Experimental Study on Expansive Soil Stabilized with Iron Slag Dust and Slacked Lime

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Abstract— Expansive soil, often referred to as shrink-swell soil, is a soil type that exhibits remarkable volume changes in response to fluctuations in moisture content. The expansive soil problem is prevalent in many regions worldwide, posing significant challenges to construction and infrastructure development. Mitigating these problems involves proper engineering practices like moisture control, foundation design and soil stabilization. The present study deals with stabilization of Expansive Soil using waste Iron Slag Dust with Slaked lime. The additives i.e., Iron slag dust and slaked lime with native soil in varying percentages to obtain the optimum percentage of additives required for soil stabilization. The samples were prepared by mixing the percentage of iron slag dust and slacked lime with expansive soil as 5%,10%,20% and 30%. The results of the tests on the expansive soil showed that as iron slag dust content increased, internal friction (φ) increased. For the California Bearing Ratio, the results of the tests obtained as improved in the CBR value with increment in iron slag dust.

Index Terms- Iron slag dust, Slacked lime, Soil stabilization Unconfined compressive strength, CBR, Expansive soil

I. INTRODUCTION

Expansive soils are prevalent across diverse geographical regions globally, making them a ubiquitous concern in construction projects. Understanding their complex behaviour is crucial for mitigating the potential risks associated with expansive soil, which include foundation failures, structural damage, and compromised infrastructure integrity. In-depth knowledge of expansive soil mechanics involves studying its physical and chemical properties, as well as the environmental factors influencing its behaviour. Researchers and engineers delve into topics such as Atterberg limits, soil suction, and swelling potential to quantify and predict the expansive soil's response to moisture fluctuations. Mitigating the challenges posed by expansive soils demands innovative engineering solutions, ranging from proper site selection and foundation design to the incorporation of stabilizing agents. This interdisciplinary field integrates principles of geotechnical engineering, soil science, and hydrology to develop sustainable strategies for construction in regions affected by expansive soils. As we explore the intricacies of expansive soils in this study, we aim to unravel the complexities surrounding their behaviour and contribute to the development of effective strategies for engineering resilient structures in expansive soil environments. The present study deals with stabilization of Expansive Soil using waste Iron Slag Dust with Slaked lime. The additives i.e., Iron slag dust and slaked lime with native soil in varying percentages to obtain the optimum percentage of additives required for soil stabilization. The samples were prepared by mixing the percentage of iron slag dust as 5%,10%,20% and 30% and slacked lime percentage as 2.5%,5%,7.5% and 10% with expansive soil as based on the weight. The results of the tests on the expansive soil showed that as iron slag dust content increased, internal friction (φ) increased. For the CBR, the results of the tests showed as improved in the CBR value with increment in iron slag dust.

II. EXPERIMENTAL ANALYSIS

A.General

Soil is a complex and variable material composed of mineral particles, water, air, and organic matter. Its engineering properties, such as strength, compressibility, and permeability, can vary significantly from one location to another. Soil stabilization is the process of modifying these properties to meet the requirements of a construction project. This technique is employed when the existing soil is unsuitable for supporting structures, roads, foundations, or other engineering applications.

B.Materials used

Expansive soil- The soil used in this study was collected from agricultural field near Tamil Nadu Agricultural University, Coimbatore. The expansive soil's physical and chemical properties were studied under the experiments such as grain size distribution, specific gravity, consistency limit, plasticity, and unconfined compressive strength of the soil. The plasticity index (PI) and liquid limit (W_L) of the soil were 28 and 43% respectively. Table 1 summarizes and shows the properties of the soil sample. The soil was classified as per Indian standard classification system as CI- (Medium compressible clay). Iron Slag Dust- Iron slag dust (ISD) were collected from Steel manufacturing industry near Gandhipuram, Coimbatore. The iron slag dust was used in the sieve 600 micron (µ) were used for this study. A by-product of the iron and steel manufacturing process, consists of finely ground particles resulting from the crushing and grinding of slag produced during metal smelting. Rich in iron content, this powdery substance finds applications in various industries. It serves as a supplementary raw material in cement production, enhancing the material's durability and strength.

Slacked Lime- Slaked lime, scientifically known as calcium hydroxide ($Ca(OH)_2$), is a chemical compound formed through the hydration reaction of quicklime (calcium oxide, CaO) with water. This process is characterized by the exothermic addition of water to quicklime, resulting in the production of slaked lime and releasing heat.

TABLE 1.TEST RESULTS OF UNMODIFIED EXPANSIVE SOIL

S.No	List of Experiments conducted		
	Test	Properties of soil	Values
1	Water absorbtion	Moisture content (%)	7
2		Specific Gravity	2.7
3	Grain Size distribution	% Gravel (>4.75 mm)	3.00
		%Sand (4.75mm0.075mm)	32.73
		% Silt and Clay(4.75 mm-0.075mm)	64.27
4	Atterberg's Limit	Liquid limit (WL)%	39
		Plastic Limit (WP)%	17
		Plasticity Index (WI)%	22
5	Compaction	Optimum Moisture Content (OMC)%	18
		Maximum Dry Density (MDD) (g/cc)	1.7
6	Shear strength	Unconfined Compressive strength kN/m^2	26.38
7	IS classification	Medium Compressible Clay	CI

A.Atterberg's Limit

Result of liquid limit (ll) of the modified soil, representing its moisture content at the semi-liquid state, tends to decrease with the addition of iron slag dust. this is attributed to the alteration of the soil structure, reducing its plasticity. the plastic limit, indicating the moisture content at which the soil transitions from a plastic to a semisolid state, may also experience a decline. this reduction is linked to changes in the soil's particle interactions due to the presence of iron slag dust. the plasticity index (PI), generally decreases in linear manner as iron slag dust content increases. and also important to shows that the modified soil is expected as non-plastic and increases of iron slag dust changed the modified soil classification from medium plastic clay to low plastic clay. this suggests a diminishing range of moisture content for workability.

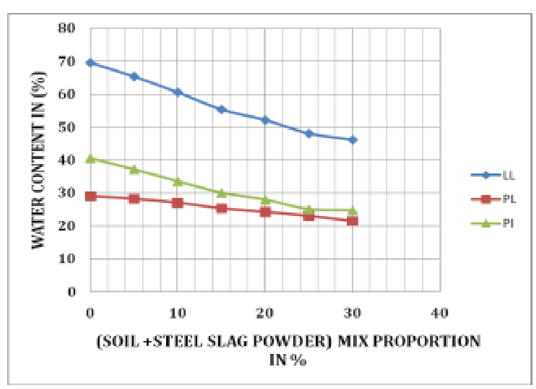

Fig.1.Atterberg's limit for various percentage of Iron Slag Dust and slacked lime added to the soil

B-Swelling potential of the expansive soil

In order to assessment the effect of iron slag dust on the swelling potential of the expansive soil, swell tests were conducted at optimum moisture content (OMC) condition using different percentages of iron slag dust content. It indicates that as the iron slag dust content increases, the percentage of free swell decreases almost linearly. The free swell of the modified soil was reduced from 6.4% for 0% iron slag,5.8% for 5% iron slag, 5.2% for 10% iron slag, 3.7% for 20% iron slag and to 2.98% for 30% iron slag. In this test, the free swell is defined as the change in the sample form with respect to its initial form. The results of zero swell tests indicated that the swell pressure decreases with the increase in iron slag content. The swell pressure decreased from 105 kPa for 0% iron slag to 98 kPa for 5% iron slag to 68 kPa for 10% iron slag and to a value of 27 kPa for 30% iron slag. If the ratio of swell pressure in kPa to swell value in percentage is considered, this ratio is 20 for 0% iron slag and for 30% iron slag dust i.e. the ratio decrement with the increment in iron slag dust content). The decrease in swell value and swell pressure iron slag dust content is due to the non-plastic nature of the iron slag dust particles.

C.Optimum Moisture Content (OMC) and Unconfined Compressive Strength (UCS)

The Optimum moisture content which is carried out by using standard proctor compaction test and the optimum moisture content of soil is identified as 20% with 1.65 dry unit weight. After addition of iron slag dust in the percentage of 5%,10%,20% and 30% to the expansive soil and also slacked lime which added such as 2.5%,5%,7.5% and 10%, the optimum moisture content with maximum dry density as identified as 18.16% with 1.69,17.86% with 1.82,16.23% with 2.10 and 14% with 2.16. The addition of iron slag dust can enhance the compatibility of the clay soil, leading to an increase in the Maximum Dry Density (MDD). This is attributed to the fine particles in iron slag dust filling void spaces, resulting in a denser soil structure. The maximum dry density of the iron slag dust stabilized soil slightly increases with increase and another side, optimum moisture content (OMC) was linearly decreases. As the result, identified as addition of iron slag dust to the expansive soil increase in compaction and partially increased strength of soil while decreasing of water content.

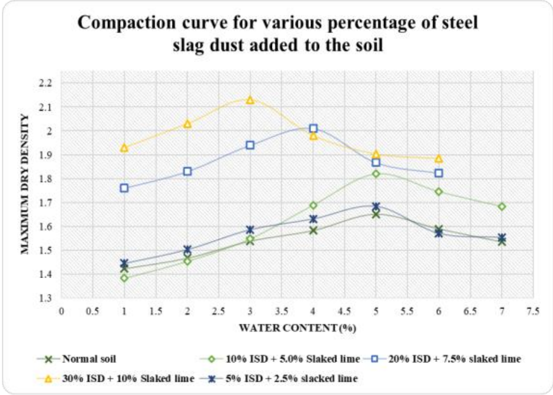

Fig.2. Compaction curve for various percentage of Iron Slag Dust and slacked lime added to the soil.

D.Unconfined Compressive Strength (UCS)

Unconfined compression test was performed soil samples of clay soil – iron slag dust prepared at the optimum compaction are presented in the table 2. The test was conducted by unmodified soil and modified soil addition of iron slag dust in the percentage of 5%,10%,20% and 30% to the expansive soil as well as slacked lime which added such as 2.5%,5%,7.5% and 10% which obtained from the optimum moisture content and dry unit weight by using standard proctor compaction test, as addition of iron slag dust and slacked lime. The results of the tests obtained from the unconfined compressive strength (UCS) test can be started with decrease with increase in iron slag dust content, as shown in Fig 2.

The test results of unconfined compression test expansive soil which indicated as increased from 26.5 kN/mm^2 for unmodified clay soil to 28.63 kN/mm^2 for 30% slag added soil. Also soil specimens were subjected to curing for 7 days on the open atmosphere, which the interactions between the iron dust slag and soil components may occur, affecting the soil's properties. Exposing the mixture to the open atmosphere can also lead to further chemical reactions, such as oxidation and or carbonation, depending on the environmental conditions.

TABLE 2.TEST RESULTS OF UNCONFINED COMPRESSIVE STRENGTH TEST FOR 7TH DAY

S.NO	*Propotion mix*	*CBR values*
1	Normal Soil	2.46
2	Soil+5% Iron Slag Dust + 2.5% Slacked lime	4.49
3	Soil+10% Iron Slag Dust + 5% Slacked lime	4.57
4	Soil+20% Iron Slag Dust + 7.5% Slacked lime	6.31
5	Soil+30% Iron Slag Dust + 10% Slacked lime	6.78

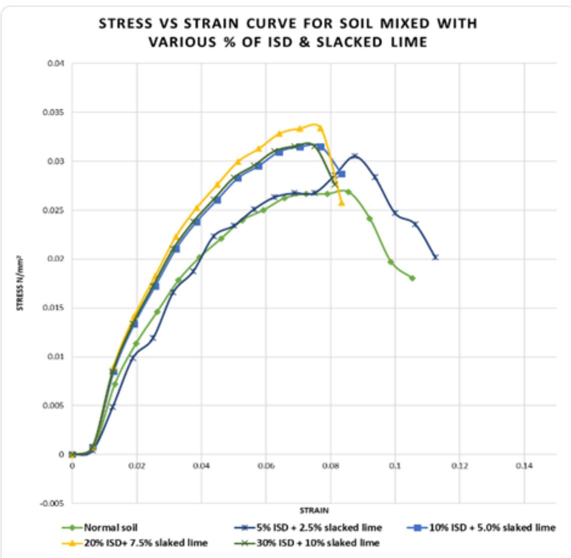

Fig 3. Unconfined compression strength for various percentage of Iron Slag Dust and slacked lime with soil on 7th day curing.

D. California Bearing Ratio test

The California bearing test is the type of penetration test. The soil specimen is subjected to evaluate of the mechanical strength of pavement and subgrade. The test is conducted by measuring the pressure required to penetrate the soil sample with the help of plunger of area. After, the measuring the pressure is the divided by the pressure required to succeed the equal penetration on the standard aggregate value. The ratio of the force per unit area order to penetrate a soil mass with standard circular plunger at the rate of 1.25mm/min. The test which have been performed to attain the potential of the iron slag dust to stabilizing the expansive soil. The soil samples were mixed with the various percentage of iron slag dust and slacked lime with a proportion as 5%,10%,20% and 30% and 2.5%,5%,7.5% and 10% which conducted the test. The result of California bearing test is which stabilized value was obtained after the addition of iron slag dust and slacked lime. The soil properties were slightly improved in strength that the sample with 5% + 2.5% of addition indicated that 47.5% increased in CBR value of modified soil where as it is 52.02%,56.23%, and 60.26% for the soil sample with addition of iron dust slag and slacked lime.

TABLE 3.TEST RESULT OF CALIFORNIA BEARING RATIO

S.no	*Propotion mix*	*7th day UCS value kN/m^2*
1	Normal Soil	26.50
2	Soil+5% Iron Slag Dust + 2.5% Slacked lime	25.02
3	Soil+10% Iron Slag Dust + 5% Slacked lime	27.23
4	Soil+20% Iron Slag Dust + 7.5% Slacked lime	27.49
5	Soil+30% Iron Slag Dust + 10% Slacked lime	28.63

III. RESULT AND DISCUSSION

1. The increase in iron slag dust aggregate content decrease the plasticity and increases the maximum dry density of the expansive soils.
2. Based on unconfined compression shear strength tests, the test results of unconfined compression test expansive soil which indicated as increased from 26.5 kN/mm^2 for unmodified clay soil to 28.63 kN/mm^2 for 30% slag.
3. The cohesion intercept of the clay soil decreases with the increase in iron slag dust and increases of slacked lime content. while may various behaviour is expected for the angle of internal friction.
4. The compressive strength (UCS) increases with iron slag dust content 20% - 7.5% slaked lime may be optimum proportion, The UCS value increases with increase in curing period.
5. CBR value of the modified expansive soil was found to increase with increase where addition of

iron slag dust content and slacked lime where soil which indicated as increased from 2.46 for unmodified clay soil to 6.78 kN/mm^2 for 30% slag

CONCLUSION

An experimental study was initiated to investigation the effect of using iron slag dust as a stabilizer on the expansive soil. In general, the results indicated show that the iron slag dust can effectively as the sustainable material as well as used to improving the engineering properties of the expansive soil with consider to the percentages that should be used. Good statistical correlations were obtained between the intended engineering properties and the iron slag dust with slaked lime. Iron slag dust can be used as a sustainable material and also as to improve the properties of expansive soils.

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