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INITIAL INVESTIGATION ON IMPROVING THE PHYSICOMECHANICAL PROPERTIES OF CLAYEY SAND USING CLAY BRICK DUST

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ABSTRACT: Clayey sand is commonly considered unsuitable for construction due to its high compressibility, low shear strength, and susceptibility to erosion and settlement. The research focuses on enhancing the physical and mechanical properties of the soil by incorporating clay brick dust (CBD) at varying proportions of 15, 20, and 25% by weight. A comprehensive laboratory testing was conducted, including particle size distribution, Atterberg limits, moisture content, Standard Proctor compaction, and California Bearing Ratio (CBR). These tests were used to assess the physical and mechanical behaviour of both untreated and treated soils. The results indicate that the inclusion of CBD significantly improves the soil's strength, as reflected by increased CBR values. However, higher percentages of CBD lead to reductions in moisture content and maximum dry density. The study concluded that the optimum percentage of CBD mixture was found to be 20% by weight, offering the best balance between improved strength and acceptable compaction properties. This study concludes that CBD is a viable and sustainable material for stabilizing clayey sand, making it more suitable for geotechnical and construction applications.

ABSTRAK: Pasir berlempung kebiasaannya tidak sesuai bagi tujuan pembinaan disebabkan oleh kemampatannya yang tinggi, kekuatan ricih yang rendah, serta kerentanan terhadap hakisan dan pemendapan. Kajian ini memfokuskan kepada penambahbaikan sifat fizikal dan mekanikal tanah dengan campuran serbuk bata tanah liat (CBD) pada kadar berbeza iaitu 15%, 20% dan 25% mengikut berat. Ujian makmal menyeluruh telah dijalankan merangkumi taburan saiz zarah, had-had Atterberg, kandungan lembapan, pemadatan Proktor piawai, dan ujian Nisbah Galas California (CBR). Ujian-ujian ini digunakan bagi menilai sifat fizikal dan mekanikal tanah sebelum dan selepas rawatan. Dapatan kajian menunjukkan bahawa penambahan CBD secara signifikan meningkatkan kekuatan tanah, seperti yang dibuktikan melalui peningkatan nilai CBR. Walau bagaimanapun, peratusan CBD yang lebih tinggi mengakibatkan pengurangan kandungan lembapan dan ketumpatan kering maksimum. Kajian ini merumuskan bahawa campuran optimum CBD adalah pada 20% berat, yang memberikan keseimbangan terbaik antara peningkatan kekuatan dan sifat pemadatan terbaik. Kajian ini membuktikan bahawa CBD merupakan bahan berdaya guna dan mampan bagi menstabilkan pasir berlempung, sekaligus menjadikannya lebih sesuai untuk aplikasi geoteknik dan pembinaan.

KEY WORDS: *Clayey sand, Soil Stabilization, Clay brick dust, Geotechnical Properties, California Bearing Ratio (CBR), Compaction characteristics* https://doi.org/10.31436/iiumej.v26i3.3821

1. INTRODUCTION

Clayey sand, a composite of fine clay and coarse sand particles, presents notable challenges in civil and environmental engineering applications. It is characterized by moderate to high compressibility, low shear strength, and a tendency to erode and settle, rendering it less ideal for construction [1]. Its high moisture retention may cause waterlogging, while its uneven particle distribution complicates compaction and shaping during site preparation [2]. Despite these drawbacks, enhancing the geotechnical behavior of clayey sand in terms of strength, compressibility, and moisture response is crucial for its application in infrastructure.

Soil stabilization is a widely used method to enhance soil performance and ensure reliable ground and foundation support. It improves load-bearing capacity and durability to meet safety standards. Various stabilizing agents have been used, including stone dust, calcium chloride, ceramic dust, lime, cement, bitumen, and brick dust, each offering distinct benefits depending on soil conditions [3].

Brick dust, derived from fired clay bricks, has gained attention due to its water resistance, refractory nature, and high compressive strength. Though less common in mainstream stabilization, it has been shown to significantly improve strength, especially the California Bearing Ratio [4]. Its effectiveness may vary based on local soil and brick properties [5].

Clay brick dust (CBD), a by-product of brick kiln operations, contains high levels of silica (55%), aluminum oxide (15%), iron oxide (8%), calcium oxide (7%), magnesium oxide (2%), and sulphur trioxide (1%) [6]. These oxides promote pozzolanic reactions, enhance particle bonding, and improve strength [7]. While CBD contains crystalline silica, which can pose respiratory risks, it is considered safe under controlled construction conditions. Importantly, CBD reuse supports sustainable construction by reducing construction and demolition waste, preserving resources, and aligning with circular economy goals [8].

In addition to brick dust, other construction-derived powders such as marble dust, stone dust, and granite dust have also been investigated for soil stabilization. For instance, [9] reported that waste marble dust reduced swelling and plasticity while significantly improving California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) of expansive clays. A recent study by [10] confirmed similar enhancements in geotechnical properties with marble dust inclusion. Similarly, [11] demonstrated that the addition of stone dust (10–50%) improved the maximum dry density (MDD) and CBR of clayey soils, while reducing the optimum moisture content (OMC). Broader evaluations, such as those by [12], examined multiple construction dusts (stone, granite, marble, and tile powders) and reported significant benefits in compaction, shear strength, and durability. These findings suggest that a variety of locally available construction by-products can serve as sustainable stabilizers, aligning with circular economy practices and environmentally friendly soil improvement strategies.

In prior studies, clay soil with 5% to 30% CBD showed improved dry density and reduced plasticity. For example, dry density increased from 1.72 g/cc to 1.89 g/cc with 5% CBD, with optimum water content at 19.52%. A 10% CBD mix yielded a density of 1.87 g/cc at 17.64% moisture [13]. Swathi (et al.) reported reduced swelling and shrinkage in expansive soils at 50% CBD, while [5] observed the highest dry density and CBR at 15% CBD, especially when combined with lime. These suggest that lower CBD ratios can yield meaningful improvements.

CBD has also been evaluated in blended stabilizers. Khan (et al.) showed that CBD combined with cement and fly ash in a 1:3 ratio enhanced unconfined compressive strength and reduced shrinkage, meeting AASHTO specifications. Gupta (et al.) tested CBD with rubber fiber and calcium chloride, showing strength gains depending on curing time, cement content, and compaction. Rubber fibers improved shear strength but had little impact on liquid limit, whereas calcium chloride in CBD reduced the liquid limit significantly.

Although prior studies support CBD as a sustainable stabilizer, results vary based on soil type, dosage, and additive combinations. High percentages offer performance gains but may not be cost-effective. Although prior studies support CBD as a sustainable stabilizer, most existing research has focused on blended stabilizers such as brick dust with cement, lime, or other additives to enhance pozzolanic reactivity and durability [16]. However, limited studies have isolated the effect of CBD as a sole stabilizing agent, particularly in clayey sand applications. Given the environmental benefits and widespread availability of brick waste, further investigation into its standalone performance is essential to validate its practical and sustainable application.

This study investigates the impact of 15%, 20%, and 25% CBD on the physical and mechanical properties of clayey sand. Laboratory tests include particle size analysis, Atterberg limits, moisture content, compaction, and California Bearing Ratio to evaluate CBD's potential as a standalone stabilizer. The findings aim to support sustainable soil improvement using construction waste in geotechnical engineering.

2. METHODOLOGY

2.1. Sample Collection

Clayey sand soil samples (Fig. 1a) were collected from a site near the riverside of Sungai Gombak, Gombak, Malaysia (3°15'21"N, 101°44'30"E), a location known for problematic soil profiles (fig. 2). Brick dust, used as the stabilizing agent, was sourced from the IIUM construction yard. The CBD (Fig. 1b) was air-dried, manually crushed, and sieved to ensure a consistent particle size and avoid oversized aggregates that could affect the mixing and compaction process.

The samples were prepared by mixing the clayey sand with 0% (control), 15, 20, and 25% CBD by weight. This allowed a comparative evaluation of different proportions to identify the most effective dosage.

(a) Clayey Sand (b) CBD

Figure 1. Samples of (a) Clayey sand and (b) CBD

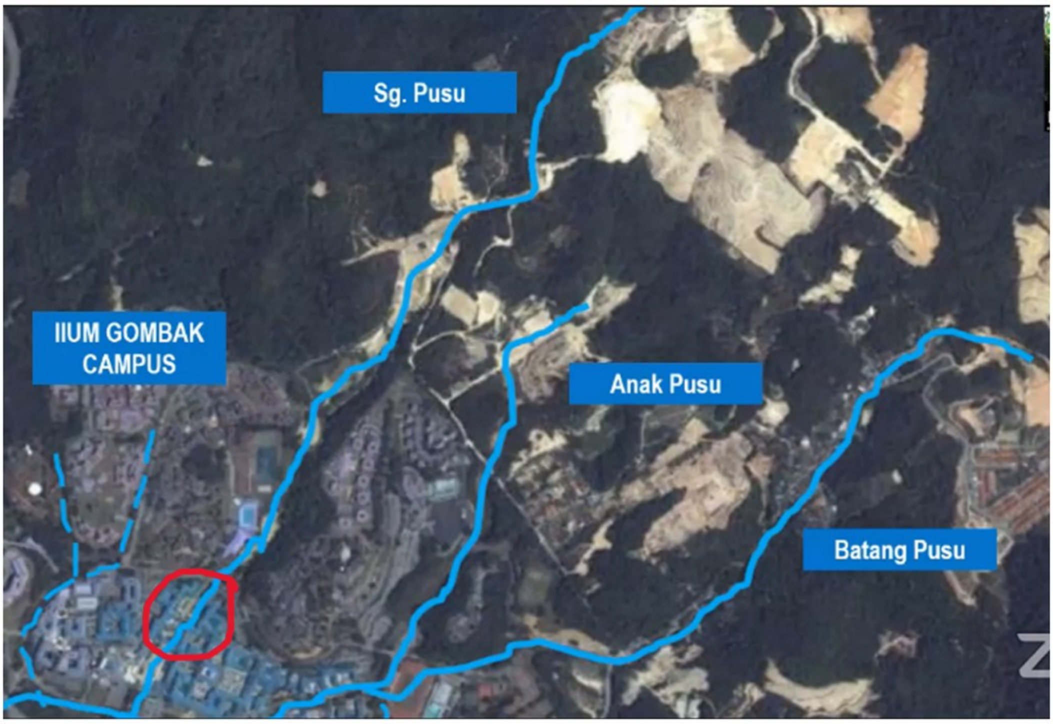

Figure 2. Location of soil sample collected at Sungai Gombak, Malaysia [19]

2.2. Atterberg limit test

The Atterberg limits test was conducted to determine the liquid limit (LL), plastic limit (PL), and plasticity index (PI), which are essential for evaluating soil consistency and its behaviour under varying moisture conditions. All procedures followed the ASTM D4318 standard.

Four soil mixtures were prepared: untreated soil (0% CBD) and soils stabilized with 15, 20, and 25% clay brick dust (CBD) by weight. The samples were air-dried and sieved through a No. 40 sieve (425 µm) to ensure uniform particle size.

For the plastic limit (PL) determination, each moist soil sample was hand-rolled on a smooth glass plate into threads approximately 3 mm in diameter. Rolling continued until the threads crumbled at around 3.2 mm, indicating the transition from the plastic to semi-solid state. The crumbled samples were placed in moisture-proof containers, weighed, and then oven-dried at 105 ± 5°C for 24 hours. The moisture content at the point of disintegration was recorded as the PL.

For the liquid limit (LL), the Casagrande cup method was employed. A soil paste was placed in the brass cup, and a groove was formed at the centre using a standard grooving tool. The cup was dropped from a height of 10 mm at a rate of two drops per second. The number of blows required to close the groove over a distance of approximately 13 mm was recorded. The LL was determined from the flow curve corresponding to 25 blows.

The plasticity index (PI) was calculated as the difference between the LL and PL (PI = LL − PL). The PI reflects the range of moisture content within which the soil remains plastic and workable. A reduction in PI after CBD treatment generally indicates improved soil behaviour, particularly through reduced shrink-swell potential and enhanced dimensional stability.

2.3. Standard Proctor Test

The compaction characteristics of both untreated and stabilized soil samples were evaluated using the Standard Proctor Test in accordance with ASTM D698, to determine their optimum moisture content (OMC) and maximum dry density (MDD). For each test, approximately 5 kilograms of air-dried soil were thoroughly mixed with clay brick dust (CBD) at proportions of 0%, 15%, 20%, and 25% by weight. The required amount of distilled water was added gradually to each mixture to achieve the desired moisture content. Each mix was then compacted in a standard cylindrical mould in three equal layers. Each layer received 25 blows from a standard Proctor rammer dropped from a height of 12 inches (305 mm), ensuring uniform compaction throughout the sample. After compaction, the collar was removed, and the soil surface was leveled with a steel straightedge.

The mass of the mould and compacted soil was measured to determine the bulk (wet) density. Small samples were then extracted from the top and bottom of each mould and placed in moisture containers. These containers were weighed and then oven-dried at 105 ± 5°C for 24 hours to determine their moisture content. Using the wet density and moisture content data, the dry density of each specimen was calculated. This process was repeated with increasing moisture content (typically in 2–3% increments) until a peak in dry density was observed. The point at which the dry density reached its maximum was recorded as the MDD, and the corresponding moisture content was taken as the OMC. These values were used to assess how the inclusion of CBD influenced the compaction behavior of clayey sand, which is critical for These values were used to assess how the inclusion of CBD influenced the compaction behaviour of clayey sand, which is critical for field performance in roadwork and foundation applications. In roadwork, achieving an optimum moisture content and high dry density is essential to ensure subgrade stability and to prevent rutting or settlement under traffic loads. For foundation applications, well-compacted soil provides uniform bearing support, reduces differential settlement, and enhances load distribution to prevent structural failure. Therefore, understanding the compaction characteristics is vital for determining the suitability of CBD-treated soils in these geotechnical scenarios.

2.4. California Bearing Ratio Test (CBR)

The bearing capacity of the soil mixtures was evaluated using the California Bearing Ratio (CBR) test, as specified in ASTM D1883. This test measures the resistance of a compacted soil sample to penetration by a standard piston under controlled loading conditions, simulating the performance of subgrade in flexible pavement design.

The soil-CBD mixtures at 0, 15, 20, and 25% by weight were compacted into CBR moulds, which differ in size from the Standard Proctor mould. The CBR moulds used in this study had an internal diameter of 152 mm and a height of 178 mm. Although the mould dimensions varied, the compaction procedure adhered to the same method, whereby the samples were compacted in three equal layers with 25 blows per layer using the standard Proctor rammer.

Following compaction, the specimens were cured for 24 hours and then fully submerged in water for a 4-day soaking period. This duration was selected to simulate prolonged saturation conditions that are typically encountered in weak subgrade environments, particularly during periods of heavy rainfall or poor drainage. The soaking time was based on previously published studies, including [20], where a four-day soaking period was used to evaluate the saturated strength behaviour of stabilized soils.

After soaking, the samples were mounted on the CBR testing machine. A metal plunger with a cross-sectional area of 1,950 mm² was then driven into the centre of each sample at a constant rate of 1.25 mm/min. During the penetration process, load values were recorded at incremental depths ranging from 0.0 mm to 7.5 mm. The CBR value at each depth was calculated by comparing the measured load to standard reference loads (13.24 kN at 2.5 mm and 19.96 kN at 5.0 mm penetration). The higher of the two calculated CBR values was taken as the final CBR for each sample. Post-test, the moisture content of the tested samples was also determined by oven drying. The test results were used to compare the load-bearing improvement of soil treated with different percentages of CBD, where higher CBR values indicate enhanced strength and suitability for pavement subgrade construction.

3. RESULTS AND DISCUSSION

3.1. Particle Size Distribution

The particle size distribution test was conducted to classify the soil type and evaluate its grading characteristics. To ensure the reproducibility of results, the test was conducted on three representative soil samples. The percentage passing values obtained from each sieve size were then averaged to plot the representative particle size distribution curve, in accordance with ASTM D422 and BS 1377. This approach minimizes the effect of variability between samples and provides a reliable gradation profile for subsequent analysis. The collected soil was subjected to two laboratory tests: sieve analysis and hydrometer analysis. The results of both tests were combined to develop the particle size distribution curve, which illustrates the relative proportions of gravel, sand, silt, and clay. The resulting curve for the parent soil is shown in Fig.3.

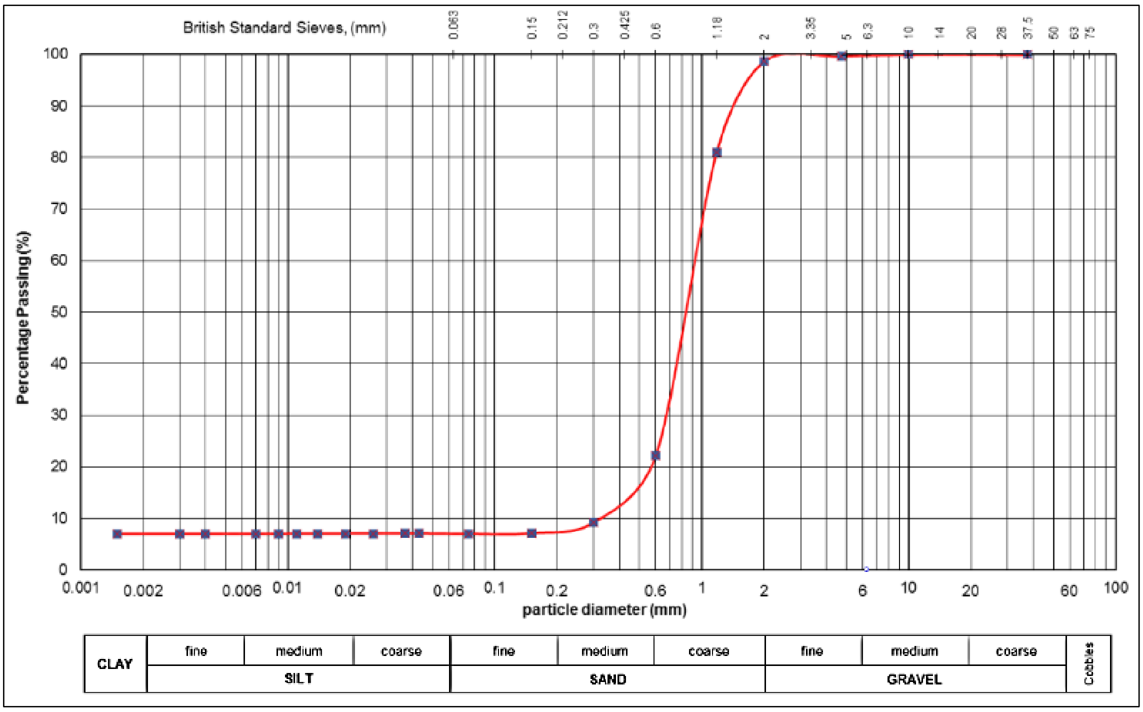

Figure 3. Particle size distribution graph

As shown in Table 1, the soil consisted predominantly of sand, which made up 84.54% of the sample. This was followed by clay (6.99%), gravel (5.51%), and silt (2.96%). According to the Unified Soil Classification System (USCS), the soil can be classified as clayey sand (SC) since more than 50% of the sample was retained on the No. 200 sieve, which has an opening size of 75 microns, and it contained a significant proportion of fines. According to the USCS, the clay fraction is defined as particles ≤0.002 mm (hydrometer), silt as 0.002–0.075 mm, sand as 0.075–4.75 mm, and gravel as >4.75 mm. The #200 sieve (75 µm) separates fines (silt + clay) from sand, but the clay fraction is determined specifically by hydrometer analysis. The similar proportions of clay (6.99%) and gravel (5.51%) reflect the residual nature of the soil, where coarse fragments coexist with fine particles; however, the dominance of sand (84.54%) still governs the overall classification as a clayey sand (SC).

Table 1. Particle size distribution

Type of particle	Percentage from total amount [%]
Gravel (4.75 mm – 76.2 mm)	5.51
Sand (0.075 mm – 4.75 mm)	84.54
Silt (0.002 mm – 0.075 mm)	2.96
Clay (≤ 0.002 mm)	6.99

The sieve analysis was conducted using a standard stack of sieves, including the No. 4 (4.75 mm), No. 10 (2 mm), No. 40 (425 µm), and No. 200 (75 µm) sieves, to ensure accurate classification of gravel, sand, silt, and clay fractions.

The particle size curve further supports the conclusion that the soil is poorly graded, as indicated by the calculated coefficients of uniformity (Cu = 5.81) and gradation (Cc = 0.86). These values suggest limited gradation and reduce interlocking potential among particles. As a result, the soil may exhibit poor compaction behaviour and increased susceptibility to water infiltration and settlement. The introduction of finer materials such as brick dust is therefore expected to fill the voids between sand particles, improving particle packing and enhancing the engineering properties of the soil.

3.2. Atterberg Limits Test

The Atterberg limits test was performed to assess the consistency limits and plasticity characteristics of the soil before and after stabilization with clay brick dust (CBD). The results, presented in Table 2, show a significant reduction in both the liquid limit (LL) and plastic limit (PL) as the percentage of CBD increased. The untreated soil sample (CS-CBD0) exhibited an LL of 63.9%, a PL of 41.4%, and a plasticity index (PI) of 22.5, classifying it as a high plasticity soil.

When 15% CBD was introduced, the LL and PL decreased to 44.2% and 27.7%, respectively, resulting in a PI of 18.6, which still falls within the intermediate plasticity range. At 20% CBD, further reductions to 44.0% (LL) and 26.5% (PL) produced a PI of 17.5, maintaining the same intermediate classification. However, at 25% CBD, the LL and PL decreased significantly to 25.5% and 9.8%, respectively, resulting in a PI of 15.7, which can be classified as low plasticity. These findings are consistent with prior research using various construction by-products. [21] and [22] reported reductions in plasticity index in expansive soils treated with marble dust. SAS Yaba also found that adding 5–10% ceramic dust to clay soils significantly decreased LL, PL, and PI. At the same time, [24] observed a steady reduction in PI, which almost halved at a 30% ceramic tile dust content. Anil (et al.) reported improvements in compaction, CBR, and index properties, including PI, when tile waste was used as a stabilizer. Similarly, [18] highlighted enhanced volumetric stability and lowered plasticity using marble dust. The behaviour of CBD in our study, which yielded a PI of 15.7 at a 25% dosage and classified the soil as low plasticity, is therefore supported by these parallel findings with other stabilizing powders.

This consistent downward trend in PI values across CBD-treated samples indicates that the inclusion of CBD effectively reduces the soil's plastic behaviour. The replacement of clay particles with non-plastic fines from CBD weakens the cohesive bonds within the soil matrix and enhances its workability. Lower plasticity is generally associated with better dimensional stability and reduced shrink–swell potential, both of which are desirable for construction and pavement applications.

Table 2. Atterberg limit results

Soil sample	Liquid limit	Plastic limit	Plasticity Index
CS-CBD0	63.9	41.4	22.5
CS-CBD15	44.2	27.7	18.6
CS-CBD20	44.0	26.5	17.5
CS- CBD25	25.5	9.8	15.7

3.3. Standard Proctor Compaction Test

The compaction characteristics of the soil samples were evaluated using the Standard Proctor Test. The optimum moisture content (OMC) and maximum dry density (MDD) for each sample were evaluated. The control sample (Soil + 0% CBD) exhibited an OMC of 5.8% and an MDD of 2.30 g/cm³. The addition of 15% brick dust increased the OMC to 6.4% and the MDD to 2.40 g/cm³, suggesting enhanced compaction due to better particle rearrangement and reduced water absorption.

However, at 20% CBD content, the OMC further increased to 6.5%, while the MDD dropped to 2.23 g/cm³. This reduction in density may be attributed to the presence of excessive fines, which can hinder effective compaction. Interestingly, the sample with 25% brick dust showed a lower OMC of 5.31% and a slight recovery in MDD to 2.35 g/cm³. These fluctuations highlight the importance of optimizing the quantity of stabilizers, as excessive brick dust can disrupt soil structure and compaction behavior.

Fig. 4 illustrates the variation in OMC with increasing CBD content. The OMC increased with the addition of CBD up to 20% but dropped to 25%. This indicates that, up to a certain level, the soil requires more water for compaction due to its high absorption capacity.

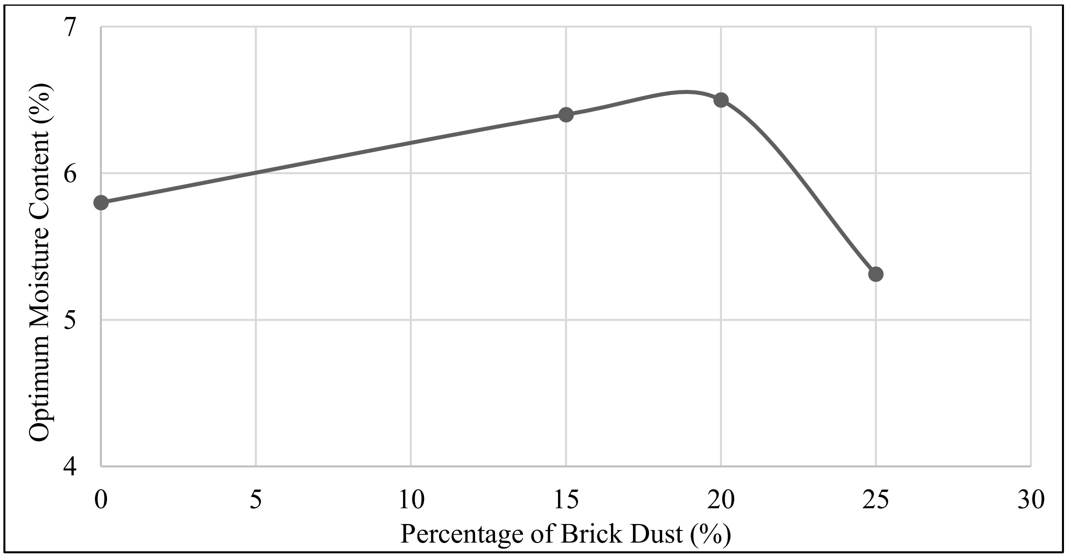

Figure 4. Optimum moisture content graph

Fig. 5 presents the trend in MDD values as the CBD content increases. Initially, MDD increases by 15% with 15% CBD due to improved packing and interlocking between particles. However, MDD decreases at 20% CBD, likely due to the excessive fine material disrupting optimal compaction. At 25% CBD, MDD increases again, possibly due to re-compaction of finer particles and better particle orientation during ramming. It is possible that increasing CBD content beyond 25%, such as to 30%, may lead to a further decline in MDD due to the excessive presence of non-cohesive fine particles. These fines may prevent proper particle interlocking and reduce the soil's overall compactability. Over-stabilization with brick dust can create a loosely packed matrix with higher void ratios, thus reducing dry density. However, this hypothesis requires experimental validation and may be explored in future work.

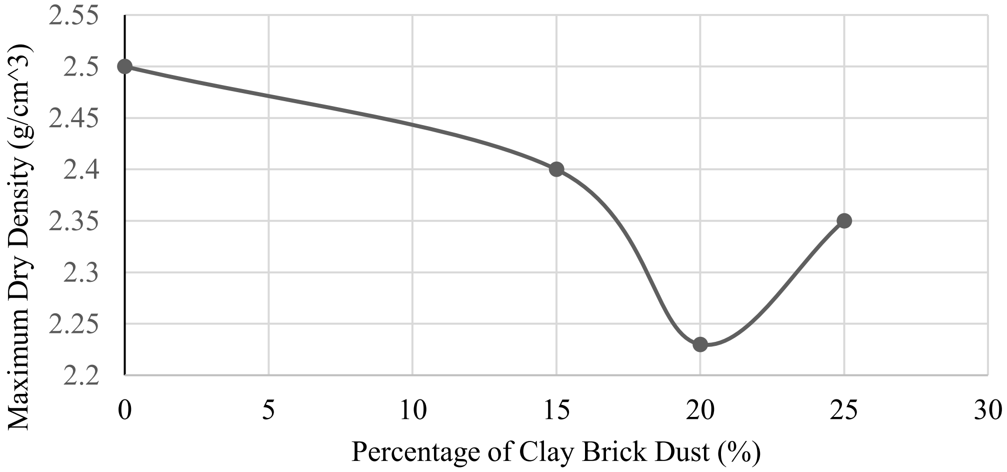

Figure 5. Maximum dry density graph

To better understand the overall behavior of soil with CBD under compaction, Fig. 6 shows the dry density versus moisture content curve for all mixtures. The curve demonstrates the typical compaction behavior where dry density increases with moisture content until a peak point is reached and then begins to decline. For the untreated soil, the peak dry density occurs at a lower moisture content (around 4.5%), while for CBD-treated samples, the peak shifts slightly, with lower MDDs observed at higher moisture contents. This shift supports the observation that CBD affects the water-holding and densification behavior of the soil.

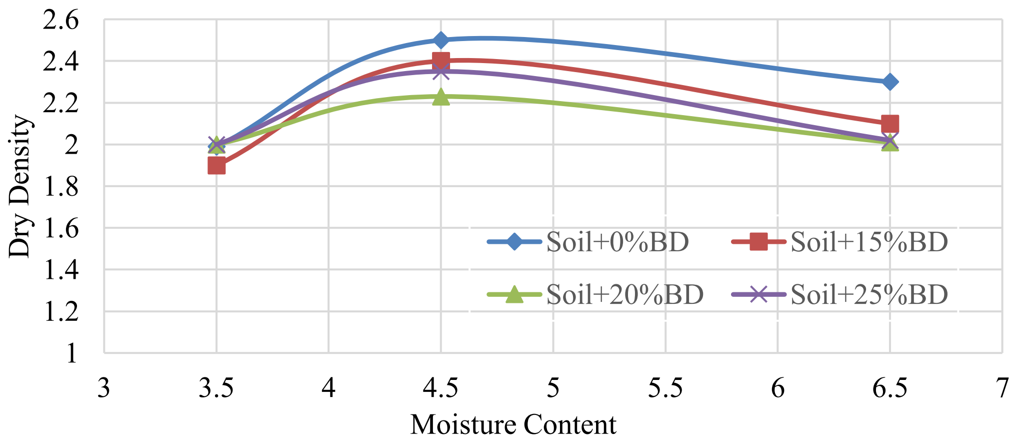

Figure 6. Dry Density vs Moisture Content Graph

In conclusion, the data from the Standard Proctor test indicate that while brick dust improves compaction characteristics up to a certain dosage, an excessive amount can reduce efficiency. The 15% CBD mixture yielded the highest MDD, but the 20% mixture offered the best balance between OMC and MDD, making it the most suitable dosage overall.

3.4. California Bearing Ratio (CBR) Test

Fig. 7 illustrates the relationship between load applied to the plunger and the corresponding penetration depth during the CBR tests for soil samples containing 0, 15, 20, and 25% CBD. This load-penetration curve provides critical insight into the mechanical response of the soil under simulated loading conditions.

From the graph, it is evident that as the CBD content increases, the soil's resistance to penetration also improves. This indicates that while brick dust improves soil strength, excessive amounts may start to negatively affect load transfer due to overfilling of voids and loss of particle interlock.

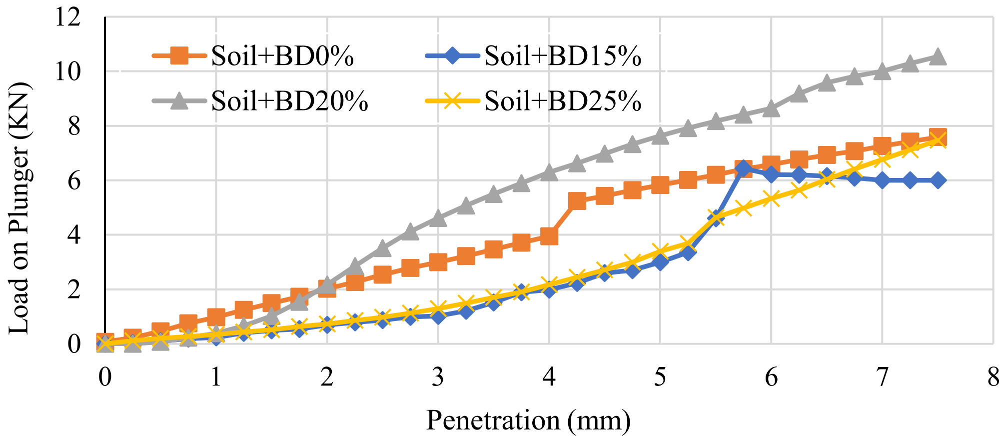

Figure 7. Load on plunger vs Penetration graph

The California Bearing Ratio (CBR) test was carried out to assess the load-bearing capacity of the clayey sand soil treated with different proportions of clay brick dust (CBD). The CBR values obtained from the test are shown in Table 4. The control sample (Soil + 0% CBD) recorded a CBR value of 27.0%, which reflects the natural strength of the untreated clayey sand. Upon introducing 15% CBD into the soil, the CBR value increased slightly to 28.6%, suggesting a modest improvement in strength. This increase may be attributed to improved grain interlocking and reduced moisture sensitivity resulting from the presence of finer, angular CBD particles.

The highest improvement in CBR was observed with the 20% CBD mixture, which achieved a CBR value of 30.0%. This indicates that 20% brick dust is the optimum content for enhancing soil strength in this study. The improvement is likely due to the optimal balance between filler content and compaction efficiency, resulting in improved stress distribution underload. However, when the CBD content was increased to 25%, the CBR value slightly declined to 29.5%, which may be due to the excess fines interfering with load transfer between soil particles. These results underscore the importance of determining the optimal dosage of stabilizer to achieve the best mechanical performance.

Although the 20% CBD sample exhibited a reduction in maximum dry density (MDD) and an increase in optimum moisture content (OMC), it achieved the highest CBR value at 30%.

This seemingly contradictory behaviour can be explained by the enhanced pozzolanic reactivity and filler effect of brick dust. The increased fine content at this dosage promotes better particle packing and a denser matrix under penetration load, even if the dry density is lower. Additionally, the presence of reactive oxides such as silica, alumina, and calcium oxide in CBD facilitates cementitious bonding in moist conditions. The higher moisture content in the 20% mix likely enabled improved hydration and pozzolanic reactions, which contributed to better bonding between soil particles. This enhanced interparticle bonding leads to higher resistance to deformation under load, thus increasing the CBR value. Therefore, while compaction density decreased slightly, the overall load-bearing performance improved due to microstructural enhancements provided by CBD at 20%.

The CBR values for each soil-brick dust mixture were evaluated. The trend shows a general increase in strength with increasing CBD content up to 20%, followed by a slight decrease to 25%. This pattern supports the conclusion that over-stabilization can be counterproductive beyond a certain point.

In addition to the tabulated data, Fig. 8 illustrates the trend of CBR values across the different samples. From the graph, it is visually evident that the sample with 20% CBD had the highest CBR value. The slope of the curve increases from 0% to 20% CBD and slightly declines at 25%, confirming that the soil's strength increases up to an optimum level and then begins to plateau or slightly decreases. For instance, [10] reported that marble dust stabilization improved soil properties, with the highest CBR values achieved at the optimum dosage. Similarly, [11] observed that stone dust reinforcement produced significant gains in CBR.

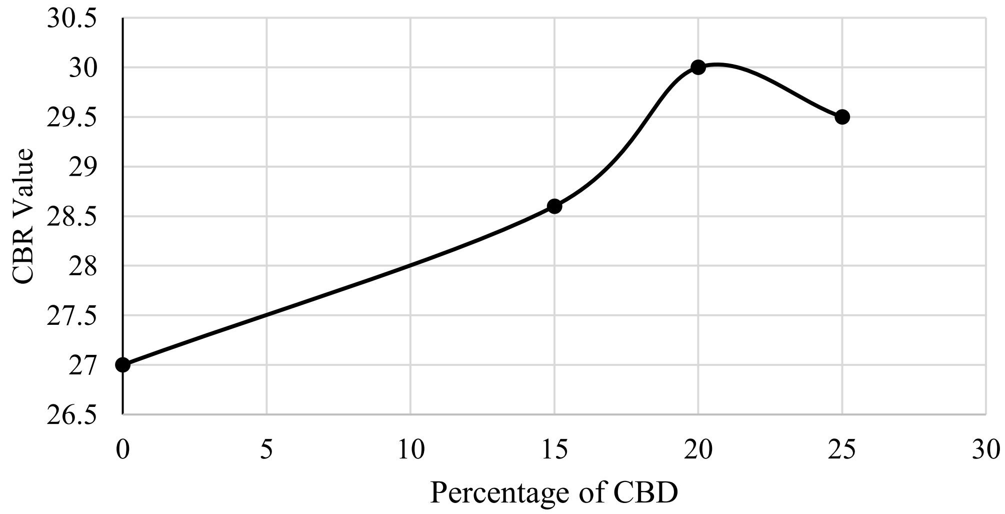

Figure 8. California Bearing Ratio values

Despite the observed increase in optimum moisture content (OMC) and decrease in maximum dry density (MDD) at 20% CBD addition, the CBR value improved significantly. This apparent contradiction is due to the pozzolanic and filler effects of CBD, which enhance bonding between particles and increase stiffness under load. The finer particles in CBD fill the voids between sand grains, resulting in a denser particle matrix that improves resistance to penetration, even if the compacted dry density is slightly lower. Additionally, higher moisture content may facilitate hydration and pozzolanic reactions, further improving the soil's load-bearing capacity. Thus, 20% CBD provides optimal subgrade strength despite not achieving the highest dry density.

4. CONCLUSION

This study investigated the effects of incorporating varying proportions of CBD on the physical and mechanical properties of clayey sand soil. Based on the results obtained from laboratory testing, including particle size distribution, Atterberg limits, Standard Proctor compaction, and California Bearing Ratio (CBR) tests. It can be concluded that brick dust has significant potential as a sustainable soil stabilizing agent.

The addition of CBD consistently reduced the plasticity of the soil, with the plasticity index (PI) decreasing from 22.5 (untreated) to 15.7 at a 25% CBD concentration. This reduction in plasticity indicates improved dimensional stability and lower susceptibility to volume change. The compaction results showed that the 15% CBD mixture achieved the highest maximum dry density (2.40 g/cm³). In comparison, the 20% CBD mixture offered a balanced outcome in terms of optimum moisture content and density. The CBR results further confirmed this, with 20% CBD yielding the highest bearing capacity of 30.0%, compared to 27.0% for untreated soil.

Overall, the findings suggest that the inclusion of 20% brick dust by weight provides the optimal improvement in strength performance, as evidenced by the highest CBR value. Although the 15% CBD mixture showed slightly higher dry density, the 20% CBD mixture offered a more favourable balance between compaction efficiency and mechanical strength. This is attributed to improved pozzolanic reactivity, better interparticle bonding, and the filler effect of the finer CBD particles, which enhance load-bearing capacity despite a marginal decrease in dry density.

The absence of chemical and mineralogical characterisation of both the clayey sand and brick dust is acknowledged as a limitation of this study. Future research will incorporate microstructural and chemical analyses, such as SEM, XRD, and XRF, to better understand the interaction mechanisms and validate the observed improvements in strength and plasticity.

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