



Influence Of Stone Dust And Recycled Fine Aggregate On CBR Of Clayey Subgrade Soil

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Abstract: The increase in highway traffic highlights the importance of a well-constructed base and sub-base for the construction of durable roads. In areas with unstable subsoil, roads are prone to damage, leading to accidents and financial losses. Stabilization is necessary to improve weak subsoil, which often faces issues like swelling, shrinkage, and low bearing capacity. The green building initiative promotes using waste materials, such as demolished debris and stone dust, to reduce environmental impact. This work explores the use of stone dust (SD) and recycled fine aggregate (RFA) in stabilizing clay subsoil whose California Bearing Ratio (CBR) is low. Different percentages of these materials (0%, 5%, 10%, 15%, 20%, 25%, and 30%) were added to clay soil to bring out their stabilizing effect. Tests including sieve analysis, Atterberg limits, compaction, unconfined compressive strength, and CBR were performed on both soaked and unsoaked samples. The results showed significant improvements in CBR, with 20% stone dust and 25% recycled fine aggregate when added to clay soil. Soil treated with 20% stone dust saw a threefold increase in CBR with light compaction and a twofold increase with modified compaction. Similarly, 25% recycled fine aggregate led to a fivefold increase in CBR under modified compaction. However, soaked samples displayed less improvement. This stabilization method can enhance road construction by reducing the need for expensive materials, improving subgrades, and allowing for thinner pavements.

Index Terms – Clay, stone dust, recycled fine aggregate, CBR, OMC, MDD

1.INTRODUCTION

Expansive soils, especially those containing montmorillonite minerals, pose significant challenges due to their tendency to swell when wet and shrink when dry, leading to reduced bearing capacity (Brajesh et al., 2013). Although these soils can be hard and strong in dry conditions, their instability creates difficulties in construction. Stabilization is essential to ensure a stable subgrade for road works (Mire et al., 2013). The use of recycled fine aggregate (RFA) and stone dust (SD) as stabilizers has gained popularity in improving the engineering properties of clay soils. Stone dust, a by-product obtained from the crushing process of stones, and RFA, derived from construction waste, can improve the load-settlement behaviour of clay (Ehsan et al., 2023a, b; Rohit et al., 2015, Amit et al., 2019). This method offers an eco-friendly and cost-effective solution for soil stabilization in geotechnical projects (Indiramma et al. 2019a, b; Aref et al. 2016., c; Yasamen et al., 2023). Analyzing the characteristics of clay soils such as low California Bearing Ratio (CBR), significant swelling and shrinkage, poor permeability, and low shear strength provides valuable insights into enhancing the construction durability of these soils (Dixit et al., 2016). Cohesive clay subgrades are susceptible to volumetric changes, resulting in fluctuations in volume. To address this, subgrade stabilization techniques are employed to increase soil strength, which is then utilized in road works (Shriful et al., 2022). Various stabilization methods, including chemical, mechanical, alternative, and innovative approaches, are used to improve the load-bearing capacity and durability of the subgrade. These methods make clay soils more suitable for construction, enhancing the overall performance of infrastructure.

Soil stabilization is vital for improving the stability, mechanical properties, and resilience of natural soils against environmental challenges. Biological stabilization employs a range of soil stabilizers. Lime, available as hydrated lime or quicklime, enhances the pozzolanic characteristics and cation exchange capacity of the soil. Cement, especially Portland cement, serves to bind soil particles together, which enhances the bearing capacity and compressive strength of the soil. Furthermore, fly ash, a by-product of power generation, increases soil durability by reacting with lime and water to form cementitious compounds. Thermal stabilization, which enhances soil stability by removing moisture and changing its composition through heat, and the electrokinetic approach, which utilizes electrical current to rearrange charged particles in the soil. Techniques like bioencapsulation utilize binding agents to improve drainage, while nano-modification introduces nano-clay particles to enhance interconnectivity and overall durability, thereby reducing the soil's susceptibility to moisture.

This paper presents how stone dust and recycled fine aggregate (RFA) can enhance the California Bearing Ratio of clay soil, making it suitable for use as subgrade material in roadways and other structures. By exploring stone dust as an eco-friendly substitute for traditional ground improvement materials, the study promotes sustainable construction practices. The experimental component examines the stabilization of clay soil with these additives to evaluate their effectiveness.

2.METHODOLOGY

This paper presents the stabilization of clay soil, which tends to expand and shrink due to moisture fluctuations, making it unsuitable for subgrade applications. Recycled fine aggregate and crushed stone dust were used to study the improvement in soil properties. The basic objective is to measure the CBR of the treated clay. Different proportions (5%, 10%, 15%, 20%, 25%, and 30%) of both materials were mixed to clay and tested. The research highlights the underexplored potential of using industrial by-products for clay stabilization. The subsequent sections provide details on the materials.

The clay soil was collected from Patancheru, Hyderabad in Telangana state and examined as per the Indian Standard procedures. The tests included grain size distribution (IS-2720 PART-4_1985), specific gravity (IS-2720 PART-3 SEC-1_1980), Atterberg limits (IS-2720 PART-5_1985), standard compaction (IS-2720 PART-7_1980), modified compaction (IS-2720 PART-8_1983) California Bearing Ratio (IS-2720 PART-16_1987), and unconfined compressive strength (IS-2720 PART-10_1991). The clay sample, consisting of 56% fine particles, displayed a high plasticity index and was categorized as highly compressible clay (CH). Stone dust was collected from Balanagar, Hyderabad, a by-product of the stone-crushing process. Recycled fine aggregate was collected from Hyderabad, made from crushed concrete industry. The materials were processed and stored effectively in air-tight containers and bags to maintain similar conditions in all the tests, where stone dust and recycled fine aggregates were used along with soil.

Table 1: Basic properties of clay, stone dust and recycled fine aggregate

S.No.	Property	Clay	SD	RFA
1	Specific gravity	2.88	2.60	2.36
2	Free swell index in %	88	NP	NP
3	Particle size analysis:			
	% Gravel	0	0	0
	% Sand	18	85	93
	% Silt	26	15	7.0
	% Clay	56	0	0
4	Liquid Limit	50.5	NP	NP
5	Plastic limit	25.5		
6	Plasticity Index(IP)	25.0		
7	Soil Classification	CH		
8	Standard compaction			
	OMC in %	22	6.5	10.0
	MDD in kN/m ³	15.25	18.18	15.05
9	Modified compaction			
	OMC in %	16.00	2.60	6.0
	MDD in kN/m ³	17.85	19.00	18.10

10	UCS in kPa	225		
11	Unsoaked CBR in %	2.0	29.90	21.30
12	Soaked CBR in %	1.0	15.30	16.40

3. RESULTS AND DISCUSSION

To understand the effect of admixtures such as stone dust (SD) and recycled fine aggregate (RFA) on compaction characteristics and CBR of clay soil, the results obtained are plotted and the same is discussed in this section. Figs.1 to 4 present the compaction curves of stone dust and recycled fine aggregate-treated clay soil subjected to standard and modified compaction tests. The dry unit weight-water content relations presented in Figs. 1 to 4 follow typical clay soil trends for the proportions of stone dust and recycled fine aggregates starting from 5% to 30%. Typically, it is observed that as the SD and RFA increase, there is an increase in maximum dry unit weight. Further, the modified compaction results revealed that there is a decrease in Optimum Moisture Content (OMC) and an increase in maximum dry unit weight when compared to the standard compaction.

Fig.1 illustrates that, with increasing stone dust content, the dry unit weight rises, with untreated soil displaying a lower curve, and the mixture containing 30% stone dust reaching the highest dry unit weight. Fig.2 shows that under modified compaction, the dry unit weight increases with the stone dust when compared to untreated clay soil having a lower curve. The mixture with 20% stone dust achieved the highest value of maximum dry unit weight. Additionally, Fig.3 highlights that, under standard compaction, the dry unit weight rises with the addition of recycled fine aggregate. Untreated clay soil exhibits a lower curve, while the highest dry unit weight is obtained in the mixture with 15% recycled fine aggregate. In Fig.4, under modified compaction, a similar trend is observed: the dry unit weight increases with increased recycled fine aggregate, and the RFA of 15% shows the highest dry unit weight.

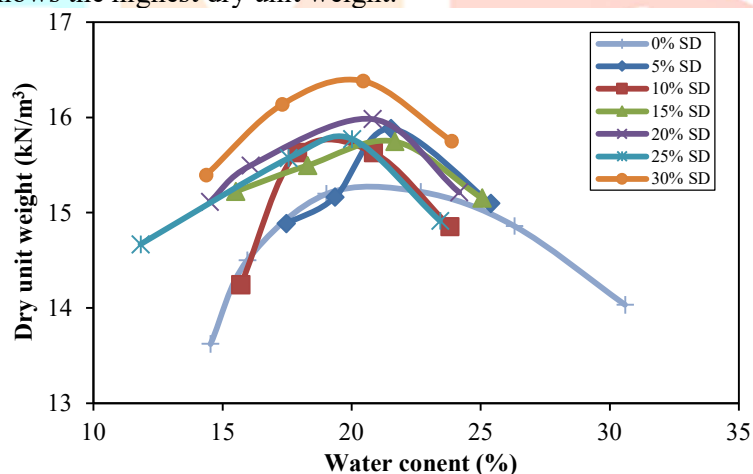


Fig. 1 Dry unit weight vs water content curves of SD treated clay subjected to standard compaction.

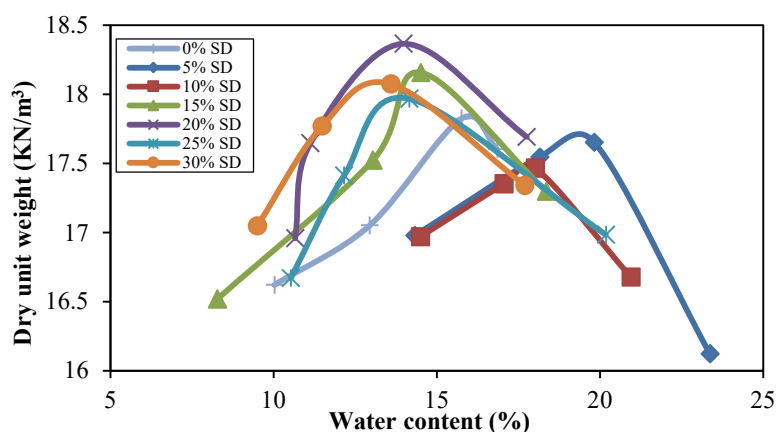


Fig. 2 Dry unit weight vs water content curves of SD-treated clay subjected to modified compaction

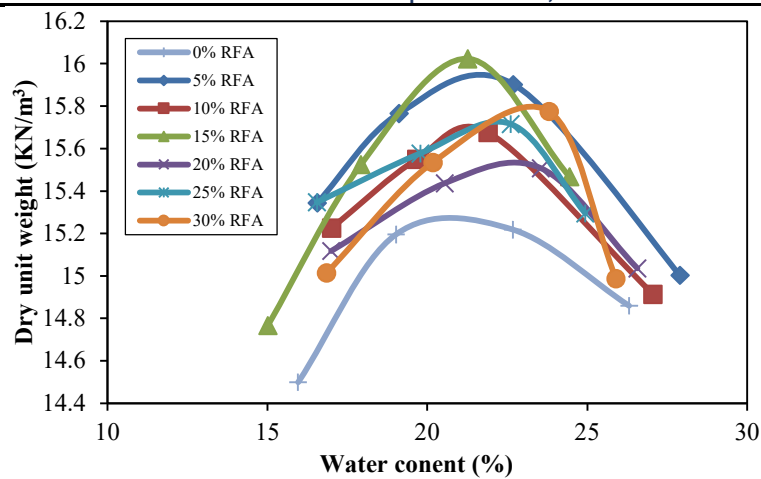


Fig. 3 Dry unit weight vs water content curves of RFA-treated clay subjected to standard compaction

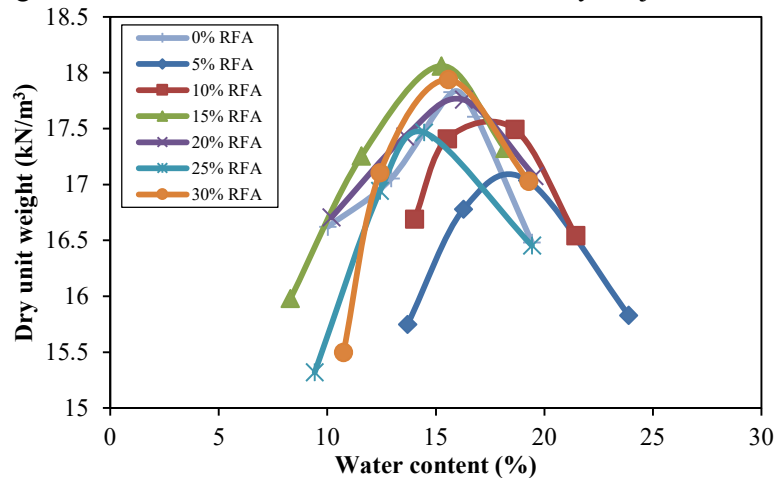


Fig. 4 Dry unit weight vs water content curves of RFA-treated clay subjected to modified compaction

Figs.5 to 8 present the load-penetration curves for samples prepared at respective optimum moisture contents of SD and RFA-treated clay soil under standard and modified compactions and unsoaked conditions. Fig.5 shows that clay soil treated with 20% stone dust under standard compaction and unsoaked one exhibits higher load values at a given penetration level compared to the untreated clay soil. Fig.6 presents the load penetration curves for clay samples stabilized with stone dust under modified compaction in unsoaked conditions. The data reveal that clay treated with 15% to 25% stone dust achieves greater load values at the given penetration depths compared to untreated soil, indicating improved strength and load capacity. Fig.7 shows the clay soil treated with 25% recycled fine aggregate achieves higher load value at penetration level under standard compaction in unsoaked conditions compared to untreated soil. The same trend is obtained in modified compaction in the unsoaked case as shown in Fig.8. A greater load penetration value at the 25% range is observed.

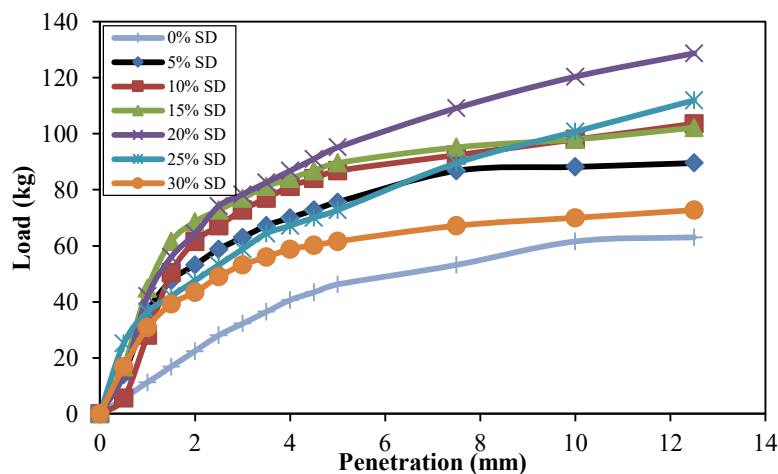


Fig: 5 Load-penetration curves of SD-treated clay subjected to unsoaked and standard compaction

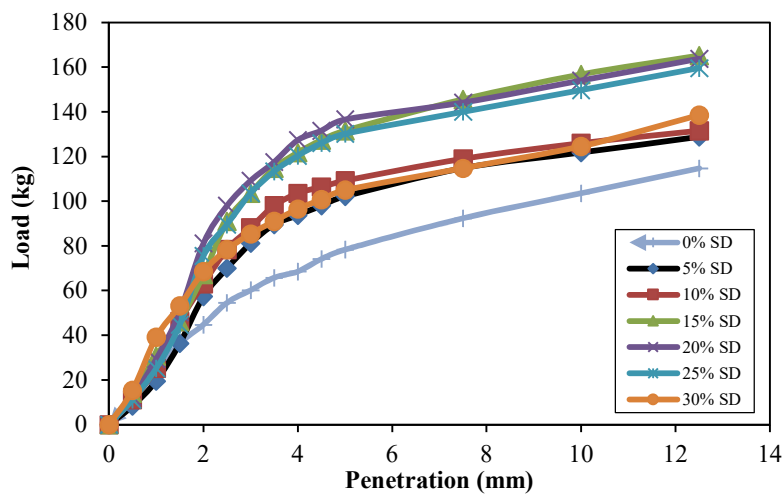


Fig: 6 Load-penetration curves of SD-treated clay subjected to unsoaked and modified compaction

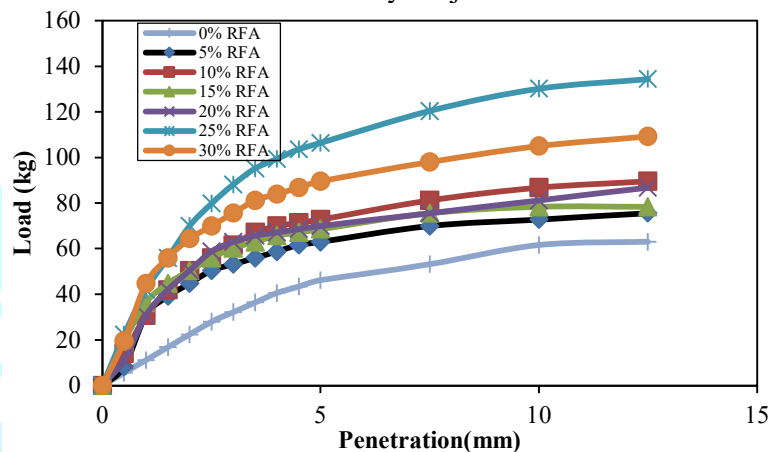


Fig: 4.7 Load-penetration curves of RFA-treated clay subjected to unsoaked and standard compaction

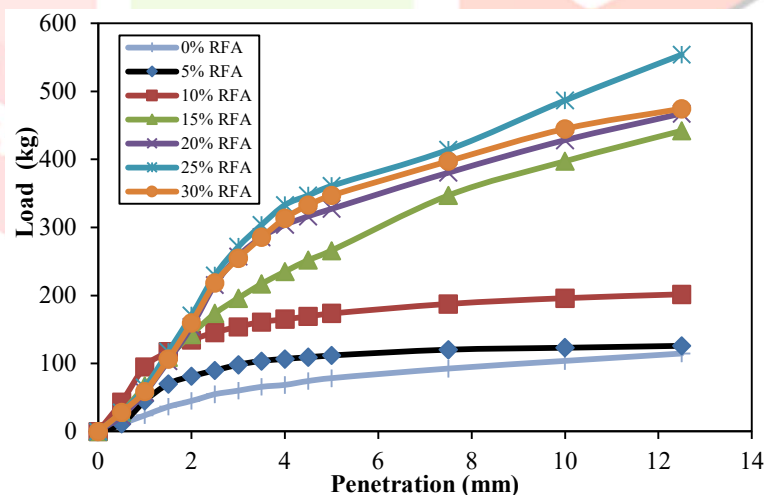


Fig: 4.8 Load-penetration curves of RFA-treated clay subjected to unsoaked and modified compaction

The compaction characteristics such as optimum moisture content (OMC) maximum dry unit weight (MDD) & Unsoaked and Soaked CBR values of SD & RFA treated clay soil obtained from standard and modified compaction tests are further presented in Tables. 2 to 5. From Table. 2, it is observed that as the % SD increases from 0 to 30%, there is about a 10% decrease in OMC and the MDD has increased about 7.5% in the standard compaction. Further from the same Table, corresponding to modified compaction, it is observed that as the stone dust increased from 0% to 30%, the increase in OMC is about 25% and the increase in MDD is about 2%. The presence of fines content in SD increased OMC with a % increase in SD.

In Table 3, the compaction characteristics of RFA-treated clay are presented. From this Table, it is noticed that about a 10% decrease in OMC at 30% RFA compared to untreated clay, and a 6% increase in MDD at 15% RFA compared to untreated clay in the standard compaction. In the modified compaction, it is observed

that there is a 6% decrease in OMC compared to untreated clay when RFA varied from 0 % to 30%. There is an increase in MDD of about 2% at 15% RFA when compared to untreated clay. In Table 4, the CBR values of SD-treated clay are presented. From this Table, it is noticed that the stone dust samples showed higher CBR values with modified compaction, reaching a peak at 20% stone dust with 2.66 times the CBR of untreated soil, while standard compaction at the same percentage achieved 1.5 times the CBR of untreated soil.

Table 2 Compaction characteristics of SD-treated clay

SD (%)	Standard compaction		Modified compaction	
	OMC (%)	MDD (kN/m ³)	OMC (%)	MDD (kN/m ³)
0	22	15.25	16	17.81
5	21	15.84	20	17.70
10	19	15.81	19	17.40
15	21	17.90	21	18.10
20	19	16.00	20	18.4
25	20	15.80	20	18.00
30	20	16.4	20	18.10

In Table 5, the CBR values of RFA-treated clay soil are presented. From this Table, it is noticed that CBR values from soaked samples are lower than those from unsoaked samples. CBR of soil samples improved in both scenarios as the percentage of recycled fine aggregate increased, reaching a peak at 25% of RFA. In standard compaction, compared to untreated soil, the unsoaked CBR at 25% recycled fine aggregate is 2 times higher and in soaked condition, it is 3 times higher. Similarly in modified compaction, compared to untreated soil, the unsoaked CBR is 3 times higher and in soaked conditions, it is 2.5 times higher.

Table 3 Compaction characteristics of RFA-treated clay

RFA (%)	Standard compaction		Modified compaction	
	OMC (%)	MDD (kN/m ³)	OMC (%)	MDD (kN/m ³)
0	22	15.25	16	17.81
5	22	15.90	19	17.10
10	20	15.70	18	17.60
15	21	16.10	15	18.10
20	20	15.5	16	17.10
25	20	15.7	14	17.50
30	20	15.58	15	17.90

Table 4 CBR characteristics of SD-treated clay

SD (%)	Standard compaction		Modified compaction	
	Unsoaked CBR (%)	Soaked CBR (%)	Unsoaked CBR (%)	Soaked CBR (%)
0	3	1	6	2
5	5	1	6	2
10	5	1	6	3
15	5	2	7	3
20	6	3	8	3
25	4	3	7	3
30	4	2	6	2

Table 5 CBR characteristics of RFA-treated clay

RFA (%)	Standard compaction		Modified compaction	
	Unsoaked CBR (%)	Soaked CBR (%)	Unsoaked CBR (%)	Soaked CBR (%)
0	3	1	7	2
5	4	2	7	2
10	4	3	11	3
15	4	3	14	3
20	4	3	18	3
25	6	3	20	5
30	5	3	18	4

4. Summary and Conclusions

The study involved the mixing of stone dust and recycled fine aggregate with clay soil in varying proportions (ranging from 0% to 30%). Standard, modified compaction and CBR tests were performed on treated soil. The results revealed that as the stone dust and recycled fine aggregate proportions increase, the OMC of clay has increased. It may be due to the presence of fines in stone dust as well as the presence of lime, cement and fines in the recycled fine aggregate. There was marginal improvement in dry unit weight. The CBR of clay samples admixed with various proportions of stone dust and recycled fine aggregate showed improvement, especially at 25% of admixture. The increase in CBR observed is about 2 to 3 times when compared to untreated clay soil. Recycled fine aggregate showed better improvement in unsoaked CBR value. Its value of untreated unsoaked condition in modified compaction is 7% and treated with 25% recycled fine aggregate its value is 20%. Recycled fine aggregate can be effectively utilized in road projects up to a proportion of 25 to 30% in stabilizing the clayey subgrade. The use of recycled fine aggregate minimizes the cost and improves the stability of clayey subgrade, in turn, the achievement of sustainability is appropriate.

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