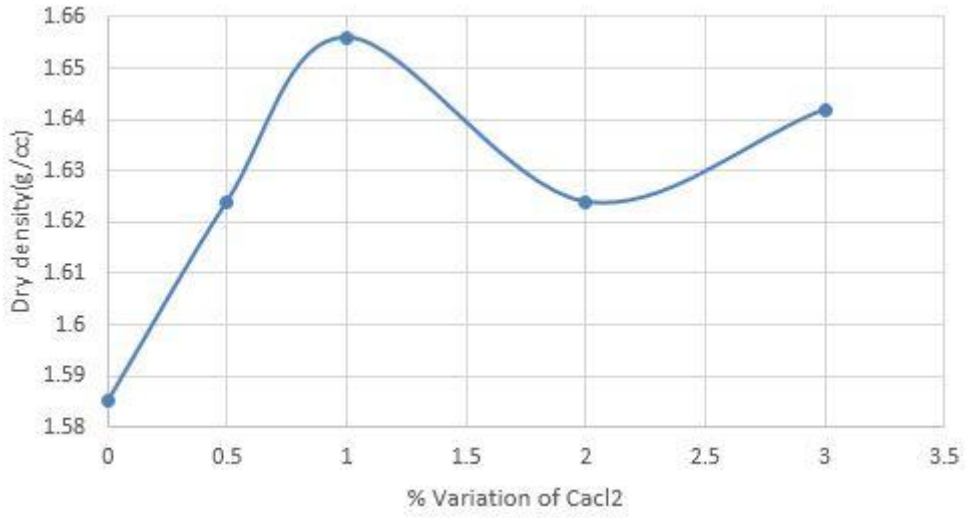

Fig.8 MDD values of Soil treated with 5% of Phosphogypsum on addition of % Variation of $Cacl_2$

TABLE 8
CBR VALUES OF THE SOIL TREATED WITH AN OPTIMUM OF PHOSPHOGYPSUM UPON ADDING PERCENTAGE VARIATION OF CALCIUM CHLORIDE

Phosphogypsum treated expansive soil with percentage variation of Calcium chloride	**CBR (%)**
Soil+1%PG+0.5% $Cacl_2$	5.36
Soil+3%PG+1% $Cacl_2$	6.52
Soil+5%PG+2% $Cacl_2$	**8.20**
Soil+7%PG+3%$Cacl_2$	7.42

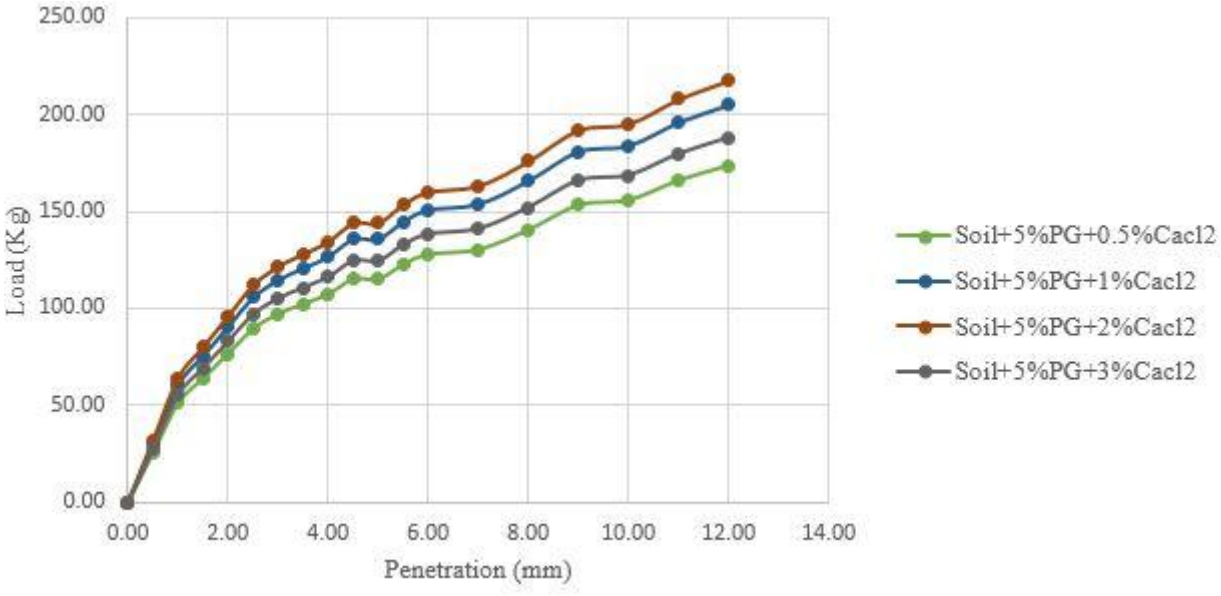

Fig.9 CBR test results of expansive soil treated with an optimum of Phosphogypsum upon adding percentage variation of $Cacl_2$

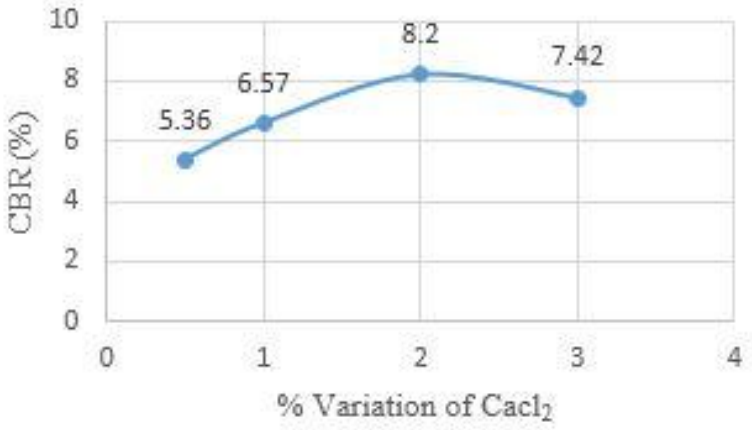

Fig.10 The Variation of CBR treated with the optimum of Phosphogypsum on Percentage variation of $Cacl_2$

DICUSSION-2

It was observed from the above laboratory test results that the expansive soil treated with an optimum of 5% Phosphogypsum and 2% Calcium chloride has exhibited a CBR value of 8.20%, which is desirable as per IRC:37-2012, pp:10 Codes of practice to use this treated expansive soil as subgrade for flexible pavements.

Hence the laboratory tests viz Liquid limit, Plastic limit, Plasticity Index, Compaction, CBR, Specific gravity, Differential Free Swell, Cohesion, angle of shearing resistance was conducted on the expansive soil treated with the optimum percentage of Phosphogypsum and Calcium chloride. The results were as follows:

TABLE 9

LABORATORY TEST RESULTS OF THE UNTREATED AND TREATED EXPANSIVE SOIL

S. No	**Property**	**Untreated expansive soil**	**Expansive soil treated with 5% of PHOSPHOGYPSUM**	**Expansive soil treated with optimum percentages of 5% PHOSPHOGYPSUM and 2% Cacl2**
1	Liquid limit (%)	55.27	50.15	46.51
2	Plastic limit (%)	29.17	26.13	24.62
3	Plastic index (%)	26.10	24.02	21.89
4	Soil classification	CH	CH	CI
5	Specific gravity	2.57	2.65	2.78
6	D. F.S (%)	132	82	48
7	O.M.C	19.88	18.48	16.52
8	M.D.D (g/cc)	1.585	1.662	1.692
9	Cohesion (Kg/cm^2)	0.8	0.62	0.46
10	Angle of shear resistance (^{0})	5.61^0	8.32^0	12.26^0
11	CBR (%)	1.59	3.12	8.20

V. CONCLUSIONS

1) It is observed that the liquid limit of the Expansive Soil has been improved by 10.20% on addition of 5% Phosphogypsum and further it has been improved by 15.84% on addition of 2% Calcium chloride when compared with untreated expansive soil.
2) It is noticed from the laboratory test results that the plasticity index of the Expansive Soil has been improved by 7.96% on addition of 5% Phosphogypsum and further this treated expansive soil has been improved by 16.13% on addition of 2% Calcium chloride when compared with untreated expansive soil.
3) It is noticed that the cohesion of Expansive Soil has been improved by 22.50% on addition of 5% Phosphogypsum and it has been further improved by 42.50% on addition of 2% Calcium chloride when compared with untreated expansive soil.
4) It is found that the angle internal friction of Expansive Soil has been improved by 48.30% on addition of 5% Phosphogypsum and it has been further improved by 118.53% on addition of 2% Calcium chloride when compared with untreated expansive soil.
5) It is found that the O.M.C of the Expansive Soil has been improved by 7.04% on addition of 5% Phosphogypsum and it has been further improved by 16.90% on addition of 2% Calcium chloride when compared with untreated expansive soil.
6) It is found that the M.D.D of the Expansive Soil has been improved by 4.85% on addition of 5% Phosphogypsum and it has been further improved by 6.75 % on addition of 2% Calcium chloride when compared with untreated expansive soil.
7) It is observed that the C.B.R value of the Expansive Soil has been improved by 96.22% on addition of 5% Phosphogypsum and it has been further improved by 415.72% on addition of 2% Calcium chloride when compared with untreated expansive soil.
8) It is observed that the DFS value of the Expansive Soil, has been improved by 37.87% on addition of 5% Phosphogypsum and it has been further improved by 63.63% on addition of 2% Calcium chloride when compared with untreated expansive soil.

REFERENCES

[1] S.W. Thakare and Priti Chauhan "*Stabilization of expansive soil with micro silica fume, lime and fly ash for pavement".*

[2] Bell, F.G., Engg. (1993), Treatment of Soils, E&FN Spon Pub. Co., 1993

[3] Chen, F.H (1988), Foundations on Expansive Soils, Elsevier Pub. Co., Amsterdam.

[4] Chhaya Negi, R.K Yadav and A.K.Singhai "*Effect of silica fume on engineering properties of black cotton soil*"

[5] Dr. D. Koteswara Rao, Venkatesh Ganja, P.R.T Pranav, "*A laboratory study of Cyclic Plate load test on lime and rice husk ash treated marine clay subgrade flexible pavements*," International Journal of Modern Engineering Research, Vol. 2, No. 5, pp. 4465-4469, Sep. 2012.

[6] Al-Rawas, N.M (2000), *Effect of curing and temperature on lime stabilization*, Proc. Of Second Australian Conf. On Engineering Materials, Sydney, 1981, pp.611-662

[7] Ameta, N. K D.G.M Purohi and A.S. Wayal (2007), Characteristics, Problems and Remedies of Expansive Soils of Rajasthan, India. EJGE-2007.

[8] Ramaiah, B.K., et.al (1972), *Stabilization of black cotton soil with lime and Rice-Husk-Ash*, Indian Geotechnical Society, Proc. Tech. Sessions, Vol. 1, New Delhi, 1972

[9] Dr. D. Koteswara Rao, "*A Laboratory Investigation on the Effect of Vitrified Polished Waste for Improving the Properties of Marine Clay,"* International Journal of Engineering and Innovative Technology, Vol. 2, No. 11, pp. 37-41, May 2013.

[10] Dr.K.Purnanandam, R. Dayakar Babu, P. Balaji Chakravarthy, V. Surya Prasad, "*Strength characteristics of Vitrified Polish Waste modified with cement*," Proceedings of Indian Geotechnical Conference Roorkee, pp. 1-6, Dec. 2013.

[11] Upma and J. Sudheer Kumar "*Effect of Cement Kiln Dust and Chemical additive on Expansive Soil at Subgrade level*".

[12] IS: 2720 (Part - 3/sec 1)-1980, "*Determination of Specific Gravity for Fine grained soils*".

[13] IS: 2720 (Part 4)-1985, "*Determination of Grain size analysis for soils*".

[14] IS: 2720 (Part 8)-1983, "*Determination of Water content - Dry density relation using Heavy compaction*"

[15] IS: 2720 (Part - 11)-1993, "*Determination of the Shear strength parameters of a specimen tested in Unconsolidated and Undrained Triaxial compression without the measurement of pore water pressure*".

[16] IS: 2720 (Part - 16)-1979, "*Laboratory determination of CBR*".

[17] IS: 2720 (Part 40)-1977, "*Determination of Differential Free Swell Index*".

[18] IS 2720- Part 10- 1991 "*Method to determine unconfined compressive strength of soils.*

VII.BIOGRAPHIES

Author 1

Dr. D. Koteswara Rao is working as a Professor of Civil Engineering, Department of Civil Engineering, University College of Engineering, Jawaharlal Nehuru Technological University Kakinada, Kakinada.

- He is the " **Triple Hat-Trick Best Teacher Awardee**" from the Department of Civil Enginering, University College of Engineering, JNTUK Kakinada.
- He was awarded **"The University Meritorious Teacher Award -2013"** by the University Authorities.
- He has received **"The National Award-2013 for Teaching Excellence in Civil Engineering"**.
- Recently he has received **"The State Best Teacher Award-2017"** by the Government of Andhra Pradesh, A.P, India.

He has published 46 research and review papers in various international journals and conferences. He has guided about 60 post graduate projects and also four research scholars are working under his guidance. He is a leading consulting member in the fields of Surveying, Transportation and Geotechnical Engineering.

Dr. D. Koteswara Rao, Professor of Civil Engineering, University College of Engineering, JNTUK Kakinada, East Godavari District-533003, Andhra Pradesh, India.

Author 2:

Md. Sajida Sulthana, Assistant Professor of Civil Engineering ,University College of Engineering, JNTUK Kakinada, East Godavari District-533003, Andhra Pradesh, India.

Author 3:

Mr . G. Samsonu PG student of SM&FE , Department of Civil Engineering , University College of Engineering, JNTUK Kakinada, East Godavari District-533003, Andhra Pradesh, India.