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Enhancement of Engineering Properties of Soil using Steel Slag and Rice Husk Ash

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ABSTRACT: Differential settlements, low strength, and excessive compressibility are challenges when building on soft or weak soils. Clayey soils have low strength, which will lead to inadequate pavement support, which will ultimately effect the pavement's lifespan and performance. Clayey soil also has an impact on pavement design and construction, raising construction costs and hastening pavement breakdown. There are numerous methods for enhancing the soil's ability to support weight, including stabilizing the soil and adding reinforcement. One of the methods for modifying the geotechnical characteristics of soil is soil stabilization, which has grown to be a standard procedure in construction engineering and allows for the efficient use of industrial wastes as stabilizers. This method gains popularity due to its versatility and ease of supply. A technique for producing affordable road construction is stabilization, which makes use of the waste materials that are readily available. This paper presents a study that was conducted to verify if adding steel slag and rice husk ash may improve the qualities of clayey soil. To get the ideal percentage of admixture needed for soil stability, different amounts of steel slag and rice husk ash are mixed with unaltered soil. Laboratory tests for both modified and unmodified clayey soil, including Atterberg's limit, compaction test, CBR test, and UCS test, were conducted in this comparative study.

KEYWORDS: Compaction test, CBR, UCS, Steel Slag, Rice Husk Ash

I. INTRODUCTION

Just like other construction materials soil also has its own chemical and physical characteristics with regard its abilities on dealing with the loadings and other external forces. From all the other civil engineering fields soil engineering and soil mechanics is most complex field when it comes to factor of safety in design of sub-structures e.g. foundations , piles and other soil based constructions like sub-grade for pavements , embankments etc, requires a significantly a higher factor of safety in comparison of other construction materials . That's why the uncertainty in soil analysis and foundations designs is higher. Therefore the geotechnical properties of the soil are analyzed before any major construction work, so as to ensure its stability against the load of the desired structures. The soil normally consists of rock particles, the air and the water are located in the empty spaces (called voids). It is essential to determine the geological properties of the soil that are influenced by the size of the particles, distribution of the grain size, form of the minerals present in the particles and the amount of that minerals. The engineering properties of the soil are generally are considered for carrying out the analysis of the site conditions and design of structures are the bulk unit weight, saturated unit weight, dry unit weight, permeability and porosity. Several laboratory tests are also conducted to check the suitability of the soil, including permeability, relative density, soil compaction characteristics and water content. Sometimes the existing soil at a particular site may not be suitable for construction of structures due to its low bearing capacity, drainage problem and other problems like high compressibility etc. Clayey soil if found which is ineffective for the construction due to its low bearing capacity against the load due to its swell-shrink characteristics, there is the requirement to improve its characteristics by various ground improvement techniques or by changing the properties of such soils by using some industrial and agricultural wastes such as fly ash, rice husk etc having pozzolanic and fly ashitious properties, resulting in reduction of cost of improvement.

II. LITERATURE SURVEY

Kumar et al. (2023)

This study aims to determine how the mixture of sawdust ash and rice husk ash affects the electrical properties of black cotton. For all mixed models, different concentrations of rice husk ash of 0, 3, 6, 9, 12 and 15% (based on the weight of

black soil) were added to the soil compared to sawdust ash at 6% by weight of the soil. cotton soil. To evaluate the electrical properties of soils and their mixtures, tests such as Attenberg Limit, Specific Gravity, Particle Size Distribution, Standard Proctor Test, Unconstrained Compressive Strength (UCS) and California Bearing Ratio (CBR) are performed. The results showed that the addition of 9% wheat hull and 6% wood ash greatly improved the electrical properties of black cotton.

Pawar et al. (2022) Using steel slag for soil stabilization is a modern application of steel slag. In this study the main approach is to investigate the effect of steel slag on the strength characteristics of clayey soil. Steel slag is blended with clayey soil in amounts of 10%, 15%, 20%, 25%, and 30% of dry weight. In our study, the optimum content of steel slag was determined by considering the maximum unconfined compressive strength. A series of further laboratory tests have been performed on this optimum mix to evaluate its suitability as a stabilizer material. The test was also conducted with conventional stabilizing material such as 10% fly ash and 5% cement with clayey soil and the obtained optimum mix was determined. Then the results are compared accordingly. In the above study, it has been observed that the addition of steel slag results in significant improvement in strength parameter as compared to fly ash but less strength in case of cement.

P. Bharath Goud et al. (2018) Present study was undertaken to evaluate the effectiveness of different percentages of rice husk ash and copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soils, Copper Slag and Rice Husk Ash are Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests. Limited studies have been reported for the combination of copper slag and rice husk ash in soil stabilization. The optimum mix was found to be in the proportion of 64%BC+30%CS+6%RHA. FSI of soil treated with RHA+CS decreased steeply from 100% to 20.4%. There was a slight change in maximum dry density of the treated soil. The unsoaked CBR test shows that strength of optimum mix was 12.7%. The stabilized soil mixtures have shown satisfactory strength characteristics and can be used for low-cost constructions to build houses and road infrastructure Laboratory vane shear tests have been carried out under undrained conditions to study the shear strength parameters of the stabilized soil.

Joshi et al. (2018) The use of steel slag improves the bearing capacity and the strength of black cotton soil and indirectly it saves the construction cost. Different percentage of 5%, 10%, 15% and 20% steel slag have been used to stabilize the black cotton soil and to verify its suitability for using it as a construction material for road. The steel slag collected from Kalika Steel, Jalna and the black cotton soil collected from Himayatbaugh, Aurangabad. The overall program was conducted in 2 phases. In first phase all necessary test such as Atterberg limit, C.B.R and standard proctor compaction test on plain soil were being performed to analyse the maximum dry density (maximum dry density) and optimum moisture content (Optimum Moisture Content). And in 2 phase the black cotton soil was mixed with 5%, 10%, 15%, 20 % of steel slag.

Shalabi et al. (2017) High expansion and reduction in shear strength and foundation bearing capacity will take place due to the increase in water content of these soils. The engineering properties of these kinds of soils can be improved by using additives and chemical stabilizers. In this work, by-product steel slag was used to improve the engineering properties of clay soils. Lab and field experimental programs were developed to investigate the effect of adding different percentages of steel slag on plasticity, swelling, compressibility, shear strength, compaction, and California bearing ratio (CBR) of the treated materials. The results of tests on the clay soil showed that as steel slag content increased, the soil dry density, plasticity, swelling potential, and cohesion intercept decreased and the angle of internal friction increased. For the CBR, the results of the tests showed an increase in the CBR value with the increase in slag content.

Hattamleh et al. (2017) This study intended to explore the effectiveness of using fine steel slag aggregate (FSSA) in improving the geotechnical properties of high plastic subgrade soil. First soil and fine steel slag mechanical and engineering properties were evaluating. Then 0%, 5%, 10%, 15%, 20%, and 25% dry weight of soil of fine steel slag (FSSA) were added and mixed into the prepared soil samples. The effectiveness of the FSSA was judged by the improvement in consistency limits, compaction, free swell, unconfined compression strength, and California bearing ratio (CBR). From the test results, it is observed that 20% FSSA additives will reduce plasticity index and free swell by 26.3% and 58.3%, respectively. Furthermore, 20% FSSA additives will increase the unconfined compressive strength, maximum dry density, and CBR value by 100%, 6.9%, and 154%. By conclusion FSSA had a positive effect on the geotechnical properties of the soil and it can be used as admixture in proving geotechnical characteristics of

subgrade soil, not only solving the waste disposal problem.

Rokade et al. (2017) Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be optimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

III. MATERIALS AND METHODOLOGY

1. SOIL

The soil required for the project is taken from an empty field in Jammu. The soil is alluvial in nature and contains high amounts of clay. The total quantity of soil collected is about 120 Kg.

All the soil that is used is sieved using 4.75mm sieve before start of the tests. The soil is oven dried for 24 hours before use to eliminate presence of any moisture in the soil. Firstly, Virgin soil without any admixture is tested for its properties and strength value and after that it is tested along with the addition of various proportions of Steel Slag and Rice Husk Ash.



Fig 1 Site of soil Extraction

The various properties of virgin soil that is used are:

Table 1 Properties of soil used

S.NO.	PROPERTIES	RESULTS
1.	Liquid Limit	36 %
2.	Plastic Limit	21.5 %
3.	Plasticity Index	14.5 %
4.	Optimum Moisture	14.06 %
5.	Maximum Dry Density	19.3 kN/m ³
6.	Specific Gravity	2.56
7.	C.B.R	3.1%
8.	U.C.S	84.62 kN/m ²
9.	Indian Soil	CI

2. Steel Slag

Source of Steel Slag

Steel Slag used in this research work was collected from Ludhiana.

Table No 2. Chemical composition of Steel Slag

S.No	Compound	Composition (%)
1	SiO ₂	10-19
2	Al ₂ O ₃	1-3
3	FeO	10-40
4	CaO	40-52
5	MgO	5-10
6	MnO	5-8
7	P ₂ O ₅	0.5-1

3. Rice Husk ASH

The husk of the rice Burning rice husk, a byproduct of paddy rice milling, results in ash. For this study endeavor, RHA was obtained from adjacent mills.

Table 3: RHA physical and chemical characteristics

Rice husk ash (RHA)	
Index Property	Index Value
Water content (W)	83.3 %
Specific gravity (G)	2.0
SiO ₃	81.2 %
Al ₂ O ₃	6.01 %
Fe ₂ O ₃	0.08 %
CaO	0.75 %
MgO	0.91 %
SO ₃	0.42 %
Na ₂ O	0.13 %
K ₂ O	2.56 %
P ₂ O ₃	6.1 %

METHODOLOGY

The present project can serve as an effective method to utilize industrial wastes Steel Slag and Rice Husk Ash in the construction of low cost rural roads and stabilize the subgrade of pavements where the soil is expansive in nature. These various tests needs to be carried out on samples selected for study:

1. Liquid Limit test and plastic limit test needed to be performed with the help of Cassegrande’s Apparatus first on virgin soil and then the various proportions of the mix. The Plasticity Index of the Optimum Mix should be always less than that of virgin soil.
2. Standard Proctor Test is carried out to calculate Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of virgin soil which is then compared to MDD of mix proportions. The MDD of the optimum mix should always be higher than pure soil.
3. California bearing ratio test is conducted to calculate CBR Values at different proportions with material.
4. Unconfined compression strength test is conducted to calculate UCS Values at different proportions with material.

IV. EXPERIMENTAL RESULTS

4.1 EXPERIMENTAL RESULTS

The consequences of trials that were seen in the research laboratory are appeared in this segment. The primary investigations watched contain Standard proctor test, California bearing ratio test and unconfined compression test.

4.2 CLAYEY SOIL-STEEL SLAG AND RICE HUSK ASH MIX

Table 4: Results of MDD and OMC of Soil- Steel Slag –Rice Husk ash mix

SOIL : SS : RHA	MDD (kN/m ³)	OMC (%)
75:5:20	18.95	13.7
70:10:20	18.70	14.1
65:15:20	18.62	14.5
60:20:20	18.41	14.9

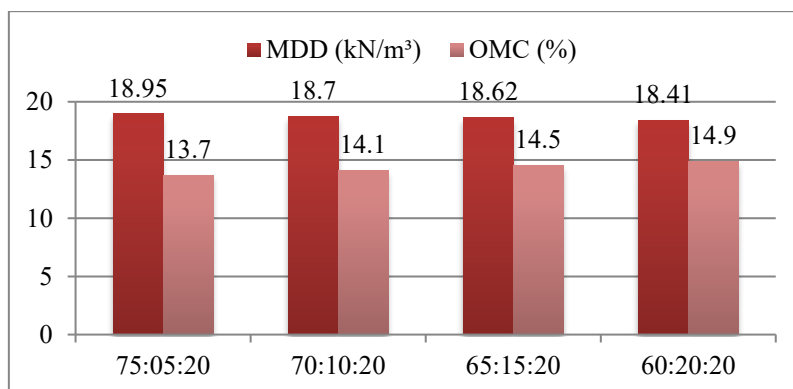


Fig:-2 Combine graph b/w MDD and OMC of Clayey Soil with Steel Slag and RHA of different proportions

- There is an expansion in OMC when the amount of Rice Husk Ash is expanded. The purpose for of this pozzolanic response of Rice Husk powder with soil that needs more water for completion of cation trade response.

- With Rice Husk Ash kept constant at 20% MDD decreases with an addition of Steel Slag content in soil and Rice Husk Ash mix.
- The reason behind of such behavior is Steel Slag is lighter in weight and it has high water absorption properties because of presence of calcium oxide and hence OMC increases with increase of Steel Slag content.

4.3 SOIL –STEEL SLAG AND RICE HUSK ASH MIX

Table 5: Results of Soil – Steel Slag – Rice Husk Ash mix

Mix Proportions (S:SS:RHA)	CBR (%)
75:05:20	4.9
70:10:20	5.2
65:15:20	5.3
60:20:20	5.2

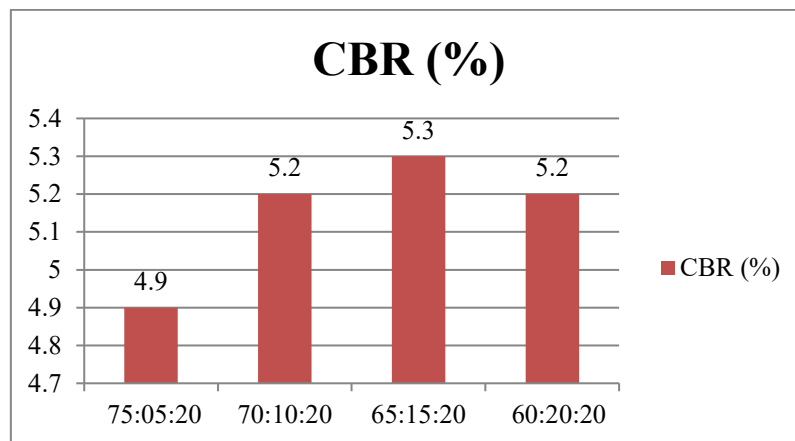


Fig:-3Combine graph b/w CBR Values of Clayey Soil with Steel Slag and RHA of different proportions

- The increase in CBR value from 4.9 to 5.3 when Rice Husk Ash is fixed at 20% and Steel Slag added at different ratios i.e. 5, 10, 15 after that it decreases. As a result of Steel Slag is a light material and with increment the amount of Steel Slag lumps are formed.
- This outcome in arrangement of pockets of low thickness and consequently compaction is impossible accurately bringing about diminishing in CBR value.

4.4 SOIL –STEEL SLAG – RICE HUSK ASH MIXES

Table 6: Results of Soil –Steel Slag - Rice Husk Ash mix

Mix Proportions (S:SS:RHA)	Curing period (days)	UCS (kN/m ²)
75:05:20	7	180.69
70:10:20	7	215.00
65:15:20	7	247.02

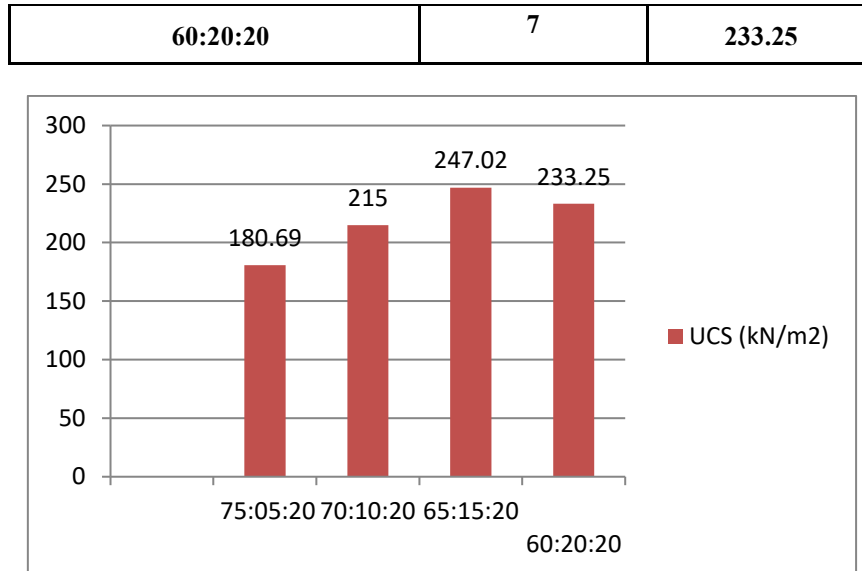


Fig:-4 Combine graph b/w UCS Values of Clayey Soil with Steel Slag and RHA of different proportions

- The UCS value of virgin soil also improves considerably with expansion of Rice Husk Ash 20% and Steel Slag 15%. The value increases from 84.62 kN/m² to 247.02 kN/m² with addition of Rice Husk Ash and Steel Slag.

V. CONCLUSION

On the basis of experimentations, the following conclusions have been drawn:

- From this study it is concluded that Rice Husk ash and Steel Slag are waste products from industries that can be used as stabilizers to clay soil and this would help to solve the conventional problem of disposal of them.
- The optimum value of Rice Husk ash is used for this work was 20% because of the optimum value of C.B.R. is found at 20% of Rice Husk ash when added to soil.
- The C.B.R value increases with increase of Steel Slag along with fixed quantity of Rice Husk ash. It increased 1.71 times from the untreated soil.
- The optimum value of Steel Slag and Rice Husk ash required for soil stabilization is 15% and 20% by weight of soil respectively.
- Unconfined compressive strength increases with increase of quantity of Steel Slag and with fixed quantity of Rice Husk ash. The value of unconfined compressive strength is increased 2.92 times from the untreated soil.

Addition of Rice Husk ash and Steel Slag stabilizer makes the soil mixes durable, low cost and effective for soil improvement. If these two materials are easily available near to the site.

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