Study of Enhancing Road Construction by Stabilizing Alluvial Soil with Marble Dust, Lime, and Burnt Brick Dust

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ABSTRACT: Infrastructure development plays a crucial role in driving the overall growth of the Indian economy. However, constructing engineering structures on weak or soft soil poses significant challenges in terms of safety and stability. The foundation of any structure must possess sufficient strength to support the entire load. Among the different types of soil, alluvial soil is commonly used but it exhibits varying behavior with changes in moisture content and has low bearing capacity. Soil stabilization techniques offer effective solutions to enhance the properties of such soil. Additionally, the increasing pace of urbanization and industrialization has led to the generation of large quantities of waste materials, posing environmental challenges in their disposal. Utilizing these waste materials for soil stabilization presents an alternative approach that allows for their high-volume consumption and reduces environmental impact. This paper aims to stabilize alluvial soil using marble dust, burnt brick dust, lime, and burnt brick dust as stabilizing agents. Laboratory investigations encompass determining the Atterberg limits, dry density, California bearing ratio (CBR), and unconfined compressive strength (UCS). The proportions of the stabilizing agents vary from 0% to 40%, with increments of 10% by mass of the dry soil. The results reveal a decreasing trend in the plasticity index as the content of marble dust, lime, and burnt brick dust increases. Furthermore, there is a general increase in the maximum dry density (MDD) and a decrease in the optimum moisture content (OMC) with higher proportions of marble dust, lime, and brick dust. Moderate improvements in CBR and UCS are observed with increasing marble and burnt brick dust content, while significant enhancements are found with higher lime and burnt brick dust content. The stabilization of soil leads to improved subgrade strength, thereby reducing the required thickness of the pavement. These findings demonstrate the potential of utilizing waste materials for soil stabilization, resulting in improved engineering properties, cost-effectiveness, and sustainability in infrastructure construction. By implementing such techniques, the industry can address both environmental concerns and the need for robust foundations in various construction projects.

Keywords: Waste materials; Soil stabilization; Atterberg's Limits; Compaction; CBR; UCS

1 INTRODUCTION

The predominant soil in the study area is Gangetic alluvium, which is commonly found in the Indo-Gangetic plain region. Alluvial soils typically have low strength, and their engineering properties vary with changes in moisture content. Constructing roads on virgin alluvial soil often requires a thicker pavement and a large quantity of construction materials, resulting in higher costs. Furthermore, the use of quarried aggregates for road construction is prohibited by the government. Therefore, there is a need for innovative approaches to reduce construction costs while ensuring sufficient quality.

Soil stabilization is one technique used to improve the quality of subgrade soil and reduce construction costs. However, conventional stabilizing materials such as cement, lime, and chemicals are expensive. Cement stabilization is also less preferable nowadays due to the rising costs and environmental concerns associated with its production. Hence, there is a growing emphasis on promoting the use of non-conventional and waste materials like fly ash, rice husk ash, sugar cane bagasse ash, marble dust, and burnt brick dust for soil stabilization. Several researchers have conducted studies in this field, and a few of their findings are mentioned here.

Anitha K. et al. (2009) investigated the effects of marble dust on different types of subgrade soil. They observed a significant reduction in the plasticity index as the percentage of marble dust varied, while the optimum moisture content (OMC) decreased and the maximum dry density (MDD) increased with the addition of marble dust.

Justo C.E.G and Krishnamurthy (2008) conducted laboratory studies on soils treated with marble powder stabilizer. They observed a reduction of about 35% to 40% in the plasticity index values with the addition of 6% stabilizer, and the soaked CBR (California Bearing Ratio) value of the stabilized soils showed a significant increase, even with a 2% stabilizer content.

Lekha B.M. and A.U. Ravi Shankar (2014) investigated the laboratory performance of marble dust-stabilized soil for pavements. They found that the treated soils exhibited a high fatigue life when subjected to repeated loading, compared to the untreated soils.

Bell (1996) studied the use of lime as a stabilizer for clay minerals and soil. The research indicated that lime could enhance the geotechnical properties of the soil.

Firat (2012) replaced two types of natural soil with lime, brick dust, and waste sand. The study showed that lime and brick dust were effective additive materials for road subgrade fill, improving the CBR and swelling ratio. A replacement level of 15% for these by-products was found to be suitable for medium and low plasticity soils.

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By studying the engineering properties of alluvial soil with different stabilizing agents, this research aims to provide valuable insights into the effectiveness of marble dust, lime, and burnt brick dust as potential alternatives for soil stabilization. The findings from this study have the potential to contribute to the development of cost-effective and environmentally friendly solutions for road construction and infrastructure projects. By utilizing waste materials and non-conventional additives, it is possible to enhance the geotechnical properties of the subgrade soil, reduce pavement thickness requirements, and improve overall construction efficiency. Such advancements in soil stabilization techniques can lead to sustainable and economical practices in the field of civil engineering.

2 MATERIAL AND METHODS

2.1 Material

The marble dust used in this study was obtained from local sources and is a byproduct of cutting and grinding marble. It has a very fine particle size, is non-plastic, and is nearly well-graded. Lime and brick dust were obtained from a chimney and were in a dry form. Before being mixed with the soil, the lime and brick dust were sieved through a 425-micron IS sieve. The chemical composition of the soil, marble dust (MD), lime, and brick dust (BD) are provided in Table 1. The physical properties of marble dust (MD), lime, and burnt brick dust (BD) are presented in Table 2.

Table 1: Chemical composition of admixtures

Component	Test Result (% by Mass)			
	Alluvial Soil	MD	Lime	BD
Silica (SiO_2)	59.03	26.53	0.45	63.89
Aluminium Oxide (Al_2O_3)	15.07	0.39	0.14	25.49
Iron Oxide (Fe_2O_3)	4.77	13.70	0.05	7.73

Calcium Oxide (CaO)	2.71	38.45	95.8	0.29
Magnesium Oxide (MgO)	2.09	18.39	0.82	0.04

Table 2: Physical Properties of admixtures

Property	Test Result		
	MD	**LIME**	**BD**
Colour	Gray	White	Red
Specific gravity	1.865	1.89	1.90
Liquid limit	43.85	45.3	40.20
Plastic Limit	Non- Plastic	Non- Plastic	Non- Plastic
Optimum moisture content	41.25	43.56	45.60
Maximum dry density	1.19	1.18	1.16

2.2 Method

The basic tests conducted in this study were carried out in accordance with the relevant Indian standard codes. These codes include Grain Size distribution (IS:2720, Part-IV), Specific Gravity (IS:2720, Part-III), Atterberg's limits (IS:2720, Part-V), Compaction characteristics (IS:2720, Part-VII,VIII), UCS (IS:2720, Part-X), and CBR soaked and unsoaked (IS:2720, Part-XVI). These standard codes provide guidelines and procedures for determining the respective properties and characteristics of the soil samples.

3 EXPERIMENTAL INVESTIGATIONS

The soil sample used for this study is collected at a depth of

1.5m to 2.5m using the method of disturbed sampling. According to Indian Standard soil classification system, the soil was classified as intermediate plastic clay (CI). Index properties are 16% shrinkage index and 52% free swell index. The degree of expansion and severity are medium and marginal (BIS-1498:1970).Virgin alluvial soil is stabilized with marble dust and burnt brick dust from 10 to 40% with increment of 10%. Virgin soil is also stabilized with lime including burnt brick dust (i) keeping 2% lime and varying percentage of brick dust from 10 to 40% and (ii) keeping 4% lime, and varying percentage of brick dust from 10 to 40%.

3.1 Atterberg's Limits Characteristics

The results of Atterberg's limits for soil and marble dust are depicted in Fig 1(a), while the results for soil and brick dust are shown in Fig 1(b). It can be observed that the index properties of the soil decrease as the stabilizer content increases. This decrease may be attributed to the transformation of soil grains from finer to coarser.

Specifically, when stabilized with marble dust, the liquid limit decreases from 36% to 30%, and the plastic limit decreases from 21% to 19%. Similarly, at a 40% addition of burnt brick dust, the liquid limit decreases by 9%, and the plasticity index also decreases by 10%.

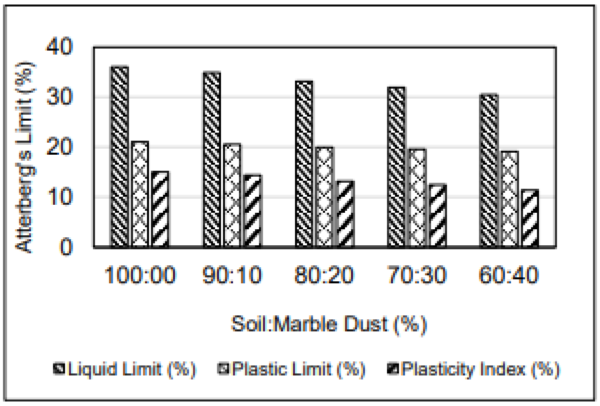

Figure 1(a): Atterberg's limit for soil and marble dust

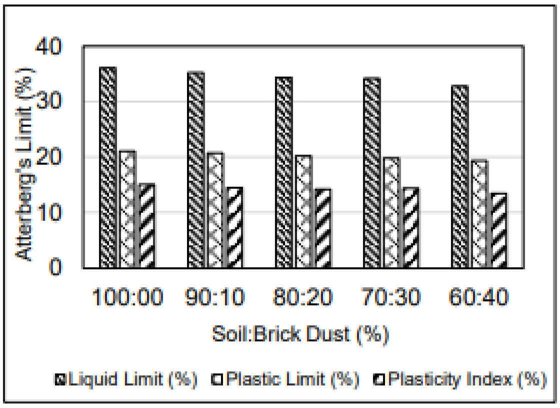

Figure 1(b): Atterberg's limit for soil and brick dust

When stabilized with 2% lime and varying percentages of brick dust from 0% to 40%, the liquid limit decreases from 36% to 26%, and the plasticity index decreases from 15% to 9%. Similarly, at 4% lime content and varying percentages of brick dust from 0% to 40%, the liquid limit decreases from 36% to 20%, and the plasticity index is reduced from 15% to 7% (Fig 2).

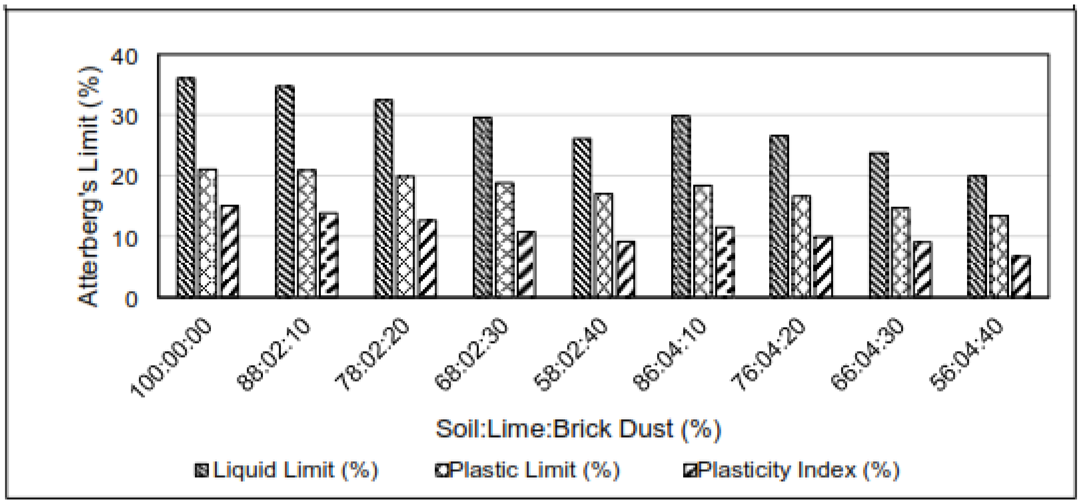

Figure 2: Atterberg's limit for soil, lime and brick dust at different composition

3.2 Compaction Characteristics

The variations in the optimum moisture content (OMC) and maximum dry density (MDD) with an increase in stabilizer content are presented in Table-3. It is observed that as the stabilizer content increases, the OMC decreases while the MDD increases. This can be attributed to the chemical reaction between the stabilizers and soil particles, which effectively transform the soil grains from finer to coarser.

When marble dust is added to the soil, the MDD value increases from 1.64 to 1.72 g/cc, while a decrease is observed in the OMC value from 17 to 14.6%. A similar trend is observed when brick dust is mixed with the soil, with a successive increment of 10%. The MDD value increases by 7.3% and the OMC value decreases to 15%. For 2% lime content with varying percentages of brick dust from 10% to 40%, the MDD value increases by 15.24% and the OMC values decrease by 22.9% compared to the virgin soil. In the compaction test conducted at 4% lime content and different percentages of brick dust (10% to 40%), the MDD value increases by 20.12% while the OMC decreases by 27.64%.

Table 3: Compaction properties using MD,BD and lime

Soil : MD	MDD (g/cc)	OMC (%)	Soil:Lime:BD	MDD (g/cc)	OMC (%)
100:0	1.64	17	100:00:00	1.64	17
90:10	1.67	16.1	88:02:10	1.74	15.1
80:20	1.70	15.7	78:02:20	1.82	14.2
70:30	1.72	15.1	68:02:30	1.87	13.8
60:40	1.71	14.6	58:02:40	1.89	13.1
Soil : BD			86:04:10	1.81	14.7
90:10	1.69	15.9	76:04:20	1.88	13.7
80:20	1.74	15.2	66:04:30	1.94	12.9
70:30	1.76	14.7	56:04:40	1.97	12.3
60:40	1.73	14.4			

4 STRENGTH CHARACTERISTICS

4.1 CBR

The CBR characteristics of both the virgin soil and the stabilized soil are depicted in Figure 3 and Figure 4. It is observed that the unsoaked and soaked CBR values increase as the content of the stabilizer increases. This improvement can be attributed to the enhancement in grain size and the pozzolanic action of the chemicals present in the soil and stabilizers.

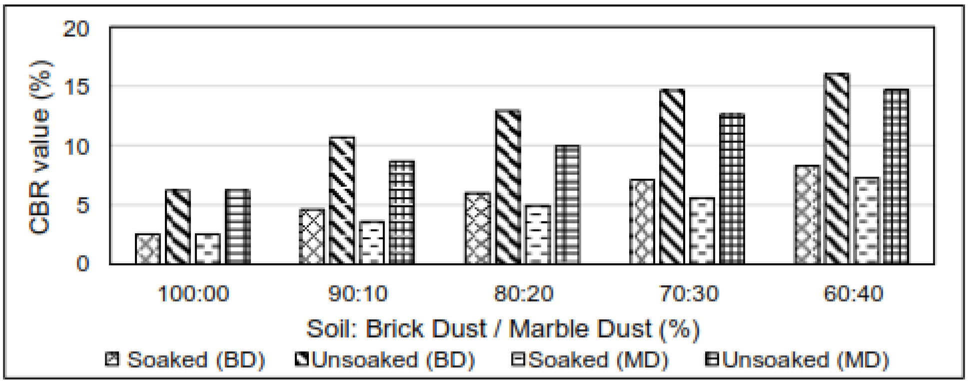

Figure 3: CBR value using Brick Dust and Marble Dust

The addition of BD and MD leads to an improvement in the soaked CBR value. A significant increase of 69.16% is observed with BD, while an increase of 67.77% is observed with MD. Similarly, the unsoaked CBR value shows a substantial improvement, with a 64.78% increase with BD and a 57.88% increase with MD, compared to the virgin soil.

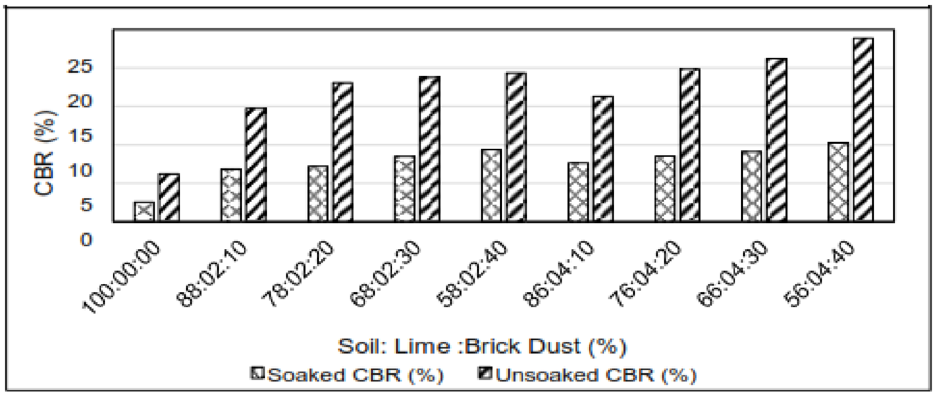

Figure 4: CBR value for soaked and unsoaked at different proportion

The results indicate that the soaked California Bearing Ratio (CBR) exhibits an increase from 2.55% to 9.37% when 2% lime is used, with varying percentages of brick dust ranging from 10% to 40%. Furthermore, at 4% lime content, the soaked CBR value reaches 75.1% with different percentages of brick dust.

Similarly, the unsoaked CBR value shows a significant improvement when 2% lime is utilized, along with varying percentages of BD. Compared to the virgin soil, the unsoaked CBR value is enhanced by 67.9%. The trend remains consistent at 4% lime content, with the unsoaked CBR value increasing to 74% as the percentage of BD varies.

These findings are visually represented in Figure 4, illustrating the increase in CBR values with different lime and BD compositions.

4.2 Unconfined Compressive Strength Characteristics

The variations in unconfined compressive strength (UCS) are presented in Table 4. The results indicate that the UCS of the mix increases when 2% lime content is added, reaching a maximum value of 4.27 kg/cm2 for the mix consisting of 68% soil, 2% lime, and 30% brick dust. Upon further increasing the lime content to 4%, the UCS initially continues to increase, with the maximum value recorded at 4.51 kg/cm2 for the same mix composition.

Notably, a significant improvement is observed when incorporating the admixtures BD and MD. The UCS value increases by 47.02% with the addition of BD, while MD contributes to a 42.73% increase in UCS. This enh ancement in UCS can be attributed to the pozzolanic action and the presence of chemicals in the soil and stabilizers.

The trend of increasing UCS values with higher concentrations of stabilizing agents suggests their positive impact on the strength characteristics of the mix.

Table 4: UCS value at different proportion of lime and brick dust

Soil: Lime :BD	**UCS (kg/cm^2)**	**Soil: BD**	**UCS (kg/cm^2)**
100:00:00	2.05	90:10	2.68
88:02:10	3.76	80:20	3.24
78:02:20	4.16	70:30	3.87
68:02:30	4.27	60:40	3.98
58:02:40	4.31	**Soil:MD**	**UCS**
86:04:10	3.82	90:10	2.47
76:04:20	4.06	80:20	3.09
66:04:30	4.51	70:30	3.58
56:04:40	4.68	60:40	3.63

6. CONCLUSIONS

Based on the findings of this study, the following conclusions can be made:

1. The alluvial soil examined in this study was classified as intermediate plastic clay (CI) according to the Indian Standard classification system. The soil was stabilized using three waste materials: marble dust (MD), lime, and brick dust (BD). These materials exhibited sufficient cementitious properties.

2. Significant improvement was observed in the soil's properties when stabilized with marble dust, brick dust, lime, and a combination of lime and brick dust. The highest level of improvement was achieved with a 4% lime and brick dust content.

3. Stabilization with marble dust, brick dust, lime, and brick dust led to an increase in maximum dry density and a decrease in optimum moisture content (OMC). The highest dry density of 1.97 g/cc was achieved at an OMC of 12.3% with a 4% lime and 40% brick dust content.

4. The California Bearing Ratio (CBR) value increased with the addition of marble dust, brick dust, lime, and brick dust content. However, an optimum CBR value was not identified. The highest soaked CBR value obtained was 10.26% with a 4% lime and 40% brick dust content.

5. The unconfined compressive strength (UCS) of the stabilized soil increased with the addition of marble dust, brick dust, lime, and brick dust content. However, an optimum UCS value was not determined. The highest UCS value recorded was 4.68 kg/cm2.

6. Consequently, marble dust and burnt brick dust can be effectively used as waste materials to enhance the properties of subgrade soil and reduce the thickness of adjacent layers.

These conclusions are based on the results and analysis conducted in this study. They suggest the potential for utilizing waste materials to improve the characteristics of subgrade soil for road construction purposes.

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