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A LABORATORY INVESTIGATION ON THE EFFICIENCY OF EXPANSIVE SOIL TREATED WITH SAWDUST ASH AND SODIUM HYDROXIDE AS FOUNDATION BED

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Abstract— India has large tracts of expansive soils commonly known as black cotton soils which covers approximately 20% of the total land area of our country. These soils experience large volume changes on exposure to climates with alternate wetting and drying. Several innovative foundation techniques have been suggested to overcome the problem of expansive soils. Those techniques include sand cushion technique, cohesive non-swelling (CNS) layer technique and under reamed piles. Stabilization of expansive soil with various types of additives is the most commonly used technique. Stabilization is process of fundamentally changing the chemical properties of soft soils by adding stabilizers or binders, either in wet or dry conditions to increase the strength and stiffness of the naturally weak soils. In present investigation, the aim is to reduce swelling and shrinkage behaviour of expansive soil by improving strength and engineering properties of soil. Also, the industrial solid waste Sawdust ash is utilised for stabilisation so as to solve the problem of indiscriminate disposal. The other additive used in this study is Sodium hydroxide. Various tests are conducted with varying proportions and results are reported.

Keywords— Expansive soil, Sawdust Ash, Sodium Hydroxide, Optimum Moisture Content (OMC), Maximum Dry Density(MDD), CBR.

I. INTRODUCTION

Due to land limitations and increase in population, people are utilizing every land available for construction. The behavior of soil at any location is not same due to anisotropic nature. When a project is to be carried out in difficult foundation condition, the possible alternate solutions are, avoid the particular sites, design the plan structure accordingly, use pile foundation which transmits the total load to hard strata, remove and replace the foundation soil and attempt to modify the existing ground i.e. Soil stabilization which is commonly used. Soil stabilization is a process of improving the engineering properties of soil. It is extremely cost-effective method of converting poor quality soil into hard impermeable medium.

In present study, Sawdust Ash and Sodium Hydroxide are added to expansive soil to evaluate the performance through laboratory tests such as consistency limits, modified proctor test and California bearing ratio strength test.

II. LITERATURE REVIEW

Dr. D. Koteswara Rao et al., (2012) studied the properties of expansive soil before and after treated with rice husk ash and potassium chloride. Geethu Saji (2016) has studied the effect of Egg Shell Powder (ESP) and Quarry Dust (QD) on the properties of clayey soil. Butt etal., (2016) conducted extensive experimental demonstrate the soil improvement prospective of saw dust ash (SDA) by performing California bearing ratio (CBR) and unconfined compression strength tests. Dharmendrasahu has investigated the effects of NaoH on mixing with the black cotton soil as a stabilizing material. C. Neeladharan (2017) studied about the stabilization of expansive soil using tile waste with sodium hydroxide as a binder. M. Vignesh (2019) studied about the stabilisation of clay soil using polypropylene and sawdust ash.

Figure 1: Sawdust Ash

Figure 2: NaOH Solution

III. OBJECTIVES OF STUDY

The objectives of the present investigation are as follows:

- To identify the strategy of techniques to overcome the problems posed by Expansive soils with a view to adopt suitable methodology through critical review of literature.

- To determine the properties of untreated expansive soil and Sawdust Ash.

- To evaluate the performance of expansive soil treated with optimum percentage of Sawdust Ash as an admixture and percentage variation of Sodium Hydroxide as an additive.

IV. MATERIALS USED

A. Expansive Soil (ES)

The soil used in this study is of expansive nature, collected from Turpulanka village which is nearby Amalapuram, East Godavari District, Andhra Pradesh at a depth of 1.5m from ground level. The Index and Engineering properties of the expansive soil were determined as per IS codes of practice. The geotechnical properties of the air dried expansive soil i.e., Specific gravity, Differential free swell, Liquid limit, Plastic limit, Compaction, CBR are determined and the results are tabulated as follows.

TABLE 1: INDEX PROPERTIES OF UNTREATED EXPANSIVE SOIL

S.No	**Property**		**Result of ES**
1	Specific gravity G		2.52
2	Differential swell index DFS (%)		120
3	Gravel (%)		0
	Sand (%)		8
	Fines	Silt (%)	27
		Clay (%)	65
4	Liquid Limit LL (%)		72
5	Plastic Limit PL(%)		28.31
6	Plasticity Index PI (%)		43.69
7	Soil Classification		CH

TABLE 2: ENGINEERING PROPERTIES OF UNTREATED EXPANSIVE SOIL

1	Optimum Moisture Content OMC (%)	28
2	Maximum Dry Density MDD (g/cc)	1.523
3	California Bearing Ratio CBR (%)	1.24
4	Cohesion (KN/m^2)	53.94
5	Angle of internal friction (ø) (^{o})	2.75

B. Sawdust Ash (SDA)

The Sawdust Ash was collected from local saw mill, Kakinada, Andhra Pradesh which is an indiscriminate waste disposed in open areas and landfills. It can cause serious problems to the environment and humans, hence the utilization of saw dust ash in geotechnical applications is likely to provide a better solution.

Saw dust is a by-product of sawmills by sawing timber. It is the loose particles or wood chippings obtained by sawing wood into useable sizes. After collection, clean saw dust without much bark and much organic content was air dried and burnt at the room temperature. The SDA was then sieved through 600 micron sieve to remove the lumps, gravels, un burnt particles and other deleterious materials to soil and obtained SDA is used for the laboratory work.

TABLE 3: PHYSICAL PROPERTIES OF SAWDUST ASH

Colour	Greyish black
Shape texture	Irregular
Mineralogy	Non crystalline
Particle size	< 600 microns
Odour	Odourless
Specific gravity	2.43
Appearance	Very fine

TABLE 4: CHEMICAL COMPOSITION OF SAWDUST ASH

Chemical composition	**Percentage (%)**
SiO_2	66.74
Al_2O_3	5.67
Fe_2O_3	3.39
CaO	1.85
MgO	3.72
K_2O	12.67

C. Sodium Hydroxide (NaOH)

Sodium hydroxide is an important laboratory chemical which is a mixture of nonvolatile odourless, white solution. It is not explosive but highly reactive. It acts furiously with water and it develops sufficient heat to inflame close to flammable equipment. NaOH consumes moisture from the air at room temperature and it is also a white crystalline odourless deliquescent solid.

V. LABORATORY INVESTIGATIONS

The laboratory investigations are carried out on the untreated Expansive Soil and Expansive Soil treated with with varying percentages of Sawdust Ash and Sodium Hydroxide. The Sawdust Ash with proportions 5%, 10%, 25%, 20% and Sodium Hydroxide with proportions 2%, 4%, 6%, 8%, 12% are used in present study.

A. Liquid Limit

Liquid limit is defined as the minimum water content at which a groove of standard dimensions cut in soil pat flows together for a distance of 10-12 mm at the bottom under an impact of 25 blows. The liquid limit test was conducted using Casagrande's liquid limit apparatus as per the procedures given in the code IS: 2720 part 5 (1970). Liquid limit test was conducted on untreated Expansive soil, Sawdust Ash treated Expansive soil and Sawdust Ash treated Expansive soil with Sodium Hydroxide as an additive.

B. Plastic Limit

Plastic limit is defined as the water content of soil which is in between plastic and semisolid state of consistency of soil. It is defined as that water content of soil when rolled into a thread of 3 mm diameter just begins to crumble and the difference between liquid limit and plastic limit is called plasticity index of the soil. The plastic limit test was conducted as per the procedures given in the code IS: 2720 part 4 (1970). Plastic limit test was conducted on untreated Expansive soil, Sawdust Ash treated Expansive soil and Sawdust Ash treated Expansive soil with Sodium Hydroxide as an additive.

C. Differential Free Swell

Differential Free Swell (DFS) is a parameter used for the identification of the expansive soil. For the determination of the differential free swell of a soil, 20g of dry soil passing through a 425µ size sieve is taken. One sample of 10g is poured into a 100cc capacity graduated cylinder containing water, and the other sample of 10g is poured into a 100cc capacity graduated cylinder containing kerosene oil. Both the cylinders are kept undisturbed in a laboratory. After 24 hours, the settled volumes of both the samples are measured.

Because kerosene is a non-polar liquid, it does not cause any swell of the soil. Degree of expansion of a soil depending upon its differential free swell is given in IS: 2720 (Part III- 1980).

D. Specific Gravity

Specific gravity of solid particles (G) is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water at 4°C. The specific gravity of solid particles can be determined in a laboratory using a density bottle fitted with a stopper having a hole. This test procedure is given in IS: 2720(Part II).

E. Modified Proctor test

This test is conducted for determination of maximum dry density (MDD) and optimum moisture content (OMC). The major aim of compaction of soil is to increase shear strength, decrease compressibility, reduce permeability, control swelling and shrinkage of soil. The degree of compaction of soil is measured in terms of dry density. The maximum dry density of soil occurs at optimum moisture content. The procedure is given in IS:2720 (Part VIII – 1983). This test was conducted on untreated Expansive soil, Sawdust Ash treated Expansive soil and Sawdust Ash treated Expansive soil with Sodium Hydroxide as an additive.

F. California Bearing Ratio test

The CBR is a measure of shearing resistance of the material under controlled density and moisture conditions. The California bearing ratio tests were conducted after curing i.e., the samples were soaked for 4 days and the procedure is given in IS: 2720 (part-16) -1979. This test was conducted on untreated Expansive soil, Sawdust Ash treated Expansive soil and Sawdust Ash treated Expansive soil with Sodium Hydroxide as an additive.

G. *Expansive soil with percentage variation of Sawdust Ash*

➢ ***Compaction test results***

TABLE 5: OMC & MDD VALUES FOR ES + SDA

Expansive soil (ES) with percentage variation of Sawdust Ash (SDA)	OMC (%)	MDD (g/cc)
ES + 0% SDA	28.67	1.523
ES + 5% SDA	27.6	1.594
ES + 10% SDA	26.45	1.648
ES + 15% SDA	**25.84**	**1.752**
ES + 20% SDA	25.29	1.716

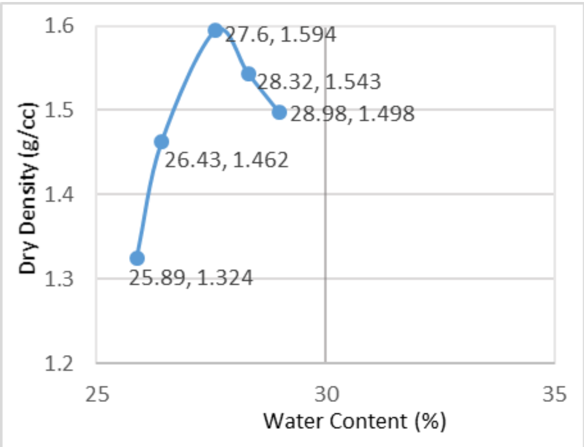

Figure 3: OMC & MDD for ES + 5% SDA

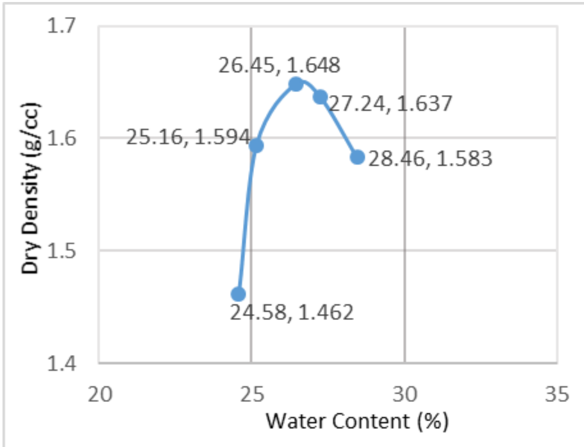

Figure 4: OMC & MDD for ES + 10% SDA

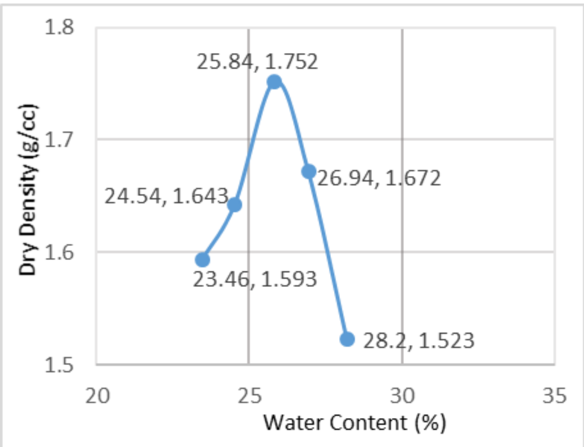

Figure 5: OMC & MDD for ES + 15% SDA

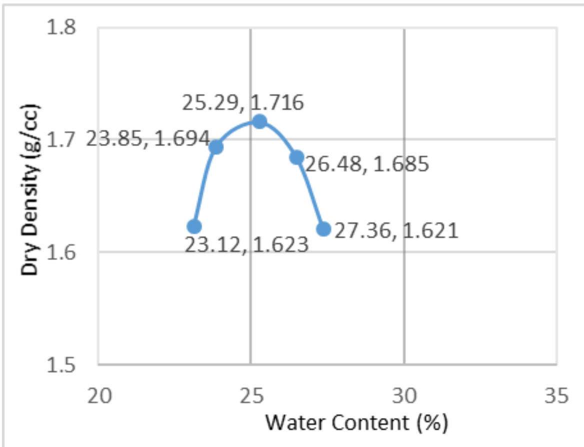

Figure 6: OMC & MDD for ES + 20% SDA

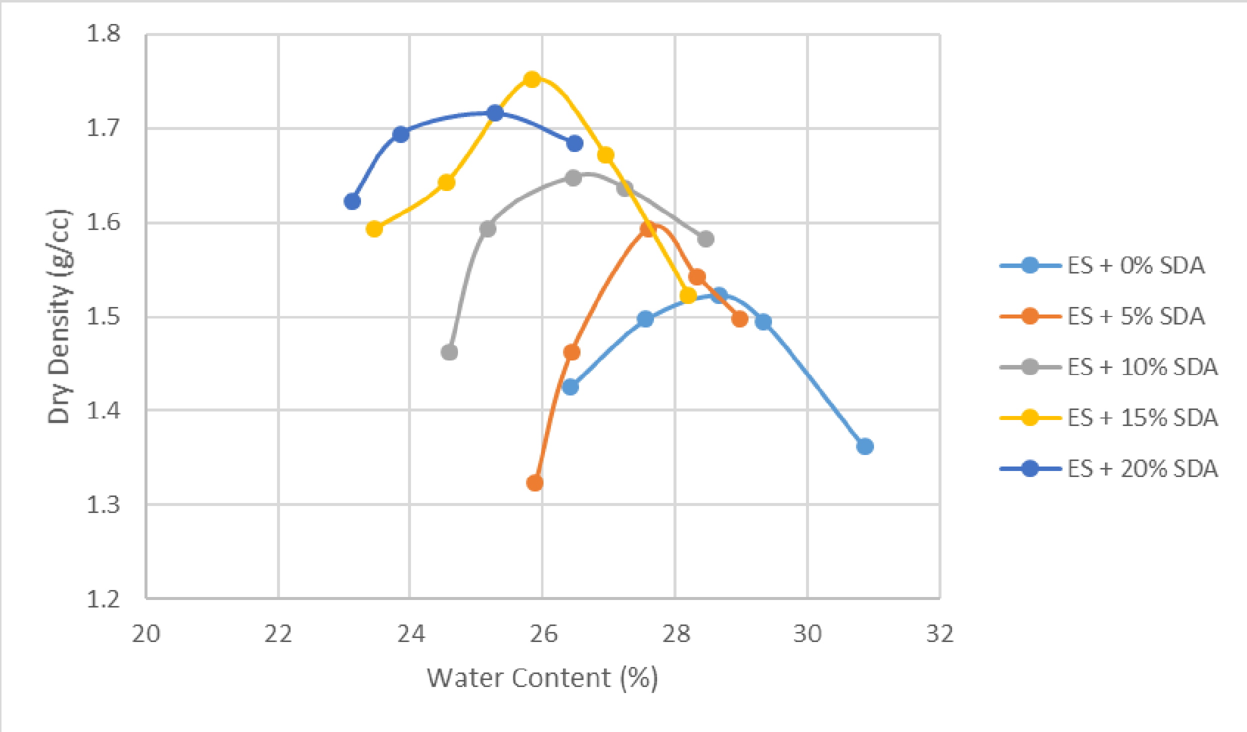

Figure 7: OMC & MDD values of treated expansive soil with varying percentages of Sawdust Ash

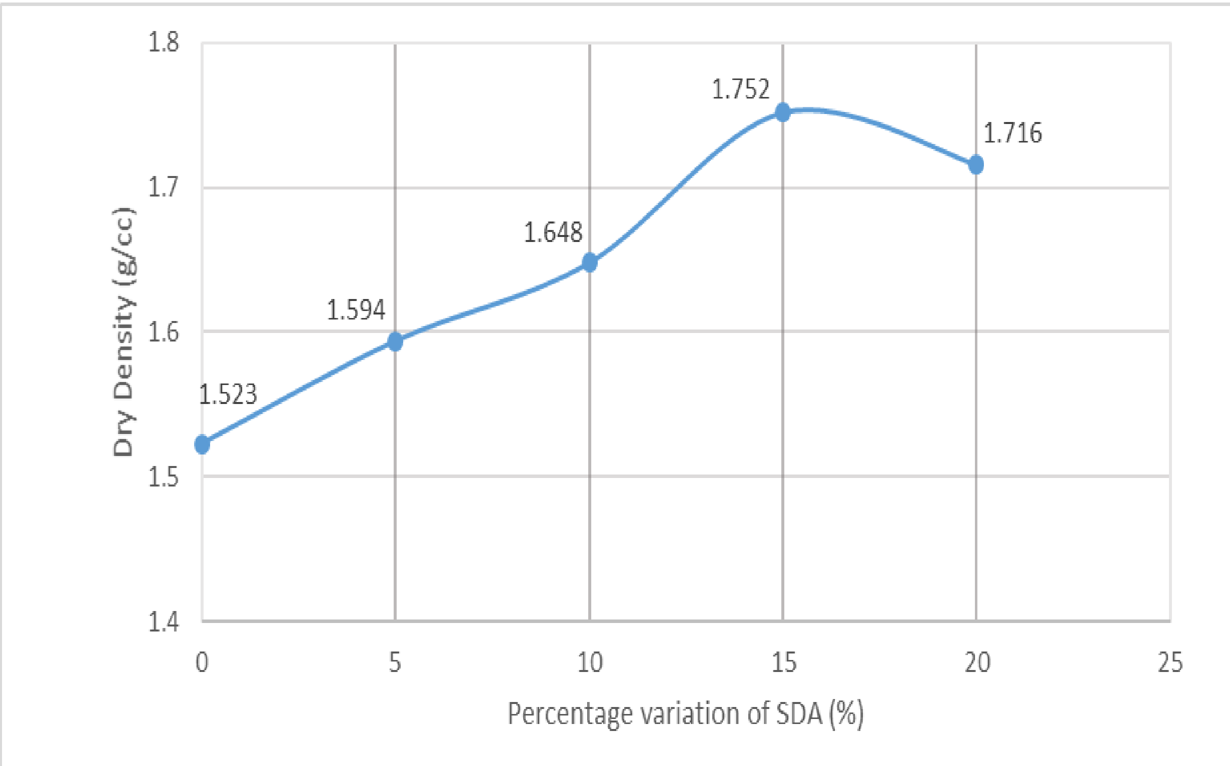

Figure 8: MDD of treated Expansive soil with varying percentages of Sawdust Ash

- ***CBR test results***

TABLE 6: CBR VALUES FOR ES + SDA

Expansive soil (ES) with percentage variation of Sawdust Ash (SDA)	**CBR (%)**
ES + 0% SDA	1.24
ES + 5% SDA	1.96
ES + 10% SDA	2.78
ES + 15% SDA	**3.58**
ES + 20% SDA	2.94

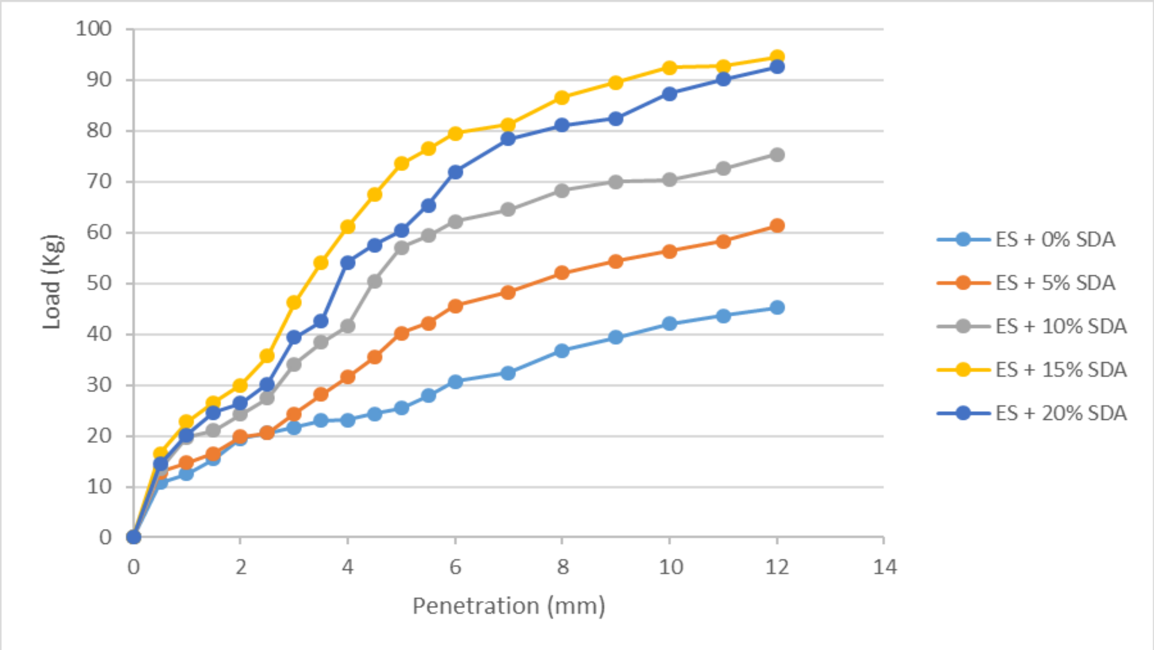

Figure 9: CBR test results of treated Expansive soil with varying percentages of Sawdust Ash

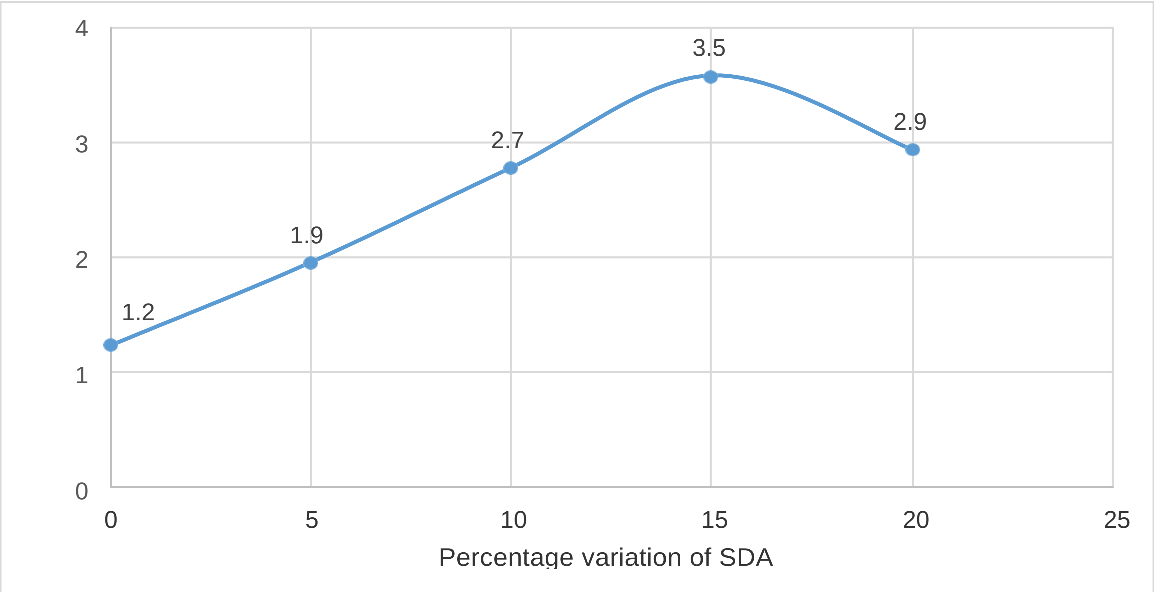

Figure 10: CBR values of treated Expansive soil with varying percentages of Sawdust Ash

➢ ***Discussion 1***

It is observed from the laboratory test results that the optimum CBR value 3.58% is obtained when expansive soil is treated with 15% Sawdust Ash (SDA). As obtained CBR value is very low, it is essential to add suitable chemical for improving the CBR value. So, Sodium Hydroxide is used for further improvement of the expansive soil treated with 15% of Sawdust Ash.

Initially OMC, MDD and CBR values were determined for the expansive soil treated with varying percentages of sawdust ash 5%, 10%, 15%, 20% and the optimum percentage is 15%. This Sawdust ash treated expansive soil is further treated with varying percentages of sodium hydroxide 2%, 4%, 6%, 8%, 10% and the results are tabulated.

H. Expansive soil with optimum percentage of Sawdust Ash and percentage variation of Sodium Hydroxide

➢ ***Compaction test results***

TABLE 7: OMC & MDD VALUES FOR ES + 15% SDA + NaOH

Expansive soil (ES) with 15% Sawdust Ash (SDA) and percentage variation of sodium chloride (NaOH)	**OMC (%)**	**MDD (g/cc)**
ES + 15% SDA + 0% NaOH	**25.84**	**1.752**
ES + 15% SDA + 2% NaOH	25.46	1.763
ES + 15% SDA + 4% NaOH	24.97	1.786
ES + 15% SDA + 6% NaOH	24.25	1.843
ES + 15% SDA + 8% NaOH	**23.64**	**1.872**
ES + 15% SDA + 10% NaOH	23.86	1.798

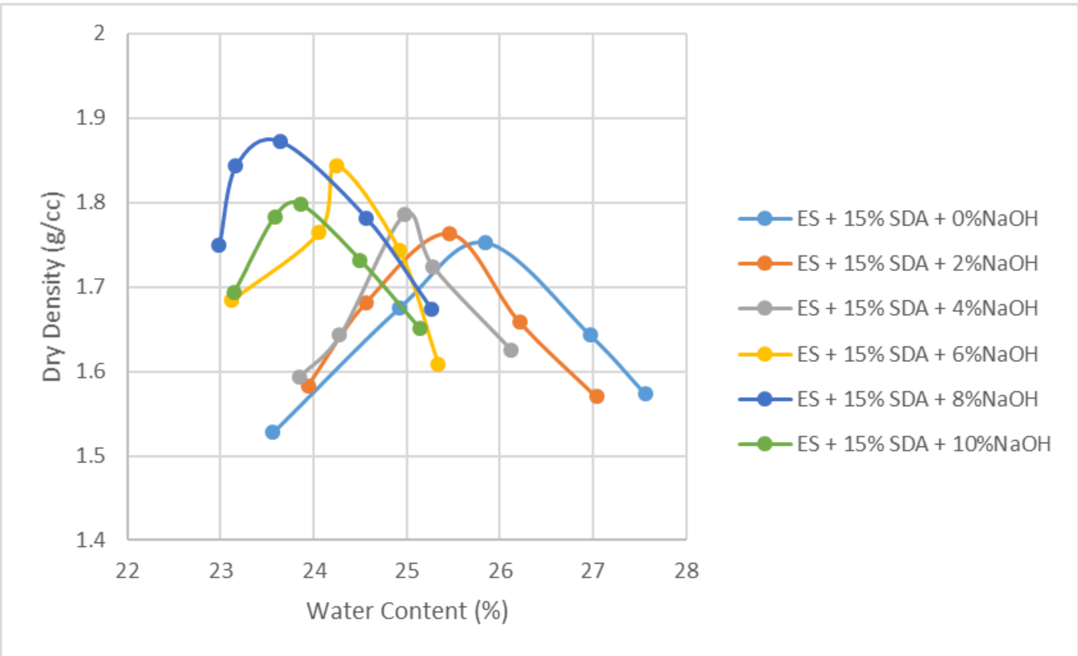

Figure 11: OMC & MDD of treated Expansive soil with optimum percentage of Sawdust Ash and varying percentages of NaOH

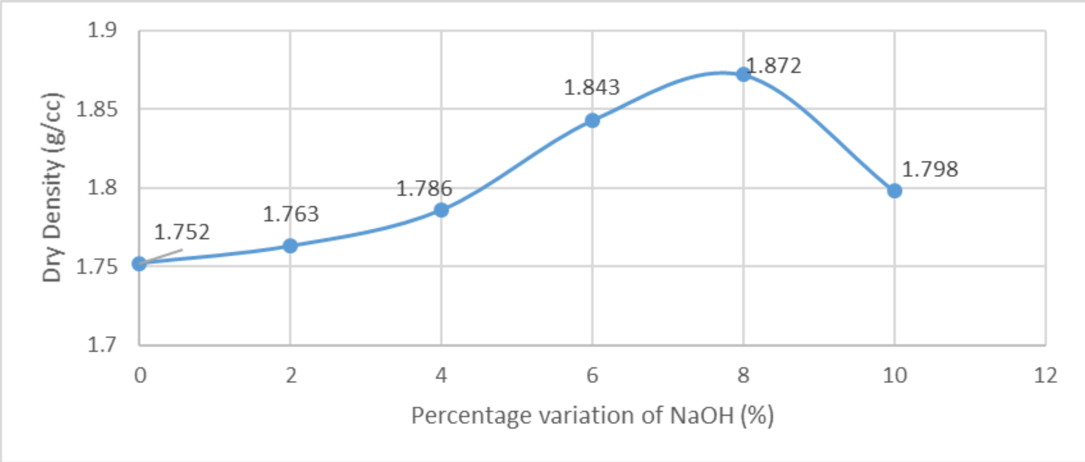

Figure 12: MDD of treated Expansive soil with optimum percentage of Sawdust Ash and varying percentages of NaOH

- ***CBR test results***

TABLE 8: CBR VALUES FOR ES + 15% SDA + NaOH

Expansive soil (ES) with 15% Sawdust Ash (SDA) and percentage variation of sodium chloride (NaOH)	CBR (%)
ES + 15% SDA + 2% NaOH	3.64
ES + 15% SDA + 4% NaOH	4.08
ES + 15% SDA + 6% NaOH	4.92
ES + 15% SDA + 8% NaOH	**5.85**
ES + 15% SDA + 10% NaOH	4.54

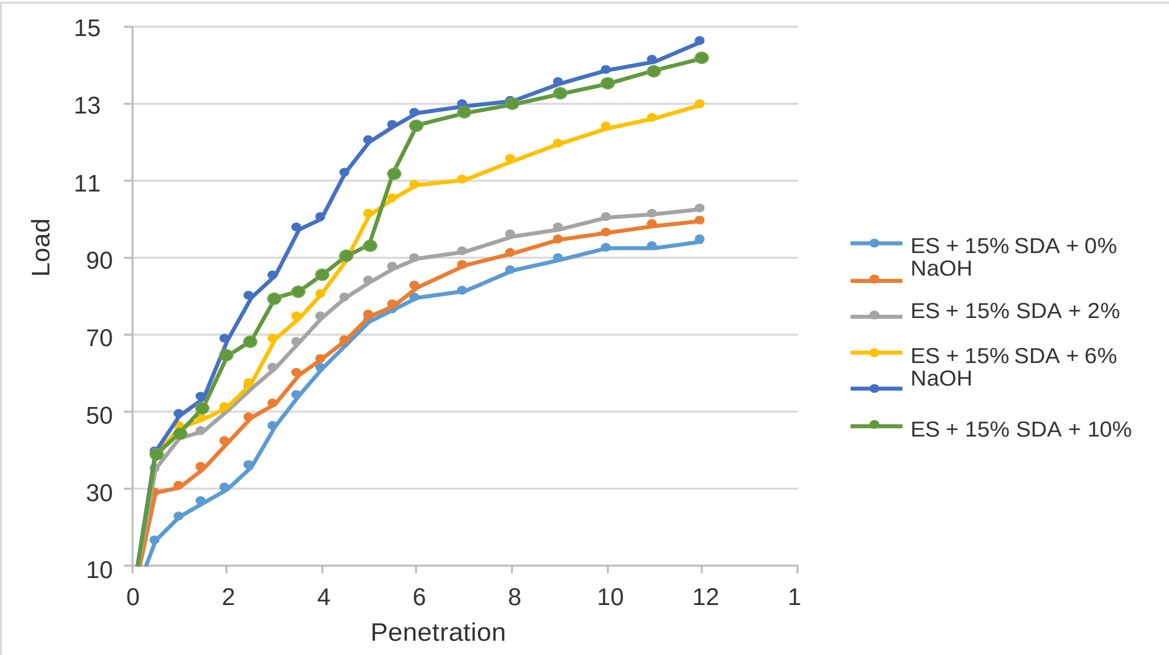

Figure 13: CBR test results of treated Expansive soil with optimum percentage of Sawdust Ash and varying percentages of NaOH

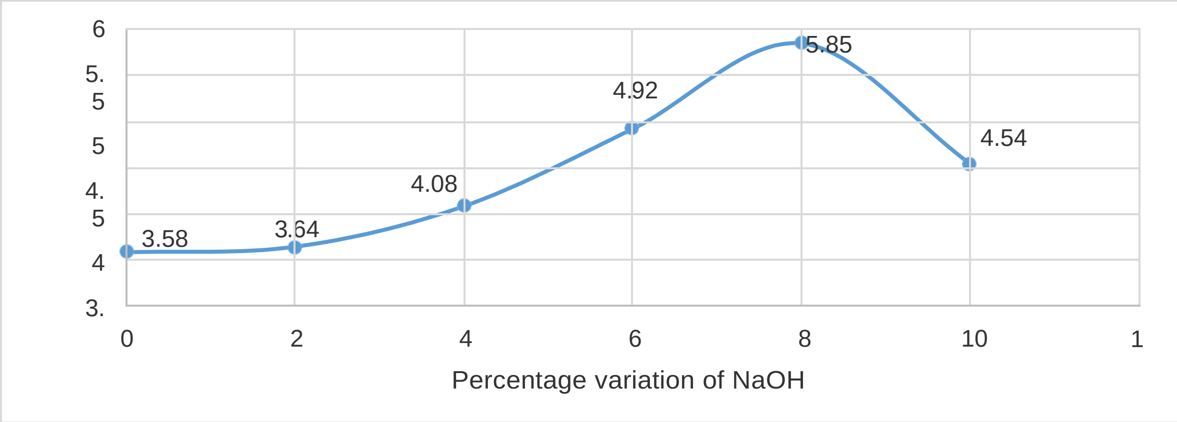

Figure 14: CBR values of treated Expansive soil with optimum percentage of Sawdust Ash and varying percentages of NaOH

- ***Discussion 2***

It is observed from the laboratory test results that the expansive soil treated with 15% Sawdust Ash and 8% sodium hydroxide (NaOH) has exhibited the CBR value of 5.85% which is less as per IS codes of practice. So, this treated expansive soil with sawdust ash and sodium hydroxide can be utilized for foundation beds.

Hence the laboratory test viz Liquid limit, Plastic limit, plasticity index, Compaction, CBR, Specific gravity, Differential free swell, cohesion, angle of internal friction was conducted on the expansive soil treated with optimum percentages of Sawdust Ash and Sodium Hydroxide. The results were presented in the following table.

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

S.No	Property	Untreated Expansive soil	Expansive soil treated with 15% SDA	Expansive soil treated with optimum percentages of 15% SDA and 8% NaOH
1	Liquid Limit LL (%)	72	54.23	45.68
2	Plastic Limit PL(%)	28.31	23.5	20.64
3	Plasticity Index PI (%)	43.69	30.73	25.04
4	Soil Classification	CH	CH	CI
5	Specific gravity	2.52	2.61	2.78
6	Differential swell index DFS (%)	120	50	30
7	Optimum Moisture Content OMC (%)	28.67	26.94	23.64
8	Maximum Dry Density MDD (g/cc)	1.523	1.672	1.872
9	California Bearing Ratio CBR (%)	1.24	3.58	5.85
10	Cohesion (KN/m^2)	53.94	49.76	36.48
11	Angle of internal friction (ø) (^{o})	2.75	4.58	7.61

VI. CONCLUSIONS

1. It is observed that the liquid limit of treated expansive soil has been decreased by 24.68% on addition of 15% Sawdust Ash and it has been further decreased by 36.55% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

2. It is observed that the plastic limit of treated expansive soil has been decreased by 16.99% on addition of 15% Sawdust Ash and it has been further decreased by 27.09% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

3. It is observed that the plasticity index of treated expansive soil has been decreased by 29.66% on addition of 15% Sawdust Ash and it has been further decreased by 42.69% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

4. It is observed that the specific gravity of treated expansive soil has been increased by 3.58% on addition of 15% Sawdust Ash and it has been further increased by 10.32% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

5. It is observed that the Differential free swell of treated expansive soil has been decreased by 58.33% on addition of 15% Sawdust Ash and it has been further decreased by 75% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

6. It is found that the Optimum Moisture Content (OMC) of treated expansive soil has been decreased by 6.03% on addition of 15% Sawdust Ash and it has been further decreased by 17.54% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

7. It is found that the Maximum Dry Density (MDD) of treated expansive soil has been increased by 9.78% on addition of 15% Sawdust Ash and it has been further increased by 22.92% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.8

8. It is noticed that the CBR value of treated expansive soil has been improved by 188.71% on addition of 15% Sawdust Ash and it has been further improved by 371.77% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

9. It is observed that the cohesion value of treated expansive soil has been decreased by 7.75% on addition of 15% Sawdust Ash and it has been further decreased by 32.37% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

10. It is observed that the angle of internal friction of treated expansive soil has been improved by 66.79% on addition of 15% Sawdust Ash and it has been further improved by 176.73% on addition of 8% of Sodium Hydroxide as an optimum compared with the untreated expansive soil.

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