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A LABORATORY INVESTIGATION ON THE EFFICIENCY OF EXPANSIVE SOIL TREATED WITH VITRIFIED POLISH WASTE AND PHOSPHOGYPSUM AS SUBGRADE FOR FLEXIBLE PAVEMENTS

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Abstract-- Expansive soils are widely distributed approximately one-sixth of the total area of our country. Expansive soil causes great damage to infrastructure viz buildings and pavements. Mostly, these soils are covered with highly plastic and the expansive soil which is unfavorable for the construction purpose. The black cotton soils are basically prone to detrimental swell and shrinkage with variations in water content. The volume changes of soil are due to the presence of mineral montmorillonite, which shows large swelling and shrinkage. By testing the behavior of these clayey soils and embracing suitable measures to alter the properties of the subjected soil. The present study deals with the strength behavior of the expansive soil collected from Rellugadda nearby Amalapuram, East Godavari district, Andhra Pradesh, India. On adding Vitrified Polish Waste as an admixture and Phosphogypsum for enhancing the strength of the subjected soil. The laboratory tests have been carried out and results were reported in the present study.

Key Words—Expansive Soil, Vitrified Polish Waste, Phosphogypsum, Optimum Moisture Content (OMC) & Maximum Dry Density (MDD), CBR

I. INTRODUCTION

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

The studies are carried out on causes of failures of pavement (Sharad.S.Adlinge and Prof.Ankit Gupta, 2004) mainly reported that the reason was, due to weak subgrade which is because of presence of weak soils which cannot take the designed load. By considering this criteria, black cotton soils are in prime need for stabilization as they are present in major portion of India. Their engineering properties can be improved by suitable stabilization techniques. Investigations on large scale were carried out for various pavement subgrade soils such as black cotton soils, marine clays, and soft soils by using 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 waste materials, produced by industries can be used for the improvement of weak soil and also the problem of their disposal can be achieved. Vitrified polish waste is a solid waste produced from tiles manufacturing process. This is also causing a great disposal problems, but it has specific pozzolanic properties, so it can be utilized as a stabilizing material on improving the weak soils such as marine clays (Dr. D. Koteswara Rao, 2013), 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 adapted by usage of vitrified polish waste for expansive subgrade soil. Optimum dosage of VPW 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 phosphogypsum 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 Vitrified Polish Waste

Fig.2 Phosphogypsum

II.OBJECTIVES OF STUDY

The objectives of the present laboratory investigation are as follows.

- To identify the strategy of techniques to overcome the problems posed by expansive soil with a view to adopt suitable methodology through critical review of literature.
- To determine the properties of the expansive soil and vitrified polish waste.
- To evaluate the performance of expansive soil treated with optimum % of Vitrified polish waste as an admixture and also on addition of % variation of Phosphogypsum 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 1.5m from ground level from Rellugadda village which is nearby Amalapuram, East Godavari District, Andhra Pradesh. The index and engineering properties of the expansive soil were determined as per IS codes of practice. The geotechnical properties of the airdried expansive soil such as the liquid limit, plastic limit, specific gravity, differential free swell, 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 (%)		62.06
5	Plastic limit (%)		29.17
6	Plastic index (%)		32.89
7	Soil classification		CH
8	Specific gravity		2.56
9	Differential of Free Swell (%)		117
10	O.M.C (%)		19.88
11	M.D.D (g/cc)		1.56
12	Cohesion (KN/m^2)		106
13	CBR (%)		1.58
14	Angle of internal friction (^{0})		5.4^0

B. Vitrified Polish Waste (VPW)

For the present study, the Vitrified polish waste was collected from RAK Ceramics, Samalkot, A.P, India. It is a waste product obtained during the manufacturing of Vitrified Tiles in the ceramic industry. In the present study the addition of VPW was varied from 5% to 20% for stabilizing the expansive soil. The chemical composition of the VPW were shown in table 2.

TABLE 2
CHEMICAL COMPOSITION OF VITRIFIED POLISH WASTE

Oxide composition	Percentage %
SiO_2	49.52
Al_2O_3	14.70
CaO	1.40
Fe_2O_3	0.40
MgO	2.45
Na_2O	2.71
K_2O	2.69
P_2O_5	0.05

(Courtesy: RAK Ceramics Samalkot **)**

For the present study, Phosphpogypsum was collected from Nagarjuna Fertilisers, Samalkot, A.P, India. Phosphogypsum is obtained from filtration process of phosphoric acid plants where efficient removal of insoluble gypsum and other insolubilities are done. At an average of 4.5 - 5 Tons of phosphogypsum (dry) is generated for every Ton of phosphoric acid (P2O5) recovered, depending upon the source of phosphate rocks. In the present study the addition of PG was varied from 1% to 7% for further stabilizing the expansive soil. The chemical composition of the phosphogypsum were shown in table 3.

TABLE 3
CHEMICAL COMPOSITION OF PHOSPHOGYPSUM

Chemical composition	**Percentage %**
CaO	31.20
SiO_2	3.92
SO_3	42.30
P_2O_5	3.60
MgO	0.49
Phosphate, Fluoride	18.49

(Courtesy: Nagarjuna Fertilizers Samalkot)

IV.LABORATORY INVESTIGATION

The laboratory studies were carried out on the expansive soil, epansive soil with percentage variation of vitrified polish waste for obtaining the optimum mix and also soil with optimum percentage of VPW on percentage variation of Phosphogypsum.

A. Liquid limit

The liquid limit test was conducted on the expansive soil, the expansive soil treated with an optimum of 15% of VPW and also on the expansive soil treated with an optimum of 15% of VPW & 5% of Phosphogypsum 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, Expansive soil, expansive soil treated with optimum of (15%) VPW and expansive soil treated with optimum of VPW and Phospogysum (5%) 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 identification of the expansiveness of the soil. To determine the free swell of a soil, 20g of oven dry soil passing through 425μ size sieve is taken. One sample of l0g is taken into a l00cc capacity graduated cylinder containing water, and the other sample of 10g is taken into a l00cc capacity graduated cylinder containing kerosene oil. Differential Free Swell (%) = $\frac{vd-vk}{vk} * 100$

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.
Because kerosene is a non-polar liquid, it does not cause any swell of the soil IS: 2720 (Part III- l980) gives degree of expansion of a soil 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 VPW. Vitrified Polish Waste was replaced with the expansive soil in different percentages varying from 5% to 20% to improve the properties of the soil. table 5 represents the OMC and MDD values of untreated expansive soil and also treated expansive soil with percentage variation of VPW.

E. Specific Gravity Test

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil. 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 VPW. Vitrified Polish waste added to soil in varying percentages (5,10,15,20%) respectively. CBR value increases up to 15 % addition of Vitrified Polish waste, by further adding VPW the CBR value of soil decreases. The maximum value of CBR for 15 % addition of VPW was obtained as 6.13%. The CBR value showed an Increase from 1.58% to 6.13% at 15% addition of VPW. Further on addition of 5% PG to soil and 15% VPW the CBR increased from 6.13% to 8.19%. 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. Modified Compaction Test Results

TABLE 5

OMC AND MDD VALUES OF UNTREATED & TREATED EXPANSIVE SOIL WITH PERCENTAGE VARIATION OF VITRIFIED POLISH WASTE

Expansive soil Treated with % variation of VPW	**MDD (gm/cc)**	**OMC (%)**
Soil	1.575	19.88
Soil+5%VPW	1.577	19.53
Soil+10%VPW	1.592	18.94
Soil+15%VPW	1.662	18.48
Soil+20%VPW	1.606	18.15

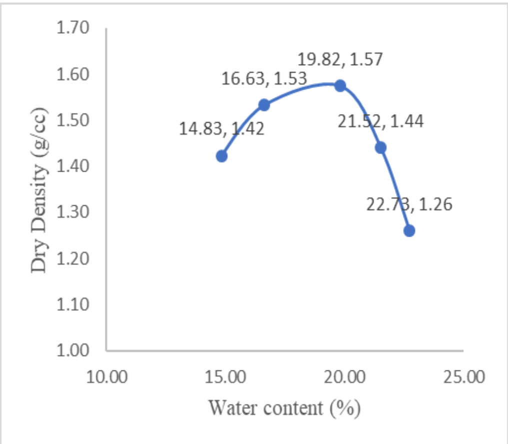

Fig.3 OMC & MDD soil treated with 5% VPW

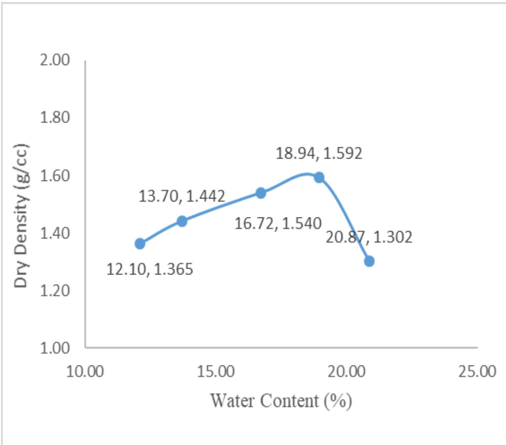

Fig.4 OMC & MDD soil treated with 10% VPW

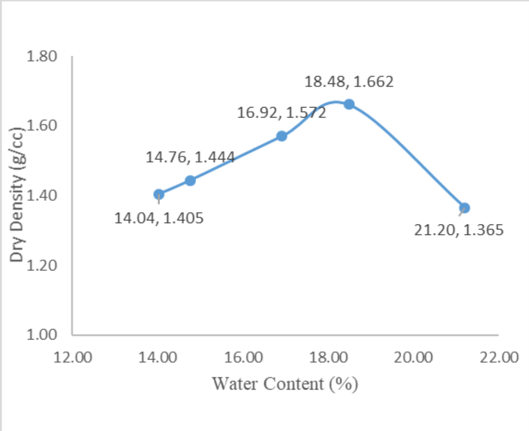

Fig.5 OMC & MDD soil treated with 15% VPW

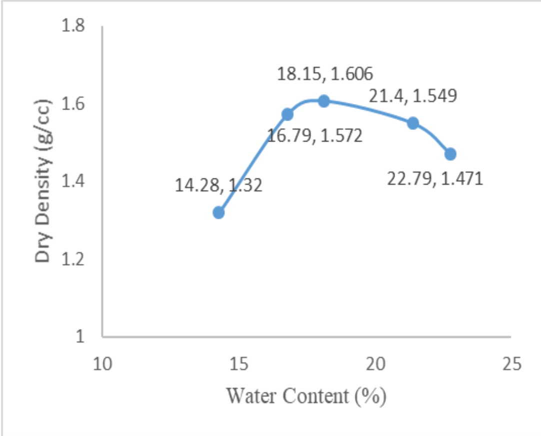

Fig.6 OMC & MDD soil treated with 20% VPW

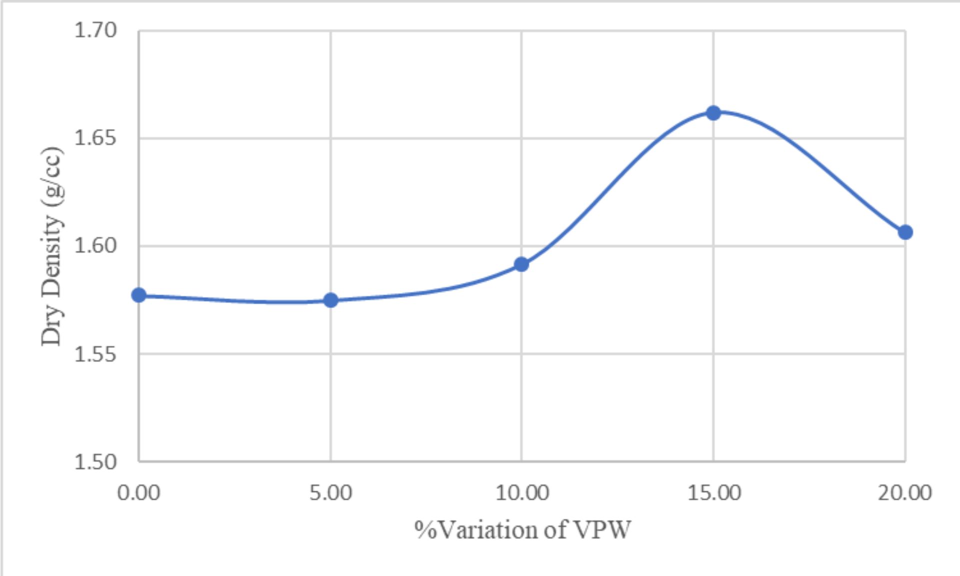

Fig.7 MDD of the soil treated with % variation of VPW

H. CBR TEST RESUTLS

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

TABLE 6

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

Soil treated with % variation of VPW	**Soaked CBR (%)**
Soil	1.58
Soil+5%VPW	1.80
Soil+10%VPW	2.24
Soil+15%VPW	**6.13**
Soil+20%VPW	2.55

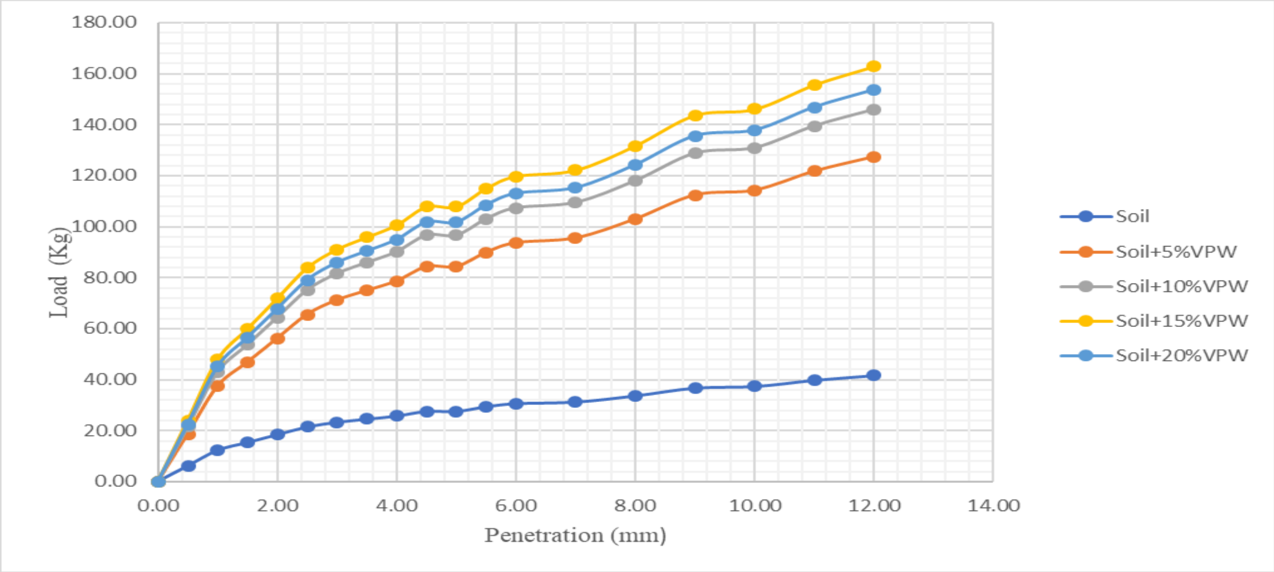

Fig.8 CBR values of untreated & expansive soil treated with % variation of VPW

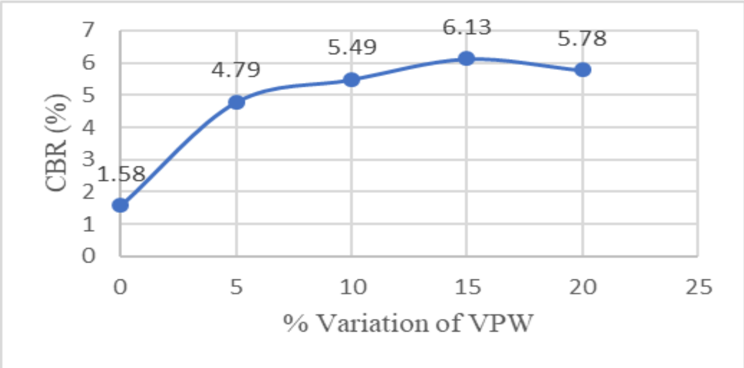

Fig.9 CBR Values of Expansive Soil with % Variation of Vitrified Polish Waste

DISCUSSION-1

It was observed from the laboratory test results that the expansive soil treated with an optimum of 15% of VPW has exhibited the CBR value of 6.13%, 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 phosphogypsum as an additive for improving the CBR value of the expansive soil treated with 15% of VPW.

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

TABLE 7

OMC & MDD VALUES OF THE EXPANSIVE SOIL TREATED WITH AN OPTIMUM OF 15% VPW AND ON ADDITION OF PERCENTAGE VARIATION OF PHOSPHOGYPSUM

VPW treated expansive soil with percentage variation of Phosphogypsum	**MDD (g/cc)**	**OMC (%)**
95%Soil+15%VPW+1%PG	1.592	18.76
95%Soil+15%VPW+3%PG	1.656	18.25
95%Soil+15%VPW+5%PG	**1.701**	**17.92**
95%Soil+15%VPW+7%PG	1.583	16.47

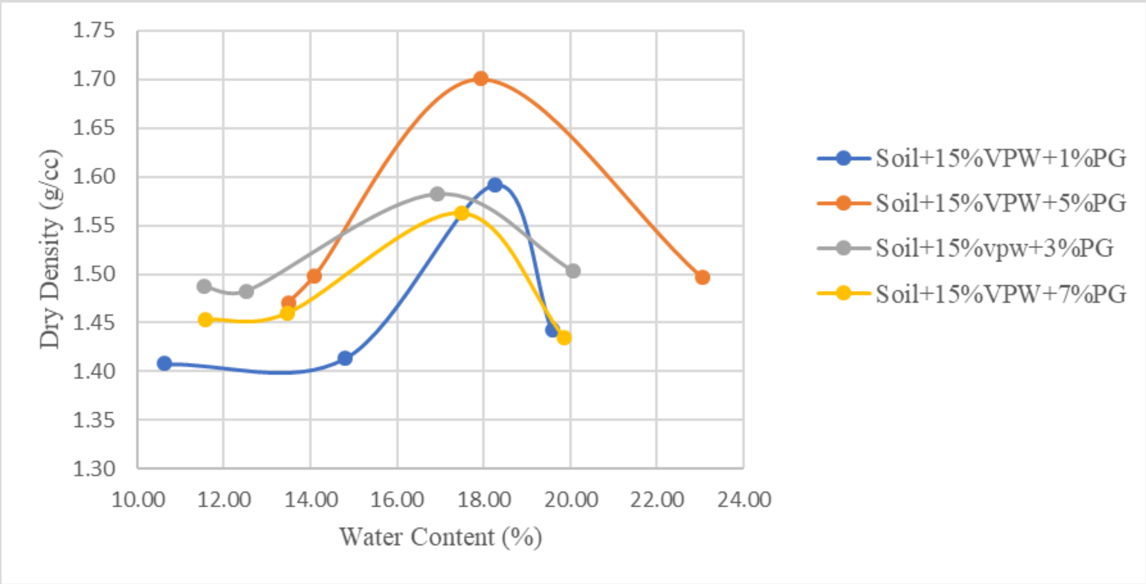

Fig.10 OMC&MDD values of soil treated with an optimum of 15% VPW upon adding percentage variation of Phosphogypsum

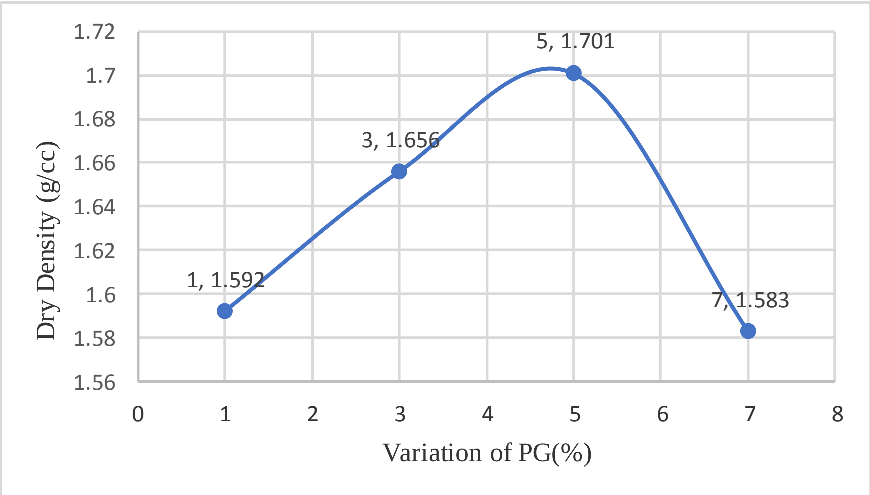

Fig.11 MDD values of Soil treated with 15% of VPW on addition of % Variation of PG

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

VPW treated expansive soil with percentage variation of PG	CBR (%)
95%Soil+5%VPW+1%PG	6.583
95%Soil+10%VPW+3%PG	7.721
95%Soil+15%VPW+5%PG	**8.193**
95%Soil+20%VPW+7%PG	7.071

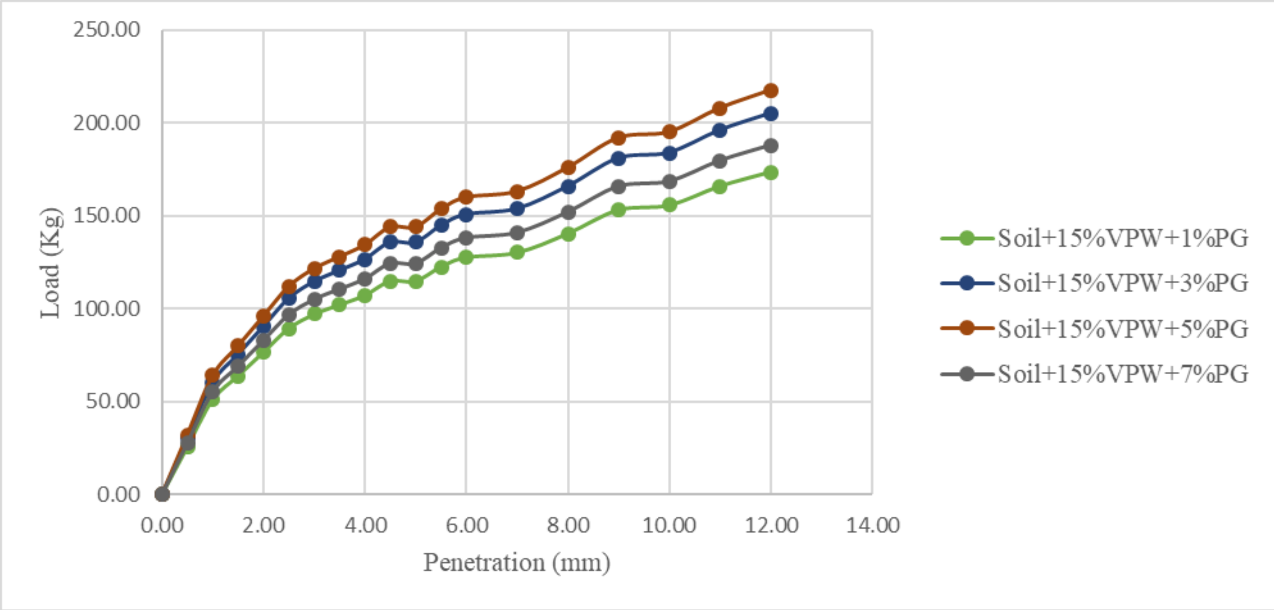

Fig.12 CBR test results of expansive soil treated with an optimum of VPW upon adding percentage variation of PG

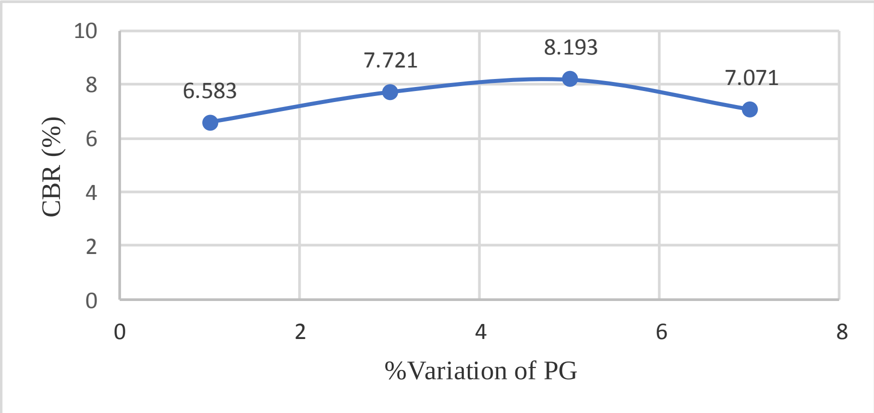

Fig.13 The Variation of CBR treated with the optimum of VPW on Percentage variation of Phosphogypsum

DICUSSION-2

It was observed from the above laboratory test results that the expansive soil treated with an optimum of 15% VPW and 5% Phosphogypsum has exhibited a CBR value of 8.19%, 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 VPW and Phosphogypsum. The results were as follows:

TABLE 9
LABORATORY TEST RESULTS OF THE UNTREATED AND TREATED EXPANSIVE SOIL

Si.No	Property	Untreated expansive soil	Expansive soil treated with 15% of VPW	Expansive soil treated with optimum percentages of 15% VPW and 5% PG
1	Liquid limit (%)	62.06	57.17	48.66
2	Plastic limit (%)	29.17	34.53	36.24
3	Plastic index (%)	32.89	22.64	12.42
4	Soil classification	CH	CH	CI
5	Specific gravity	2.56	2.72	2.75
6	D. F.S (%)	117	75	47
7	O.M.C	19.88	18.48	17.92

8	M.D.D (g/cc)	1.56	1.662	1.701
9	Cohesion (KN/m^2)	106	72	69
10	Angle of shear resistance (^{0})	5.4^0	17.7^0	18.2^0
11	CBR (%)	1.58	6.13	8.19

V. CONCLUSIONS

1) It is observed that the liquid limit of the Expansive Soil has been improved by 7.87% on addition of 15% Vitrified Polish Waste and further it has been improved by 21.59% on addition of 5% Phosphogypsum 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 31.16% on addition of 15% Vitrified Polish Waste and further this treated expansive soil has been improved by 62.23% on addition of 5% Phosphogypsum when compared with untreated expansive soil.
3) It is noticed that the cohesion of Expansive Soil has been improved by 32.07% on addition of 15% Vitrified Polish Waste and it has been further improved by 34.90% on addition of 5% Phosphogypsum when compared with untreated expansive soil.
4) It is found that the angle internal friction of Expansive Soil has been improved by 227.77% on addition of 15% Vitrified Polish Waste and it has been further improved by 237.03% on addition of 5% Phosphogypsum 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 15% Vitrified Polish Waste and it has been further improved by 9.86% on addition of 5% Phosphogypsum when compared with untreated expansive soil.
6) It is found that the M.D.D of the Expansive Soil has been improved by 6.53% on addition of 15%, Vitrified Polish Waste and it has been further improved by 9.03 % on addition of 5% Phosphogypsum when compared with untreated expansive soil.
7) It is observed that the C.B.R value of the Expansive Soil has been improved by 287.97% on addition of 15% Vitrified Polish Waste and it has been further improved by 418.35% on addition of 5% Phosphogypsum when compared with untreated expansive soil.
8) It is observed that the DFS value of the Expansive Soil, has been improved by 61.53% on addition of 15% Vitrified Polish Waste and it has been further improved by 59.82% on addition of 5% Phosphogypsum when compared with untreated expansive soil.

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VII.BIOGRAPHIES

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