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Experimental Study on Stabilization of Soft Soil Using Stone Dust

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Abstract: Soil stabilization is an essential technique in geotechnical engineering to enhance the engineering properties of weak subgrade soils. In this study, the effect of stone dust as a stabilizing material on the California Bearing Ratio (CBR) value of soil has been investigated. The natural soil used in the study exhibited a low CBR value of 3.5%, indicating poor load-bearing capacity and unsuitability for pavement subgrade applications. To improve its strength characteristics, stone dust was added to the soil in a proportion of 5% and 10% by weight. Laboratory CBR tests were conducted on both untreated and treated soil samples under similar conditions. The results demonstrated a significant improvement in the strength of the soil upon the addition of stone dust. The CBR value increased from 3.5% for natural soil to 9% for the soil mixed with 5% stone dust and also the CBR value increased from 3.5% from natural soil to 11.14% for the soil mixed with 10% stone dust. This enhancement can be attributed to better particle interlocking, reduced void ratio, and improved compaction characteristics due to the inclusion of stone dust particles. The findings of this study indicate that even a small percentage of stone dust can considerably improve the bearing capacity of weak soils, making them more suitable for use in road construction and subgrade preparation. Therefore, stone dust can be considered an economical and effective stabilizing agent for improving subgrade performance. The use of such locally available materials also contributes to sustainable construction practices by reducing waste and minimizing construction costs.
Keywords: Soft soil, Stone dust, Soil stabilization, CBR, Proctor test.

I. INTRODUCTION

Soft soil is a type of soil that has low shear strength and high compressibility, which makes it unsuitable for construction activities. Structures built on such soil often face problems like excessive settlement and low load-bearing capacity. Therefore, it becomes necessary to improve the engineering properties of soft soil before using it in construction works.

Soil stabilization is one of the most effective methods used to enhance the strength and stability of weak soils. It involves adding stabilizing materials to soil in order to improve its physical and mechanical properties. Various materials such as lime, cement, fly ash, and industrial wastes are commonly used for this purpose. In recent years, stone dust has gained attention as a potential stabilizing material due to its easy availability and low cost. Stone dust is a by-product obtained from stone crushing industries and is often considered as waste material. Utilizing stone dust in soil stabilization not only improves soil properties but also helps in waste management and environmental protection. The addition of stone dust to soft soil can increase its dry density, reduce plasticity, and improve strength characteristics such as CBR value. This makes the soil more suitable for construction applications like road subgrade and foundation works. The main objective of this study is to evaluate the effectiveness of stone dust in stabilizing soft soil by conducting laboratory tests and analyzing the improvement in its engineering properties.

II. METHODOLOGY

A. Material Used

The materials used in this study include soft clay soil and stone dust. The soft soil was collected from a local site and air-dried before testing. Stone dust, obtained from a nearby stone crushing unit, was used as a stabilizing agent. The stone dust was sieved to remove larger particles and ensure uniform mixing with soil.

B. Sample Preparation

The collected soil was first dried and pulverized to remove lumps. Stone dust was then added to the soil in different proportions such as 0%, 5%, 10%, and 15% by weight of dry soil. Each mixture was thoroughly mixed to achieve uniform distribution of stone dust in the soil

C. Laboratory Test Conducted

The following laboratory tests were carried out to evaluate the engineering properties of soil:

1. Standard Proctor Test

This test was conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of soil samples. Different water contents were used to prepare samples, and compaction was done in layers using a standard rammer.

2. California Bearing Ratio (CBR) Test

CBR test was performed to determine the load-bearing capacity of soil. The test was conducted on both untreated and treated soil samples. The penetration values at 2.5 mm and 5 mm were recorded, and the corresponding CBR values were calculated.

Figure 1(a): Stone Dust and Soil Mixture

Figure 1(b): CBR Test

Figure 1(c): CBR Test Result

D. Procedure

(1) Soil sample was collected, dried, and sieved.
(2) Required amount of stone dust was added to soil.
(3) Water was added to achieve desired moisture content.
(4) Proctor test was conducted to determine OMC and MDD.
(5) CBR test was performed on prepared samples
(6) Results were recorded and compared

E. Analysis of Results

The results obtained from different tests were analyzed to observe the improvement in soil properties. Parameters such as MDD, OMC, and CBR values were compared for different percentages of stone dust. Graphs were plotted to show the variation and identify the optimum percentage of stone dust.

III. RESULT AND DISCUSSION

The experimental investigation was carried out to evaluate the effect of bamboo fibre on the engineering properties of soft clay soil. The results obtained from various laboratory tests are discussed below:

A. Liquid Limit of Plain Soil

The natural soil exhibited a Liquid Limit (LL) of 38.5%, Plastic Limit (PL) of 30.42%, and Plasticity Index (PI) of 8.08%, indicating low plasticity characteristics. Upon the addition of bamboo fibre, a slight reduction in liquid limit and plasticity index was observed.

Interpretation: This reduction in plasticity indicates improved soil stability and reduced swelling/shrinkage behaviour, which is desirable for subgrade materials.

Table 1: Liquid Limit test results

S.N.	Number of Blows (N)	Water Content (W, %)
1	16	41.2%
2	20	39.8%
3	25	38.5%
4	28	37.8%

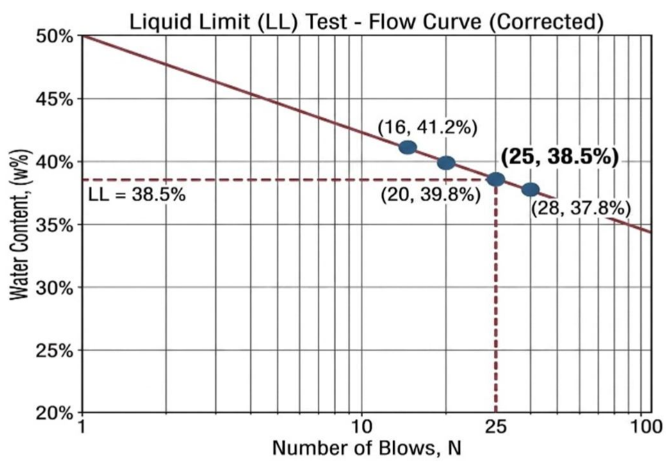

Figure 2: Liquid Limit (LL) Test at 25 Blows, 38.5%

B. Plastic Limit of Plain Soil

The Plastic Limit was recorded as 30.4% by the hand-rolling method (3 mm thread). Consequently, the Plasticity Index (Ip) was calculated as 8.1%, classifying the soil as ML (Low Plasticity Silt) according to the Unified Soil Classification System (USCS).

Table 2: Plastic Limit result

Trial No.	W_1	W_2	W_3	W_C (%)
1	41	38	28	30
2	42	38.7	28	30.89
3	43	39.5	28	30.43

C. Plain Soil (Natural Soil) Proctor Test

The Standard Proctor test results for natural soil indicate that: Optimum Moisture Content (OMC) = 22.88% Maximum Dry Density (MDD) = 1.56 g/cc Bulk Density = 1.91 g/cc

Interpretation:

The soil shows moderate compaction characteristics with relatively higher OMC, which is typical for soft clay due to its water affinity.

Table 3: Plain Soil Test Result

S.N.	Water Content (%)	Maximum Dry Density	Bulk Density
1	13.78	1.50	1.70
2	14.3	1.51	1.72
3	22.88	1.56	1.91
4	27.9	1.45	1.86
5	33.83	1.38	1.80

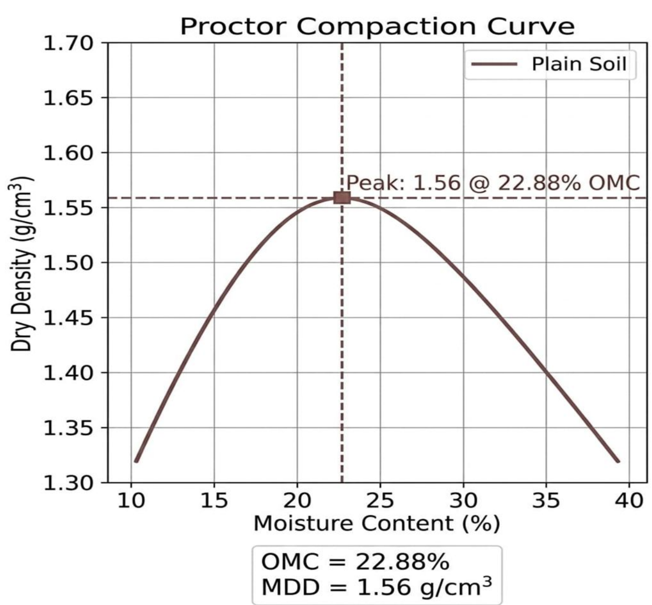

Figure 3: Dry Density and Moisture Content

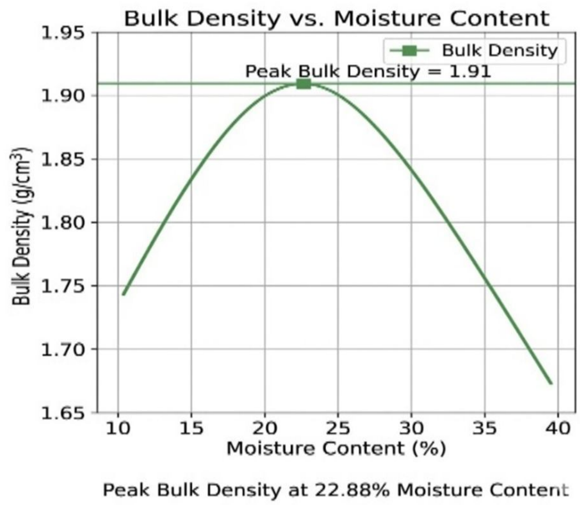

Figure 4: Peak Bulk Density at 22.88% Moisture Content

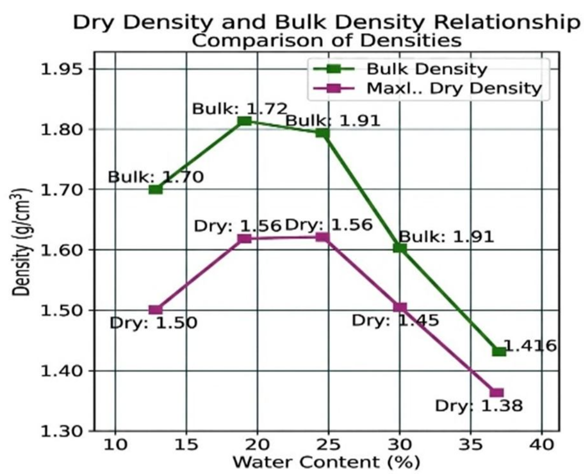

Figure 5: Dry Density and Bulk Density relationship

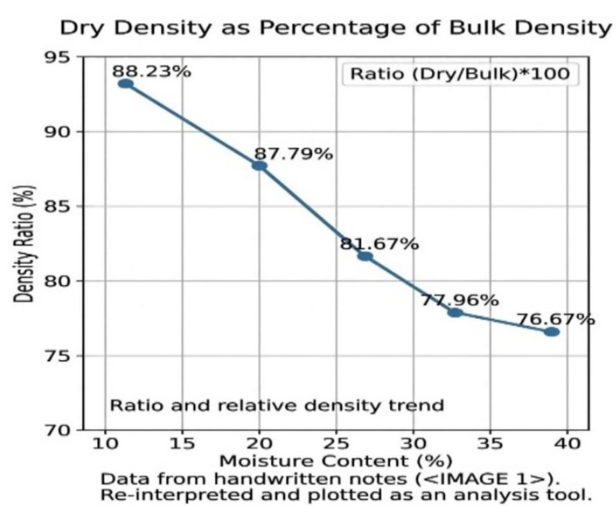

Figure 6: Density Ratio and Moisture Content

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D. Plain Soil California Bearing Ratio (CBR) Test

Standard Load values:
2.5 mm = 1370 kg, 5 mm = 2055 kg
Result: CBR at 2.5 mm = 3.56 %
CBR at 5 mm = 3.57 %
Final CBR = 3.57

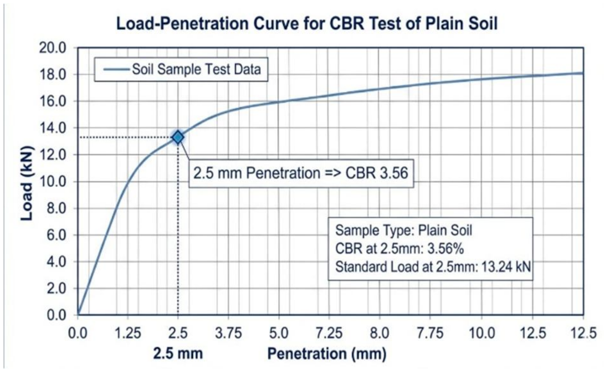

Figure 7: CBR Test of Plain Soil at 2.5mm: 3.56%

E. Liquid Limit (LL) with Stone Dust

The liquid limit of soil mixed with stone dust was observed to be slightly reduced compared to natural soil. This reduction is due to the non-plastic nature of stone dust, which decreases the water absorption capacity of soil.

Discussion:

Lower liquid limit indicates that the soil becomes less sensitive to moisture and shows improved stability. The addition of stone dust reduces the tendency of soil to undergo excessive deformation at higher water content.

Table 4: 5% Stone Dust Mix Test Result

S.N.	Number of Blows	W_1	W_2	W_3	W_C
1	35	28.40	35.50	33.60	
2	25	28.50	37.00	34.70	37.1%
3	15	28.30	38.80	35.20	

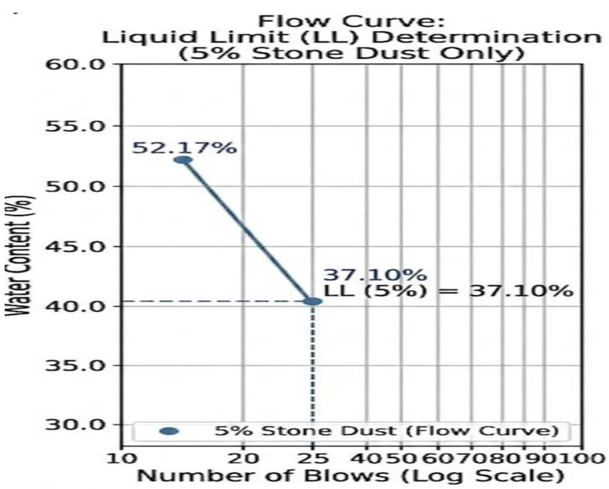

Figure 8: 5% mix of stone dust at 25 blows, 37.10%

Table 5: 10% Stone Dust Mix Test Result

S.N.	Number of Blows	W_1	W_2	W_3	W_C
1	31	28.42	65.34	57.90	
2	25	29.05	61.23	54.20	27.8%
3	19	28.65	68.45	60.12	

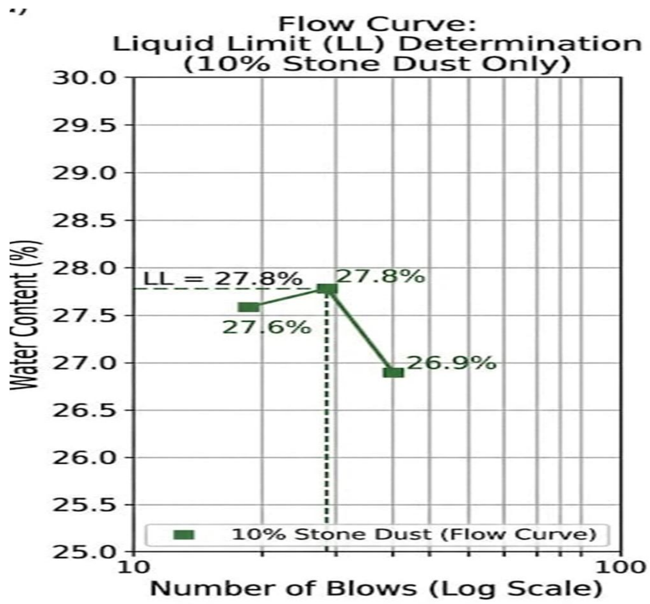

Figure 9: 10% mix of stone dust at 25 blows, 27.8%

F. Plastic Limit (PL) with Stone Dust

The plastic limit of the treated soil showed a slight increase or minor variation compared to plain soil.

Discussion:

This behaviour indicates that the soil requires slightly more moisture to reach plastic state, which improves its workability. The presence of stone dust helps in reducing stickiness and enhances handling properties of soil.

Table 6: Plastic Limit (5% Stone Dust)

Trial	W_1(g)	W_2(g)	W3(g)	W_C%
1	28.24	65.47	57.18	28.95
2	29.05	63.23	55.68	28.38
3	28.45	61.78	54.45	27.98

Average Plastic Limit = 28.52%

Table 7: Plastic Limit (10% Stone Dust)

Trial	W_1(g)	W_2(g)	W_3(g)	W_C%
1	28.46	65.10	57.70	25.30
2	29.05	63.60	56.80	25.06
3	28.65	62.10	55.80	23.20

Average Plastic Limit = 24.52%

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G. Stone Dust and Soil Mixture CBR Test

The CBR value of soil mixed with 5% stone dust was found to be approximately 9%, which is significantly higher than plain soil (~3.5%).

The experimental results indicate that the untreated soil has a CBR value of 3.5%, representing weak subgrade conditions. With the addition of 10% stone dust, the CBR value increased significantly to 11.14%.

This considerable increase in CBR value shows that stone dust effectively improves the strength characteristics of the soil. The improvement is attributed to the filling of voids and better particle interlocking, which results in higher compaction and a denser soil mass. Consequently, the soil exhibits greater resistance to penetration and reduced deformation under applied loads.

Therefore, the addition of 10% stone dust enhances the load-bearing capacity and overall stability of the soil, making it more suitable for use in pavement subgrade applications.

Discussion:

The increase in CBR value is due to improved particle interlocking and better compaction. Stone dust fills the voids between soil particles, increasing density and resistance to penetration. This results in enhanced load-bearing capacity of the soil.

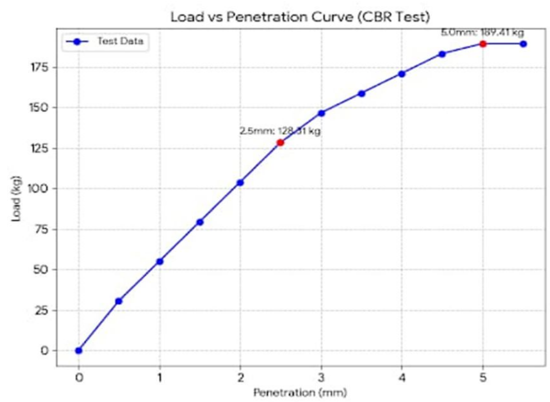

Figure 10: CBR at 5% Stone Dust

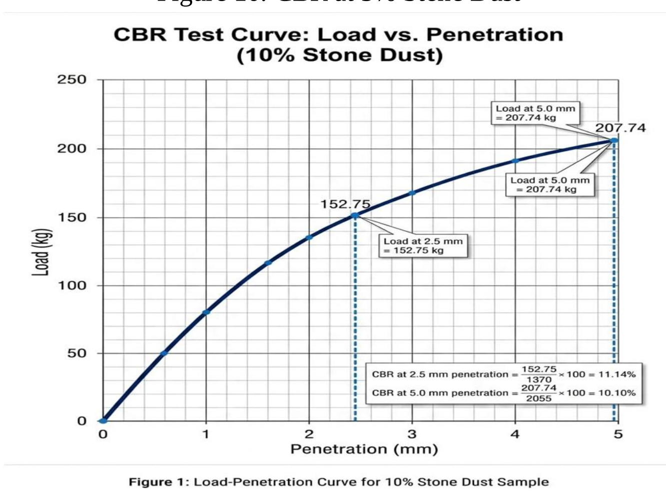

Figure 11: CBR at 10% Stone Dust

IV. CONCLUSION

The present study evaluates the effect of stone dust on the engineering properties of soil. Based on the experimental results, it is observed that the addition of stone dust significantly influences both the consistency limits and strength characteristics of soil.

The Liquid Limit and Plastic Limit decrease with the increase in stone dust content. The Liquid Limit reduces from 38.5% for plain soil to 34.9% at 10% stone dust, while the Plastic Limit decreases from 30.42% to 24.52%. This indicates a reduction in the plasticity of the soil, making it less compressible and more stable.

On the other hand, the California Bearing Ratio (CBR) value shows a substantial increase with the addition of stone dust. The CBR value improves from 3.5 for untreated soil to 11.14 at 10% stone dust. This enhancement in strength is due to better particle interlocking and improved gradation caused by the addition of stone dust. Overall, the results indicate that the inclusion of stone dust enhances the load-bearing capacity of soil and reduces its plasticity. Among the different proportions studied, 10% stone dust content is found to be the optimum, providing maximum improvement in strength characteristics.

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