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Comparative Study of Soil Stabilization by Using Steel Slag, Fly Ash and Coconut Shell

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Abstract: Due to the rapid increase in urbanization, there's a growing need to safeguard the environment and the soil. To address this, we're utilizing industrial and agro – waste. For example, steel slag has already proven effective in stabilizing soil. Along similar lines, research shows that fly ash and coconut shells can also be valuable. Based on a specific research paper, we've decided to combine all three materials in varying proportion for soil stabilization. Steel slag will be used at 5%, 10% and 15%, while coconut shell present in all samples at 5%. Additionally fly ash will be incorporated at 12%, 15% and 16%, by conducting a series of tests including CBR, MDD, OMC, Plastic limit, Liquid limit and Plasticity index, we aim to assess the outcomes of the approach.

Keywords: stabilization, fly ash, steel slag, coconut shell, black cotton soil, MDD, CBR, OMC, Liquid limit, Plastic limit, Plasticity index.

1. INTRODUCTION

Soil stabilization generally refers to the process of enhancing and improving the engineering properties of a soil to enhance its durability, load-bearing capacity, and deformation resistance. Soil stabilization is commonly applied to building foundations, pavement, railways, road construction, industrial sites, etc. The main objective here is to increase the strength and stability of the soil with reduced construction costs and making the best use of locally available materials. For the purpose of soil stabilization, we are using industrial waste material and locally available waste materials such as steel slag, fly ash, and coconut shell. Property of steel slag is to enhance the load bearing capacity of soil. Fly ash can increase density and compaction of soil, making it more stable and able to support heavier loads. Coconut shell helps to reduce the plasticity of clay soil, making them less susceptible to shrink and swell during wet and dry period.

2. MATERIAL TO BE USED

- **Steel slag** is an industrial waste material that is formed as a byproduct of the steelmaking process. It is generated when iron is processed in a glare furnace to produce mortar iron. It is composed of various oxides such as primary silicone dioxide (Sio2), magnesium oxide (MgO), calcium oxide (Cao), iron oxide (FeO), etc. Currently, the daily estimated production of steel slag is 15 to 20 million tones. It improves the swelling potential of the clay soil, as the amount of added steel slag increases the swell pressure or free swell of the soil. Steel slag can enhance the load bearing capacity of soil. When mixed with soil, it can increase shear strength and reduce settlement.

- **Fly ash** forms when coal is burned in a power plant to generate electricity. To collect fly ash, electrostatic precipitators are used to filter it from the flue gases in the construction industry. Fly ash is employed as a material in making concrete. When mixed with cement and water, it enhances the workability, durability, and strength of the structure. Moreover, its use in production helps lessen the impact by reusing waste as a binder for soil stabilization. It can increase the density and compaction of soil, making it more stable and able to support heavier loads. It reduces the permeability of soil, which can be beneficial in preventing water infiltration and improving soil resistance to erosion
- **Coconut shells** are natural and sustainable resources that can be used for soil stabilization. It's a waste product. The outermost layer is called the husk, which is hard and fibrous. There is a layer of coir, a tough and fibrous material used for making rope and mats. The actual hard shell protects the coconut meat and water. Using coconut shell and its byproducts, like coir, is often considered environmentally friendly. Coconut shells are light-weight and can be used as aggregate in soil. This reduces the overall density of the soil and can improve its load-bearing capacity. It helps to reduce the plasticity of clay soil, making it less susceptible to shrinking and swelling during wet and dry periods

OBJECTIVES

1. To assess soil strength using the CBR test
2. To check the compressibility of soil
3. To check the shear strength of the soil.
4. To enhance the stabilization of black cotton soil.
5. To decrease the plasticity of black cotton soil.
6. To increase the load-bearing capacity of black cotton soil.
7. To study the provision of IRC SP 121 for steel slag, IRC 1984 Recommended Practice for Lime Fly Ash Stabilization of Soil Base/Subbase in Pavement Concrete

3. METHODOLOGY

- Soil stabilization tests are important for assessing the suitability of soil for construction or other purposes. CBR is a test that measures the load-bearing capacity of a soil sample. It helps determine how well the soil can support road or pavement construction.
- The plastic limit test identifies the moisture content at which the soil transitions from a plastic to a semi-solid state. This is essential to assess the plasticity of the soil.
- The liquid limit test determines the moisture content at which the soil behaves as a liquid. It's essential for understanding the soil's consistency and its ability to retain moisture.
- MDD is a test that determines the maximum density achievable for a given soil with a specific moisture content. It's essential for compaction and engineering purposes. OMC is the moisture content at which the soil reaches its maximum dry density. It helps in designing compaction efforts for construction.
- These tests collectively provide critical information about the physical and mechanical properties of soil helping engineers and construction professionals make informed decisions regarding soil, stabilization and construction design

4. RESULTS

1. Water Content

We conducted the first trial with 5% of steel slag, fly ash and coconut shell in proportion with 200g of black cotton soil, In the first trial we obtained the resultant water content 28.50% to

	Particulars	5	6	7
1.	Mass of empty container	18	22	17
2.	Empty wt. of container + moist soil	113	113	101
3.	Empty wt. of container + dry soil	104	103	92
4.	Mass of water	9	10	9
5.	Mass of soil sample	86	81	75
6.	Water content	10.46	12.34	12
7.	Average water content		11.6	

calculate the water content we used the formula

$W = W_w/W_s \times 100$

where,

W_w= Moisture present in soil

W_s= soil solid

W= water content

Similarly, we conducted the 2nd trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion with 200g of black cotton soil, In the second trial we obtained the resultant water content 24.88%.

Similarly, we conducted the 3rd trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion with 200g of black cotton soil, In the third trial we obtained the resultant water content 11.6%.

Based on the result obtained from this test these materials proved to be enhancing the engineering properties of soil. The resultant black cotton soil was found to be improved in stability and also having enhanced permeability, also there is enhance load bearing capacity of soil.

Table: Water Content 15%

2. Specific Gravity

We conducted the specific gravity test as discussed above, we conducted the first trial with 5% of steel slag, fly ash and coconut shell in proportion with 300g of black cotton soil, In the first trial we obtained the resultant specific gravity 2.80. To calculate the specific gravity we used the formula as follows,

$$G = \frac{M2-M1}{(M2-M1)-(M3-M4)}$$

where,

M_1= Mass of empty pycnometer

M_2= Mass of pycnometer + dry soil

M_3= Mass of pycnometer + dry soil + water
M4= Pycnometer + water

Similarly, we conducted the second trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion with 300g of black cotton soil, In the second trial we obtained the resultant specific gravity 2.55.
We conducted the third trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion with 300g of black cotton soil, In the third trial we obtained the resultant specific gravity 2.40.
The average specific gravity of sample black cotton soil calculated is 2.58.
Based on the result obtained from this test, it has been proved that there is an increase in porosity in the resultant black cotton soil as well as there was found to be altered swell shrink behaviour in soil.

Sr. No.	pycnometer	1	2	3
1.	empty weight of pycnometer (m1)	613	615	611
2.	Empty wt. of pycnometer + dry soil (m2)	954	993	1019
3.	Empty wt. of pycnometer + dry soil + water (m3)	1702	1728	1715
4.	empty weight of pycnometer + water	1500	1516	1483
5.	Specific gravity	2.45	2.27	2.31
6.	Average specific gravity		2.58	

Table: Specific Gravity

3. Liquid limit
We conducted the first trial with 5% of steel slag, fly ash and coconut shell in proportion with 200g of black cotton soil, In the first trial we obtained the resultant water content for liquid limit 60% to calculate the water content we used the formula

$W= W_w/W_s$ x 100
where,
W_w= Moisture present in soil
W_s= soil solid
W= water content

Similarly, we conducted the 2nd trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion with 200g of black cotton soil, In the second trial we obtained the resultant water content for liquid limit 38.46%.

Similarly, we conducted the 3rd trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion with 200g of black cotton soil, In the third trial we obtained the resultant water content for liquid limit 48.76%. The liquid limit of normal black cotton soil range from 40% to 100% depending on the specific composition and characteristics of soil.

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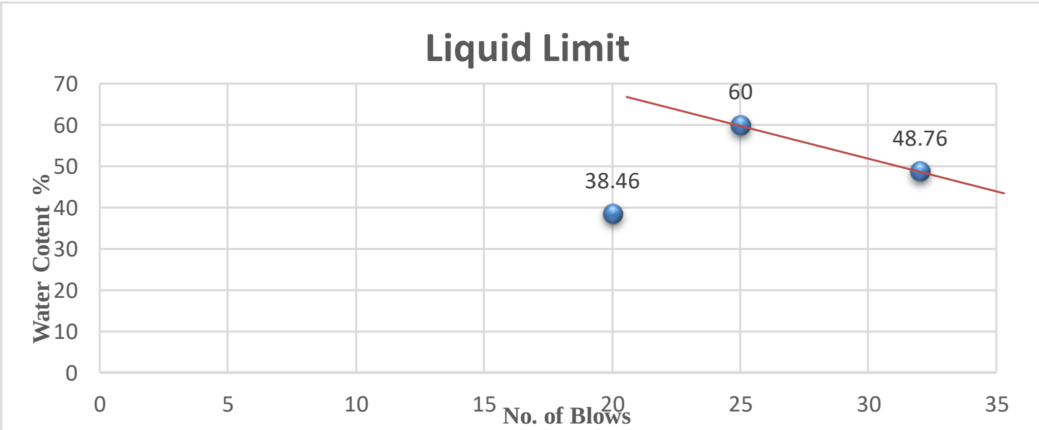
Based on the result obtained from this test these materials proved to be enhancing the engineering properties of soil. The resultant black cotton soil was found to be improved in stability and also having enhanced permeability, also there is enhance load bearing capacity of soil.

Sr.No	Particulars	5%	10%	15%
	No. of blows	25	20	32
	Mass of empty container	10	10	10
	Mass of container + moist soil	42	46	44
	Mass of container + dry Soil	30	36	33
	Mass of water content	12	10	11
	Mass of soil solid	20	26	23
	Water content(%)	60%	38.46%	47.82%
	Liquid Limit		48.76%	

Table 4.3.1 Liquid limit table



4. Plastic limit

We conducted the first trial with 5% of steel slag, fly ash and coconut shell in proportion with 200g of black cotton soil, In the first trial we took two containers for this test, the resultant plastic limit obtained is 37.5 %.

To calculate the plastic limit we used the formula

$W = W_w/W_s \times 100$

where,

W_w= Moisture present in soil

W_s= soil solid

W= water content

Plastic Limit = $\frac{water\ content\ of\ 1st\ sample + water\ content\ of\ 2nd\ sample}{2}$

Similarly, we conducted the 2nd trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion with 20g of black cotton soil, In the second trial we obtained the resultant plastic limit obtained is 25.39 %

Similarly, we conducted the 3rd trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion with 20g of black cotton soil, In the third trial we obtained the resultant plastic limit obtained is 45.83%.

The average plastic limit obtained from all three tests is 37.5%

Based on the result obtained from this test these materials proved to be enhancing the engineering properties of soil. The resultant black cotton soil was found to be improved in stability and also having enhanced permeability, also there is enhance load bearing capacity of soil. When stabilized soil has a lower plastic limit than normal black cotton soil, it means that the stabilized soil has less clay content and is therefore less prone to shrinkage and swelling. This can be advantageous in construction as it may reduce the potential for soil movement and structural instability. Plastic limit varies between 15% to 35% of black cotton soil. The average plastic limit of stabilized soil obtained from all three tests is 37.5%

4.5 Standard Proctor Test (MDD & OMC)

To obtain the results of MDD & OMC we used Standard Proctor Test. We conducted the standard proctor test as discussed above, we conducted the first trial with 5% of steel slag, fly ash and coconut shell, we took these materials in 5% proportion of 2kg black cotton soil. The resultant dry density obtained was 1.69g/cc and the resultant water content obtained was 18.61%.

The formula for calculation of dry density is = m/v(1+w)

Where,

M= mass of compacted soil

V= volume of mould

W= water content

Similarly, we conducted the second trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion of 2Kg black cotton soil. The resultant dry density obtained in this trial was 1.56g/cc and resultant water content obtained was 27.22%.

we conducted the third trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion of 2Kg black cotton soil. The resultant dry density obtained in this trial of 2.39g/cc and resultant water content obtained was 21.97%.

Based on the results we found there is improved stability in black cotton soil and enhanced load bearing capacity with reduced swell shrink behaviour as well in the black cotton soil.

Fig. Sample Soil

Fig. Performing Test

The table below shows water content of soil sample when steel slag, fly ash and coconut shell are added are added in 5% of soil sample.

Sr.No.	Particulars	5	6	10
1.	Empty weight of container	17	22	14
2.	Empty wt. of container + moist soil	89	81	70
3.	Empty wt. of container + dry soil	77	72	60
4.	Mass of water	12	9	10
5.	Mass of soil sample	60	50	56
6.	Water content	20	18	17.85
7.	Average water content		18.61	

Table: SPT for 5%

The table below shows water content of soil sample when steel slag, fly ash and coconut shell are added are added in 10% of soil sample.

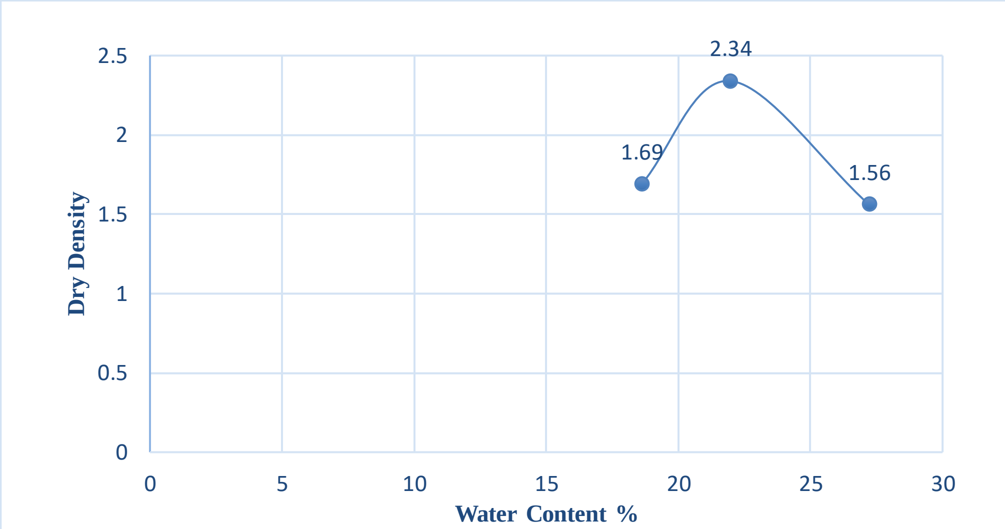
Sr.No.	Partiuculars	5	6	7
1.	Empty weight of container	18	22	18
2.	Empty wt. of container + moist soil	90	110	80
3.	Empty wt. of container + dry soil	74	93	66
4.	Mass of water	16	17	14
5.	Mass of soil sample	56	71	48
6.	Water content	28.57	23.94	29.16
7.	Average water content		27.22	

Table: SPT for 10%

The table below shows water content of soil sample when steel slag, fly ash and coconut shell are added are added in 15% of soil sample.

Sr. No.	Particulars	5%	10%	15%
1.	Mass of empty mould ‘w_m’ gm	4820	4820	4820
2.	Mass of mould + Compacted soil	6640	6620	7400
3.	Mass of compacted soil ‘w_m’ gm	1820	1800	2580
4.	Volume of mould	903.207	903.207	903.207
5.	Mass of dry soil gm	2000	2000	2000
6.	Bulk Density	2.015	1.99	2.86
7.	Moisture Content	18.61	27.22	21.97
8.	Dry Density	1.69	1.56	2.34

Table: Standard Proctor Test



The Maximum Dry density for the soil sample tested 2.34gm/cc and optimum moisture content is 21.97%.

CBR TEST

Based on the result obtained from this test these materials proved to be enhancing the engineering properties of soil. The result indicates that the stabilized soil is stronger and more suitable for construction purposes than the black cotton soil, and the stabilized soil has low shrink-swell potential and high bearing capacity.

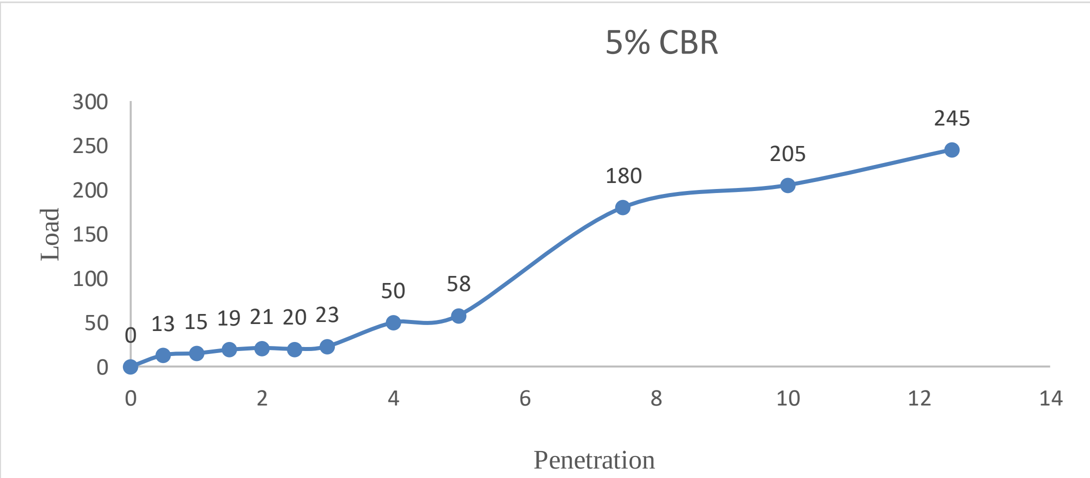
We calculated the CBR value of soil by using the formula:-

CBR (%) = $\frac{P_t}{P_s} \times 100$

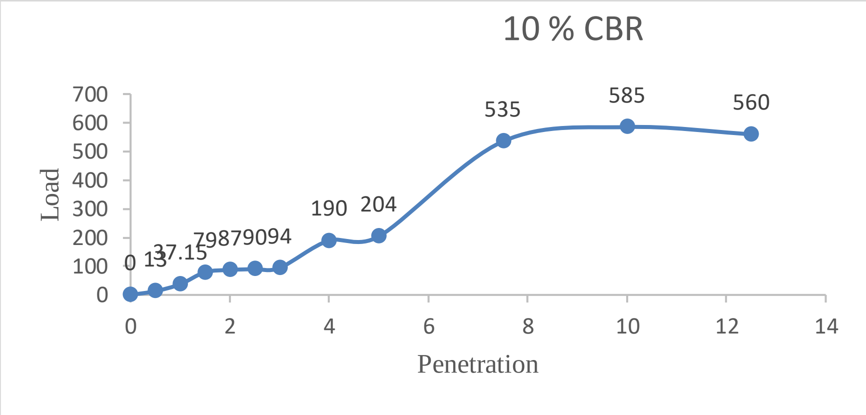
where,

P_t= Corrected unit the load corresponding to the chosen penetration from the load penetration curve.

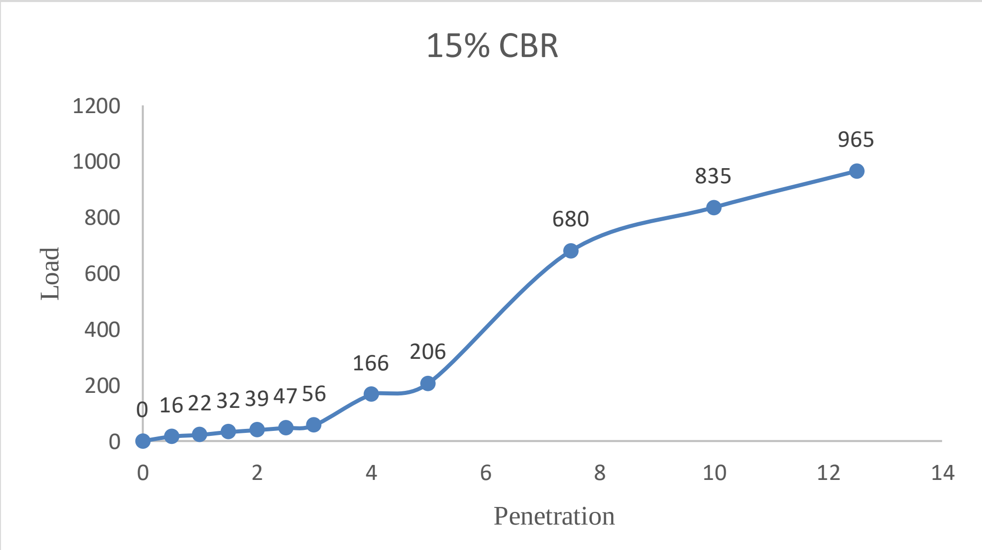
P_s= Standard load for the some depth of penetration as for Ps



We conducted the first trial with 5% of steel slag, fly ash and coconut shell in proportion with 6000 g of black cotton soil, In the first trial we obtained the resultant penetration 2.82 %.



Similarly, we conducted the 2nd trial with 10% of steel slag, fly ash and 5% of coconut shell in proportion with 6000g of black cotton soil, In the second trial we obtained the resultant penetration 9.92 %.



Similarly, we conducted the 3rd trial with 15% of steel slag, fly ash and 5% of coconut shell in proportion with 6000g of black cotton soil, In the third trial we obtained the resultant penetration10.02%.

4. CONCLUSION

a. Fly ash and steel slag are byproducts of industrial waste, while coconut shell is agricultural waste. Nowadays, fly ash is used as a replacement for cement, but steel slag and coconut shell are not commonly used in construction. Our primary goal is to utilize these waste materials as stabilizers for soil
b. For the purpose of stabilization, soil was collected from a farm, which is black cotton soil. Tests were performed. The SPT test was done for compression purposes, and MDD and OMC were found out by conducting this test.
c. As we can see from the different percentages of steel slag, fly ash, and coconut shell, the maximum dry density increases, indicating that the strength increases after the addition of

these materials to the soil. We found that the maximum dry density is achieved at a 15% proportion of these materials, as shown in the above results.

d. Addition of these materials to the soil will improve its engineering properties. These materials are cheap and eco-friendly. The demand for fly ash increases in construction. According to this project and comparing it with previous studies, no one has used these three materials together. It is observed that using these wastes in soil stabilization gives good engineering properties to the soil and also fullfill the objectives of the study

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