Albahit Journal of Applied Sciences
"open-access, peer-reviewed biannual journal"
eISSN: 2708-8936, pISSN: 2708-244X
Volume 5, Issue 2, 2026
Page No: 54-63
Website: *https://albahitjas.com.ly/index.php/albahit/en/index*

California Bearing Ratio (CBR) Value for Expansive Soil Subgrade Stabilized Using Brick Dust-Lime Mixtures

Ali Muftah Abdussalam Ezreig[1*], **M.O.M. Mashri**[2]
[1,2] Civil Engineering Department, College of Technical Sciences, Bani Walid, Libya

**Corresponding author:* Azreg1986@gmail.com

Received: 15-01-2026	**Accepted:** 10-04-2026	**Published:** 22-04-2026

Abstract:
Expansive clayey soils are widely distributed in the southern semi-arid regions of the world. This study focuses on improving the strength of locally available expansive clayey soil using waste brick dust as a stabilizer and lime (CaO) as an activating agent. This approach provides a practical solution for recycling brick dust while mitigating environmental impacts. To determine the optimal lime content for soil stabilization, Atterberg limits, Modified Proctor, and California Bearing Ratio (CBR) tests were conducted, with 10% brick dust identified as the optimal proportion. To assess its effect on the physical and mechanical properties of expansive soil, varying proportions of brick dust (5%, 10%, 15%, and 20%) were mixed with the natural soil, along with a constant 5% lime content as a source of calcium oxide. The plasticity index results showed that the swell potential of the expansive soil decreased from very high to low when treated with the optimum mixture of 10% brick dust and 5% lime. In contrast, using 15% or 20% brick dust alone reduced the swell potential only from very high to medium. Furthermore, the addition of 10% BD and 5% L increased the CBR value of the natural soil from 4.71% to 22% within one day. Similar improvements were observed when 10% BD and 5% L were added separately. The optimum mixture of 10% BD with 5% L produced even greater results. The CBR value increased significantly after 14 and 28 days of curing. These results demonstrate the suitability of lime and brick dust as effective agents for the stabilization of expansive soil. Based on these results, it can be said that stabilization of expansive soils with brick dust is an effective method, making it suitable for improving the geotechnical parameters.

Keywords: Soil stabilization, Brick Dust, Lime, Compaction, California Bearing Ratio.

قيمة نسبة التحمل الكاليفورنية (*CBR*) للتربة الانتفاخية المستخدمة كتربة تأسيس فرعية بعد تثبيتها بخليط غبار الطوب والجير

علي مفتاح عبد السلام ازريق *1، محمد عمر محمد مشري 2
2،1 قسم الهندسة المعمارية والمدنية، كلية العلوم التقنية بني وليد، ليبيا.

الملخص
تنتشر الترب الطينية الانتفاخية على نطاق واسع في المناطق شبه الجافة الجنوبية من العالم. تركز هذه الدراسة على تحسين مقاومة التربة الطينية الانتفاخية المتوفرة محليًا باستخدام غبار الطوب كمادة تثبيت، والجير (CaO) كمادة منشطة. ويُعد هذا التوجه حلًا عمليًا لإعادة تدوير غبار الطوب مع الحد من الآثار البيئية الناتجة عنه.

ولتحديد المحتوى الأمثل من الجير المستخدم في تثبيت التربة، أُجريت اختبارات حدود أتربرغ، واختبار بروكتور المعدل، واختبار نسبة التحمل الكاليفورنية(CBR) ، حيث تم تحديد نسبة 10% من غبار الطوب باعتبارها النسبة المثلى. ولتقييم تأثيره على الخصائص الفيزيائية والميكانيكية للتربة الانتفاخية، تم خلط نسب مختلفة من غبار الطوب (5%، 10%، 15%، و20%) مع التربة الطبيعية، بالإضافة إلى نسبة ثابتة مقدارها 5% من الجير كمصدر لأكسيد الكالسيوم.

أظهرت نتائج دليل اللدونة أن قابلية الانتفاخ للتربة الانتفاخية انخفضت من مرتفعة جدًا إلى منخفضة عند معالجتها بالخليط الأمثل المكوَّن من 10% غبار طوب و5% جير. في المقابل، فإن استخدام 15% أو 20% من غبار الطوب وحده أدى إلى خفض قابلية الانتفاخ من مرتفعة جدًا إلى متوسطة فقط.

علاوة على ذلك، فإن إضافة 10% من غبار الطوب و5% من الجير رفعت قيمة الـ CBR للتربة الطبيعية من 4.71% إلى 22% خلال يوم واحد. ولوحظت تحسينات مماثلة عند إضافة 10% غبار طوب و5% جير بشكل منفصل، بينما أعطى الخليط الأمثل المكوَّن من 10% غبار طوب مع 5% جير نتائج أفضل وأكثر فعالية. كما ارتفعت قيمة الـ CBR بشكل ملحوظ بعد 14 و28 يومًا من المعالجة.

توضح هذه النتائج ملاءمة كلٍّ من الجير وغبار الطوب كمواد فعالة في تثبيت التربة الانتفاخية. واستنادًا إلى هذه النتائج، يمكن القول إن تثبيت الترب الانتفاخية باستخدام غبار الطوب يُعد طريقة فعالة، مما يجعله مناسبًا لتحسين الخصائص الجيوتقنية للتربة.

الكلمات المفتاحية: تثبيت التربة، غبار الطوب، الجير، الدمك، نسبة التحمل الكاليفورنية (CBR).

1. Introduction

Expansive soils are geomaterials that exhibit significant volume changes, including swelling and shrinkage, primarily due to fluctuations in their moisture content [1]. These soils pose a major geotechnical concern worldwide because their behavior can lead to substantial structural damage and necessitate expensive repairs to infrastructure, including foundations, roadways, and pavement systems [2]. Soil stabilization may address these issues, serving as an essential method to enhance soil behaviour and its engineering characteristics while alleviating volume change problems [3]. Soil stabilization is a geotechnical technique aimed at improving the mechanical properties of soils to meet the stringent requirements of construction and infrastructure projects. Traditional stabilizers such as cement, lime, and fly ash are commonly used due to their proven effectiveness in enhancing soil strength, durability, and workability [4]. However, the environmental impacts associated with these materials, particularly cement, should not be overlooked. Cement production significantly contributes to global carbon dioxide (CO^2) emissions, representing almost 8% of total worldwide emissions, highlighting its substantial impact on global warming and climate change. These environmental concerns have prompted the search for more sustainable alternatives to reduce the carbon footprint linked to soil stabilizing methods [5].

In this regard, waste-derived materials have gained attention as practical and eco-friendly alternatives for soil stabilization, including fibers, fly ash (FA), ground granulated blast-furnace slag (GGBS), metakaolin (MK), rice husk ash (RHA), palm oil fuel ash (POFA), and brick kiln by-products. The usage of waste bricks from demolished buildings can reduce environmental waste, as well as it is an economic way to improve soil quality [6,7]. These waste materials mentioned above are considered pozzolans (pozzolanic) that have considerable potential owing to their distinctive features and efficacy in soil enhancement due to the contains of silica and alumina oxides [8]. These oxides or pozzolan materials operate by creating gel-like structures (Calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH) that aggregate soil particles, thereby enhancing cohesion and overall stability[9]. The pozzolanic reaction mechanism can be described by the reactions shown in Eqs. (1) and (2).

$$\boldsymbol{Ca^{2+} + 2(HO)^{-} + SiO_2 \rightarrow C - S - H} \qquad 1$$

$$\boldsymbol{Ca^{2+} + 2(HO)^{-} + Al_2O_3 \rightarrow C - S - H} \qquad 2$$

The hydration of lime with water releases hydroxyl $(\mathrm{HO})^{-}$, which raise the pH of the soil solution. This elevated alkalinity enhances the dissolution of silica and alumina, thereby facilitating pozzolanic reactions [10]. The pozzolanic reaction can be divided into two stages. In the initial stage, the addition of lime triggers an immediate cation exchange process in the soil, during which high-valence cations such as Ca^{2+} rapidly replace monovalent ions and bind to the negatively charged surfaces of clay particles. This process decreases the thickness of the diffuse double layer, leading to flocculation of soil particles and a consequent reduction in soil plasticity [10,11]. In the second stage, cementitious compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) progressively bind the clay particles together. Consequently, this stage spans an extended period of time. The formation of pozzolanic compounds enhances the mechanical performance of the soil by cementing the soil particles together. Moreover, as the pozzolanic reaction consumes a portion of the pore water, it increases soil stiffness and reduces its swelling and shrinkage potential [12].

Earlier research has examined the performance of traditional soil stabilizers such as cement and lime [13–18]. Previous research has indicated that the incorporation of brick dust (BD) can enhance soil strength. However, only a limited number of studies have explored the use of BD industrial waste for soil stabilization. Activated brick dust waste has been identified as an effective binding material that can potentially replace cement while offering an environmentally friendly alternative, as reported in [6,19]. Susan Paudel [20] examined brick dust in a ratio of 10% to 50% by weight for the activation process in soft soil stabilization. The laboratory tests focused on the Atterberg's Limit and unconfined compressive strength tests. Test results showed that the peak strength increased with the increment of brick dust content up to 40%, and then it continued with a decreasing trend as brick dust content increased. Based on these results, 40% waste brick dust was chosen as an effective dosage. In another related study [21] investigated the potential of utilizing two different types of waste, which comprise brick dust and eggshell powder, in combination to treat expansive soil. The results showed that the use of Eggshell powder and brick dust improved expansive soil's engineering properties by enhancing cohesion through the lime content in the eggshell powder, which affects moisture content via cation exchange, leading to soil particle cementation. Jitendra Sankre [22] evaluated the strength characteristics of black cotton soil using the Standard Proctor Compaction and California Bearing Ratio (CBR) tests. The findings indicated that incorporating brick dust and fly ash significantly improved the soil's compaction behavior and bearing capacity. Consequently, this blend can be effectively applied for stabilizing pavements, subgrade layers, embankments, and other civil engineering works where black cotton soils are present [23]. Considering the literature above, this study demonstrates a simple yet powerful use of the improvement of expansive soil as a green stabilizer and low cost in the Geotechnical Engineering discipline.

The present study focuses on the reuse of industrial waste materials in geotechnical applications. Specifically, it investigates the effect of brick dust, an industrial byproduct, on the engineering properties of expansive soils. As noted in previous research, studies combining brick dust and lime for expansive soil stabilization are limited, and they often overlook the strength behavior of the treated soil. To address these gaps, this study examines the soil's strength characteristics—critical for understanding the performance of swelling clays in semi-arid regions—as well as the strength of soil over curing periods of 7, 14, and 28 days. To this end, different percentages of brick dust (5%, 10%, 15%, and 20%) were incorporated into the soil, combined with the calcium oxide (CaO) activator to be used as a base course in constructing high- and low-volume roads. 28-day curing period for California Bearing Ratio (CBR) specimens has been incorporated in this study. The experimental study included tests on Atterberg Limit, compaction, and CBR. The study evaluates the dual purpose of using brick dust: stabilizing a local expansive soil and promoting its recycling, along with the addition of lime necessary to trigger the pozzolanic reaction.

Materials

Expansive Soil (ES)

For this study, natural expansive soil was collected from Taşkent, located in the northern part of Nicosia, Cyprus. The soil classification was carried out using the Unified Soil Classification System (USCS) following ASTM D2487-10, 2010 [25]. As summarized in Table 1, the physical properties of the crushed expansive soil were determined after drying the soil at 50°C. To prevent moisture absorption, the prepared soil samples were stored in plastic bags. Table 1 also represents the physicochemical properties of the soil.

Brick Dust (BD)

Broken bricks were sourced from the (Levent Brick Factory in Haspolat, Nicosia). The bricks were ground into fine dust and passed through a No. 40 (0.425 mm) sieve, resulting in particles ranging in size from 0.002 to 0.075 mm and Table 2.2 shows the physicochemical properties of the (BD).

Lime (CaO)

Lime (CaO) was selected for this work as an activator; Table 2 also represents the physicochemical properties of the (CaO).

Table 1 Geotechnical properties of expansive soil sample.

Property	Values
(Natural moisture content %)	20.24
Specific Gravity	2.64
(Liquid Limit %)	64
(Plastic Limit %)	29
(Plasticity Index %)	35
(Gravel %)	0
(Sand %)	14
(Silt %)	51
(Clay %)	35
Classification	MH
(Optimum Moisture Content %)	24
(Maximum Dry Density kg/cm^3)	1640
(pH)	9.7

Source: (Author)

Table 2 Chemical composition of materials used.

Ingredient	Value of chemical composition (%)		
	Lime	Brick dust	Expansive soil
Na_2O.	0.000	0.894	0.539
MgO.	0.811	6.290	5.305
Al_2O_3.	0.616	12.922	11.885
SiO_2.	2.225	43.463	38.783
P_2O_5.	0.102	0.233	0.179
SO_3.	1.442	1.490	1.208
CI.	0.155	0.076	0.097
K_2O.	0.101	1.505	1.656
CaO.	94.200	0.473	24.211
TiO_2.	0.007	1.158	1.456
$Cr2O_3$.	0.010	0.066	0.078
Mn_2O_3.	0.016	0.234	0.293
Fe_2O_3.	0.252	11.114	14.181
ZnO.	0.000	0.015	0.020
SrO.	0.063	0.067	0.108

Source: (Author)

Methods

In this study, 5% lime, calculated as calcium oxide (CaO), was utilised and blended with natural expansive soil along with brick dust at proportions of (5, 10, 15, and 20%) by the dry mass of the soil. The study focused on assessing the physical, chemical, and mechanical characteristics of both stabilised and unstabilised samples at curing times of 1, 14, and 28 days. A comparison was conducted between samples stabilized with brick dust alone and those combined with lime to fully assess the effect of brick dust at its optimal dosage.

Testing method

This study conducted three main tests, including Atterberg Limit, Compaction, CBR, and SEM analysis, to evaluate the performance of the designed samples.

Atterberg Limit Test (AL)

The Atterberg Limits test, which includes the Liquid Limit and Plastic Limit tests, measures the soil's water affinity. The tests were performed on the soil and various mixtures as described earlier, following ASTM-D-2216-98, (1998) standards.

Modified Compaction Test (MC)

In carrying out this test, it is important to note that compaction is key in order to make the soil dense so as to attain satisfactory engineering properties, and as such determining the optimum condition of a given sample for a compacted soil. This was also performed following ASTM-D1557 (2012) standards.

California Bearing Ratio Test (CBR)

The California Bearing Ratio (CBR) test was performed in accordance with ASTM-D1883 (2016a) to measure the force per unit area needed to penetrate a soil sample using a 5 cm diameter circular plunger at a penetration rate of 1.27 mm/min. Load measurements were taken at various penetration depths, spanning from 0.64 mm to 12.70 mm, to generate a detailed penetration profile. The test was conducted on both treated and untreated soils after curing periods of 1, 14, and 28 days. The CBR values were then calculated using Equation (3).

$$(\mathbf{CBR}) = \left(\frac{\textbf{Test load on the sample}}{\textbf{Standard load}}\right) \times \mathbf{100\%} \qquad \textbf{(3)}$$

This section provides a comprehensive description of the materials and testing methods used in the present study. All chemical, mineralogical, physical, and mechanical tests were conducted following ASTM standards. Chemical analyses included X-ray fluorescence (XRF), while scanning electron microscopy (SEM) was performed to examine structural changes resulting from soil stabilization. Physical tests comprised moisture content, specific gravity, liquid limit, plastic limit, and particle size distribution. Also, mechanical testing was carried out using the modified Proctor test and California Bearing Ratio (CBR) method.

Scanning Electron Microscope Test (SEM)

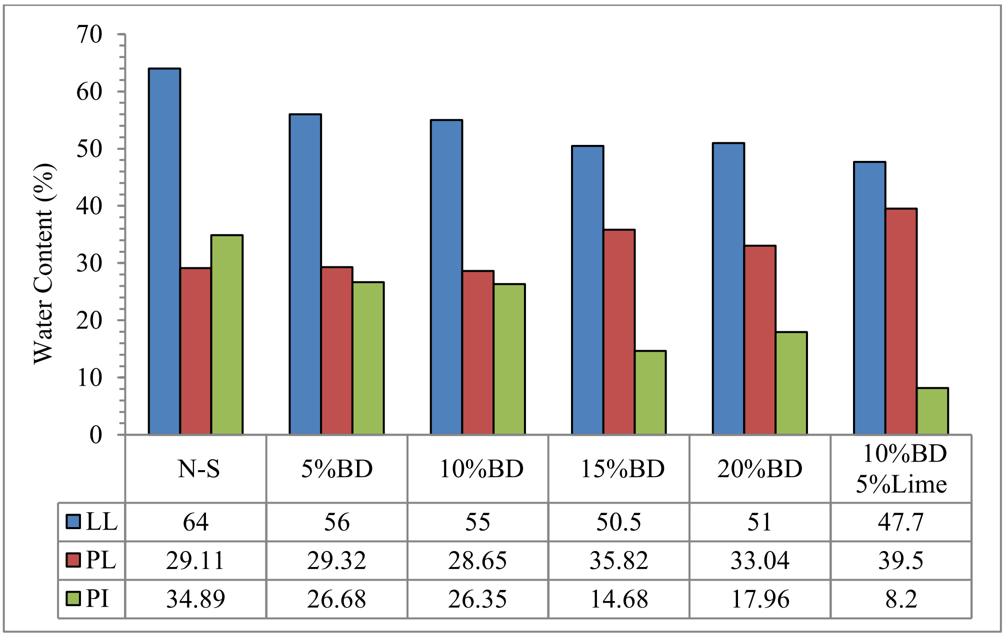
[1] In this study, scanning electron microscopy (SEM) was employed to analyze both untreated and treated soil samples, allowing the observation of brick dust adhesion. The results of this analysis are presented in the following section.

Experimental results and discussions

This study aims to evaluate the effects of adding non-conventional waste materials, Brick Dust, on the curing time, CBR and swelling characteristics of expansive soil. The observed characteristics of the studied soil are presented in Tables 1 and 2, while the outcomes of the CBR, swelling potential and SEM studies are discussed as follows.

Effect of brick dust and lime on Atterberg limits test

The influence of various additives on the Atterberg limits was examined to assess the mechanical behavior of each soil-additive mixture. The plastic limit and liquid limit of the natural soil were determined following ASTM-D-2216-98, (1998), yielding values of 29.11% and 64%, respectively. This corresponded to a plasticity index of 34.89%. Expansive soil was then blended with varying proportions of brick dust (5%, 10%, 15%, and 20%) along with a constant 5% lime content. Based on the results, the optimum mixture was identified as 10% brick dust combined with 5% lime, as illustrated in Figure 4.1.



	N-S	5%BD	10%BD	15%BD	20%BD	10%BD 5%Lime
🟦 LL	64	56	55	50.5	51	47.7
🟥 PL	29.11	29.32	28.65	35.82	33.04	39.5
🟩 PI	34.89	26.68	26.35	14.68	17.96	8.2

Figure خطأ! لا يوجد نص من النمط المعين في المستند.1 Atterberg limits versus brick dust content.

It is clearly seen that in (Figure 4.1) the optimum mixture consists of 10% brick dust combined with 5% lime. According to the USCS classification, as shown in (Figure 4.2), the local soil plots below the A-line, indicating that it belongs to the MH group, which represents inorganic silt with high plasticity. Treatment of the expansive soil with 10% brick dust and 5% lime reduced its swell potential from high to low, as presented in (Table 3). In contrast, using 15% brick dust alone decreased the swell potential from high to medium. Additionally, the addition of 5% lime alone was ineffective, as the resulting data indicated an anomaly due to a second strike merging the line. A soil having a plasticity index of zero indicates that the soil has less or no amount of silt and clay, and the soil is non-plastic. The lesser the PI is, the lesser the soil compressibility. Furthermore, the zero value of liquidity index indicates that the soil is in semi-plastic or solid state. Thereby, minimizing the risk of volume changes due to moisture variations. This is important in those regions where there are clayey soils, and their shrink-swell potential can lead to structural damage.

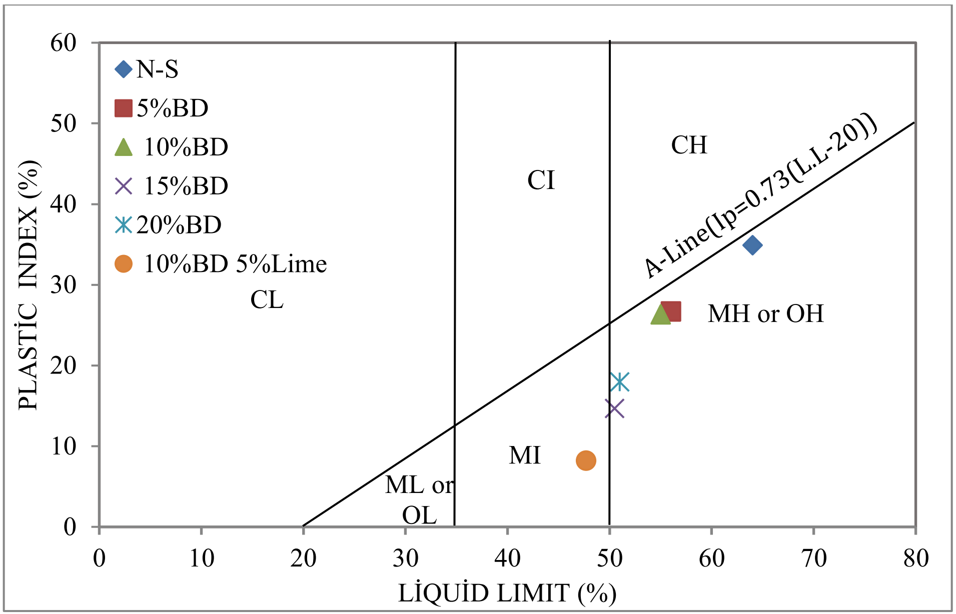


Figure خطأ! لا يوجد نص من النمط المعين في المستند.**2** USCS plasticity chart versus brick dust content.

Table 3 Qualitative classification of swell potential based on Atterberg limits (after Chen 1988 and Ramen 1967).

Materials	LL. (%)	PL. (%)	PI. (%)	Swelling Potential
S	64	29.11	34.89	High
S+5%L	NP	-	-	-
S+5%BD	56	29.32	6.68	High
S+10%BD	55	28.65	6.85	High
S+15%BD	50	35.82	4.18	Medium
S+20%BD	51	33.04	7.96	Medium
S+10%BD+5L	47.7	39.5	8.2	low

Effect of brick dust and lime on the Compaction test (MD)

The soil compaction was conducted by the Modified Proctor test on the natural soil and its mixtures with varying proportions of brick dust and lime. The test results were used to determine the optimum moisture content and maximum dry density, which are presented in Figure 4.3.

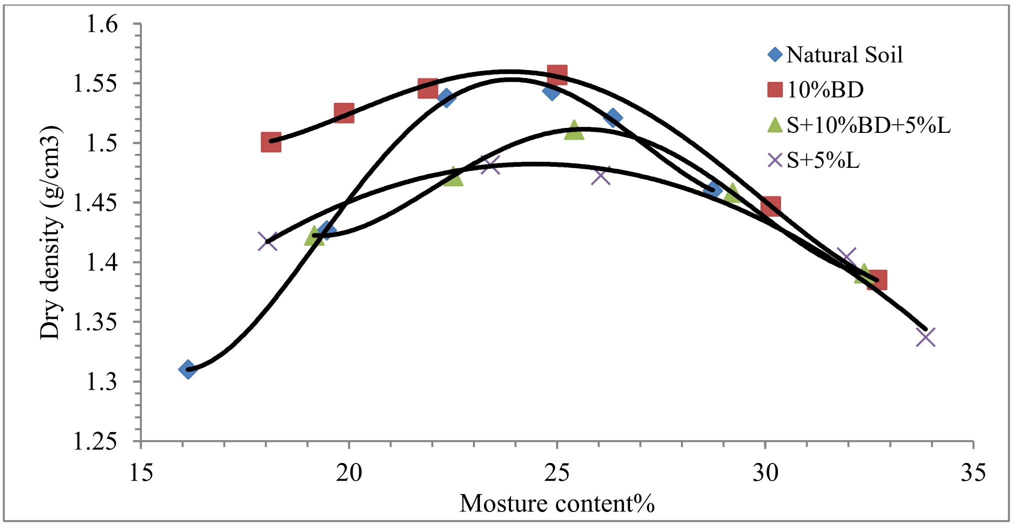


Figure خطأ! لا يوجد نص من النمط المعين في المستند.**3** Compaction curves for Expansive Soil and mixtures.

Figure 4.3 shows the relationship between the dry density and moist content under compaction energy by different proportions of brick dust and lime. For the natural soil, the maximum dry density increased from 1640 kg/m³ to 1650 kg/m³ when 10% brick dust was added, while the optimum moisture content remained largely unchanged at 24%. In contrast, for the soil treated with 10% brick dust and 5% lime, the maximum dry density decreased to approximately 1610 kg/m³, with the optimum moisture content rising to 25.4%. When 5% lime was added alone, the maximum dry density dropped significantly to 1570 kg/m³, accompanied by an increase in optimum moisture content to 26% compared to the untreated soil. It can be seen that in Figure 4.3, the result of stabilized soil, the dry density decreased with 5% lime alone and binder containing 10%BD+5%L. This decrease resulted from the flocculation and agglomeration of clay particles, caused by the cation exchange reaction. Ion exchange is considered the main mechanism responsible for soil stabilization. Alkaline oxides, including CaO and MgO, react with water to generate Ca^{2+} and Mg^{2+} ions, which substitute K^{+} and Na^{+} ions present in clay minerals through cation exchange. This reaction decreases the thickness and separation of the water layer surrounding soil particles. Experimental investigations have shown that incorporating fly ash can significantly reduce soil plasticity and swelling behavior due to these cation exchange processes. Furthermore, the exchange of cations promotes flocculation and agglomeration among soil particles, leading to improved soil strength [29].

Effect of brick dust and lime on the California Bearing Ratio Test (CBR)

The strength of the road subgrade is described by the CBR measurement system. The pavement's thickness and the layers that make it up are determined by the CBR parameter. Expansive soil is not suitable for road subgrade due to its comparatively low CBR values (<15) [30]. The results of the study indicated a significant increase in CBR values (Table 4). The treated soil mixtures showed a moderate yet meaningful improvement in strength, indicating that the tested soil can be considered appropriate for road construction. Specifically, the addition of 10% brick dust, 5% lime, and 10% brick dust combined with 5% lime increased the CBR values from 4.71% for the untreated soil to 7.76%, 18.93%, and 21.93%, respectively, after one day of curing.

The results show that the combination of brick dust and lime produced the greatest strength improvement after 1 day of curing, as shown in Table 4. Furthermore, at the optimal mix proportion, extended curing periods of 14 and 28 days resulted in substantial increases in CBR values, reaching 55.39% and 80.06%, respectively, as illustrated in Figure 4.4. In general, the obtained CBR score from test results, according to the Classification of soil based on (USCS) System states that laterite soils with CBR score between 20% to 50% for subgrade is good category and use for subbase.

Table 4 Summary of the CBR values from laboratory tests.

Material	Curing periods day	CBR% values
(N-S)	1	4.71
(S+10%BD)	1	7.76
(S+5%L)	1	18.93
(S+10%BD+5%L)	1	21.93
(S+10%BD+5%L)	14	55.39
(S+10%BD+5%L)	28	80.06

On the other hand, the mixtures of 5% lime with 10% brick dust demonstrate an increase in strength by seventeen times (80.06%) after 28-day cure, demonstrating peak strength thereafter curing, which is due to long-term pozzolanic reaction and development of cementitious pozzolanic compounds [9,31]. This behavior can be attributed to the microstructural changes observed in micrographs obtained from SEM tests as explained in the next section. The addition of lime and brick dust promotes the formation of a flocculated soil structure, which enhances particle bonding and consequently increases the strength of the soil.

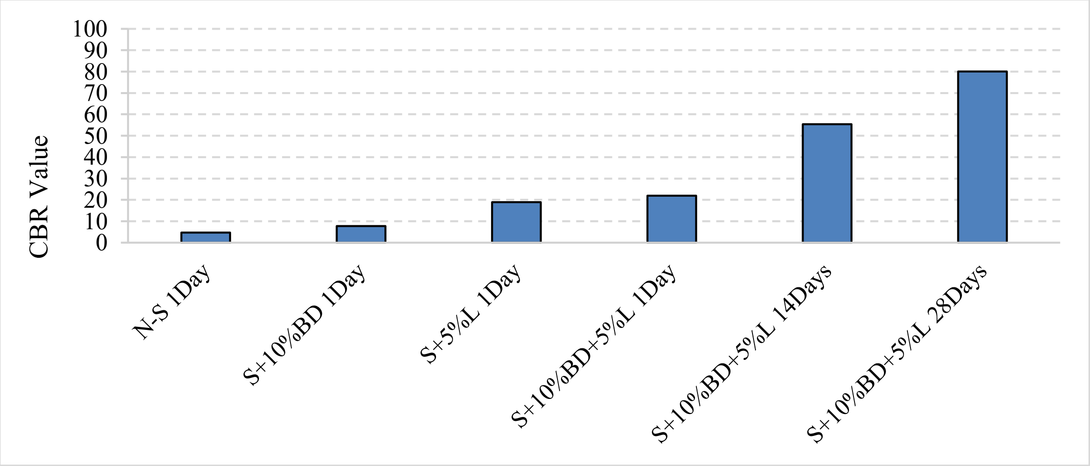


Figure خطأ! لا يوجد نص من النمط المعين في المستند..4 CBR value of expansive soil to the addition of brick dust with lime in the unsoaked condition of the curing periods.

Scanning electron microscopy analysis

To further evaluate the interactions between the additives and clay particles, scanning electron microscopy (SEM) was conducted on both treated and untreated samples after 28 days of moist curing. Figures 5.1 and 5.2 present SEM micrographs of the untreated expansive soil and the soils treated with 5% lime and with a mixture of 10% BD + 5% lime, respectively. As shown in Figure 5.1, the SEM image of the clay reveals thin plate-like particles with a dispersed structure. Furthermore, the clay layers appear stacked over one another in the untreated soil. Figure 5.2 shows that the soil mixture with brick dust and lime mixture underwent changes in its microstructure that culminated in a denser structure. From a chemical perspective, calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) gels are generated when water reacts with calcium silicate and aluminate compounds present in the binder [30]. Pozzolanic reactions occur when the soil pH is above 10.5, allowing the cementitious gels to develop gradually over a long duration [32]. Although the particles appear more consolidated after lime addition, the formation of cementitious products resulting from pozzolanic reactions is more pronounced in the soil samples stabilized with both brick dust and lime; this interpretation was in agreement with the previous study [9]. This change in the structure of clay particles leads to an increase in strength and improvement of swell potential of treated soil. These findings are in good agreement with [33].

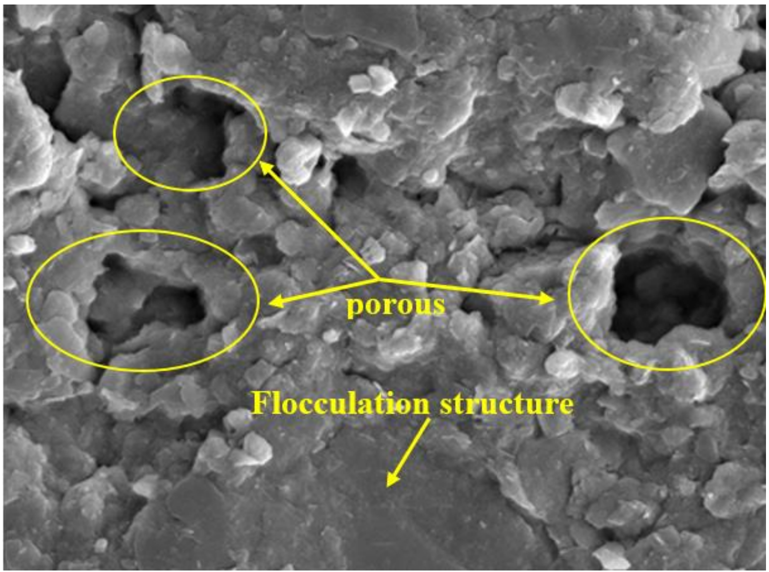


Figure خطأ! لا يوجد نص من النمط المعين في المستند.5 SEM images of the untreated soil after 28 days of curing period.

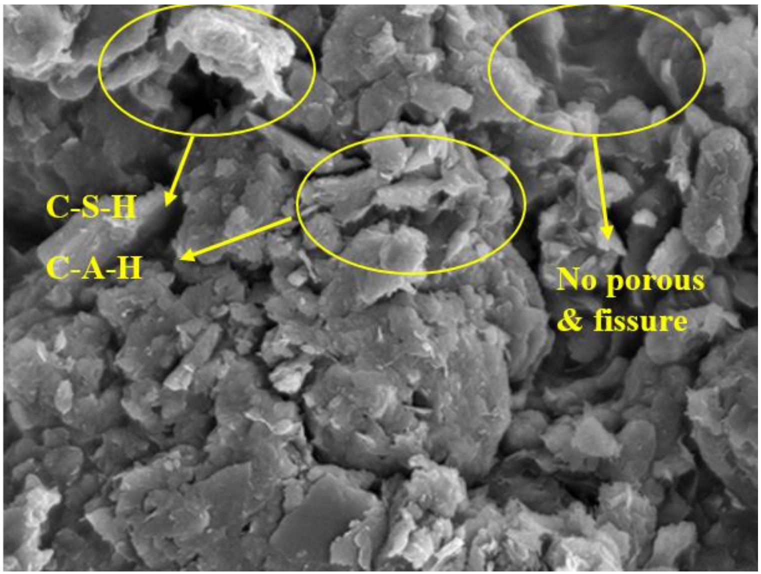


Figure خطأ! لا يوجد نص من النمط المعين في المستند.6 SEM images of the treated soil after 28 days of curing period.

Conclusion

This study investigates the effectiveness of lime-activated brick dust in stabilizing expansive soil to address challenges associated with weak subgrade conditions, reduce environmental impacts through lower energy consumption, and promote the sustainable utilization of locally available industrial waste materials. The results indicate that the prepared mixtures containing brick dust activated with lime effectively improved the soil properties. However, the geotechnical performance of the treated soil was influenced by factors such as binder content, soil type, and curing conditions.

- According to the Atterberg limits and the classification charts proposed by Raman (1967) and Chen (1988), the swell potential of the natural soil decreased from high to low when treated with a mixture of 10% brick dust and 5% lime, as presented in Table 4.8. In contrast, treatment with 15% brick dust alone reduced the swell potential only from high to medium.
- The optimum moisture content and maximum dry density increased with the addition of 10% brick dust. In contrast, for the mixture containing 10% brick dust and 5% lime, the maximum dry density decreased to approximately 1610 kg/m³, while the optimum moisture content rose to 25.40%. The higher maximum dry density observed at 10% brick dust content can be attributed to the flocculation of soil particles when blended with the additives. However, the inclusion of 5% lime resulted in a slight reduction in maximum dry density.
- The CBR results indicate that strength increased with longer curing periods for the mixture containing 10% brick dust and 5% lime. The highest strength was recorded at 80.06% for the optimum binder content (10% brick dust and 5% lime) after 28 days of curing.
- The use of lime-activated brick dust in expansive soils significantly altered the soil structure. In the treated mixtures, previously dispersed soil particles became more tightly bound, and voids appeared to be filled, resulting in a marked improvement in soil strength due to the pozzolanic reaction. These results are highly promising for pavement construction and may serve as valuable guidance for researchers, geotechnical engineers, and civil engineers.
- This study produced promising outcomes for great application potential in deep soil mixing construction. Geotechnical engineers, civil engineers, and academics can use the results as guidelines for further studies.

References

[1] Utkarsh, P.K. Jain, A review on innovative approaches to expansive soil stabilization: Focussing on EPS beads, sand, and jute, Science and Engineering of Composite Materials. 31 (2024). https://doi.org/10.1515/secm-2024-0005.

[2] N. Haque Nayem, Stabilization of Expansive Soil by Improving the Engineering Properties Using Lime and Fly Ash, International Journal of Engineering Management. 7 (2023) 27–34. https://doi.org/10.11648/j.ijem.20230702.12.

[3] S. GhavamShirazi, H. Bilsel, Characterization of volume change and strength behavior of micro-silica and lime-stabilized Cyprus clay, Acta Geotechnica. 16 (2021) 827–840. https://doi.org/10.1007/s11440-020-01060-1.

[4] M. Macías-Párraga, F.J.T. Echarri, O. Alonso-Pandavenes, J. Garzón-Roca, Improvement of Expansive Soils: A Review Focused on Applying Innovative and Sustainable Techniques in the Ecuadorian Coastal Soils, Applied Sciences. 15 (2025) 8184. https://doi.org/10.3390/app15158184.

[5] A.A. Mohammed, H. Nahazanan, N.A.M. Nasir, G.F. Huseien, A.H. Saad, Calcium-Based Binders in Concrete or Soil Stabilization: Challenges, Problems, and Calcined Clay as Partial Replacement to Produce Low-Carbon Cement, Materials. 16 (2023). https://doi.org/10.3390/ma16052020.

[6] P. Sen, Effect of Chemicals on Engineering Properties of Soil, International Journal for Research in Applied Science and Engineering Technology. V (2017) 1677–1685. https://doi.org/10.22214/ijraset.2017.10244.

[7] A.M.A. Ezreig, M.A.M. Ismail, K.I.. Ehwailat, A state of review : challenges and techniques of laterite soil stabilisation using chemical , economical , and eco - friendly materials, Innovative Infrastructure Solutions. (2022). https://doi.org/10.1007/s41062-022-00821-z.

[8] A.M. Abdussalam Ezreig, M.A. Mohamad Ismail, K.I. Azarroug Ehwailat, Geotechnical performance of tropical laterite soil using palm oil fuel ash and activator magnesium oxide stabilizer, Physics and Chemistry of the Earth. 129 (2023) 103293. https://doi.org/10.1016/j.pce.2022.103293.

[9] S. GhavamShirazi, H. Bilsel, Characterization of volume change and strength behavior of micro-silica and lime-stabilized Cyprus clay, Acta Geotechnica. 16 (2021) 827–840. https://doi.org/10.1007/s11440-020-01060-1.

[10] J.K.H. Wong, S.T. Kok, S.Y. Wong, Cementitious, pozzolanic and filler materials for DSM binders, Civil Engineering Journal (Iran). 6 (2020) 402–417. https://doi.org/10.28991/cej-2020-03091479.

[11] C. Gillot, The use of pozzolanic materials in Maya mortars: New evidence from Río Bec (Campeche, Mexico), Journal of Archaeological Science. 47 (2014) 1–9. https://doi.org/10.1016/j.jas.2014.03.037.

[12] K.C. Onyelowe, M.E. Onyia, D.B. Van, H. Baykara, H.U. Ugwu, Pozzolanic reaction in clayey soils for stabilization purposes: A classical overview of sustainable transport geotechnics, Advances in Materials Science and Engineering. 2021 (2021) 1–7. https://doi.org/10.1155/2021/6632171.

[13] Y. Hong, X. Wu, P. Zhang, Construction technology and mechanical properties of a cement-soil mixing

pile reinforced by basalt fibre, Advances in Materials Science and Engineering. 2017 (2017). https://doi.org/10.1155/2017/9736465.

[14] X. Yao, K. Liu, G. Huang, M. Wang, X. Dong, Mechanical Properties and Durability of Deep Soil–Cement Column Reinforced by Jute and PVA Fiber, Journal of Materials in Civil Engineering. 33 (2021) 04021021. https://doi.org/10.1061/(asce)mt.1943-5533.0003636.

[15] I.A. Baguhin, J.B. Ken Balangao, V.S. Karla Caingles, Soil Strength of Chemically Stabilized Road Subbase Materials With Lime Sludge and Fly Ash: a Statistical Evaluation Using Anova, Science International (Lahore). 2023 (2023) 405–409. https://hal.science/hal-04170006.

[16] Y. Yi, M. Liska, A. Al-Tabbaa, Properties of Two Model Soils Stabilized with Different Blends and Contents of GGBS, MgO, Lime, and PC, Journal of Materials in Civil Engineering. 26 (2014) 267–274. https://doi.org/10.1061/(asce)mt.1943-5533.0000806.

[17] K. Ramu, R. Dayakar Babu, Mitigating Problematic Expansive Soil by Using POFA, Lime and DRWPI, Lecture Notes in Civil Engineering. 138 (2021) 85–96. https://doi.org/10.1007/978-981-33-6564-3_8.

[18] A. Bhurtel, A. Eisazadeh, Strength and Durability of Bottom Ash and Lime Stabilized Bangkok Clay, KSCE Journal of Civil Engineering. 24 (2020) 404–411. https://doi.org/10.1007/s12205-019-0850-3.

[19] S. Teja, S. L., Kumar, S. S., Needhidasan, Stabilization of Expansive Soil Using Brick Dust, International Journal of Pure and Applied Mathematics. 119 (2018) 1–8. http://www.acadpubl.eu/hub/.

[20] S. Paudel, B. Kumar Dahal, Effect of Brick Dust on Soil and Strength Improvement with the use of Plastic Waste, (2022).

[21] Marjom Ete, J.R.& A.K. Moni Mishra, Ravino Mekro, Lensar Jamir, Taniya Oniya, Experimental Investigation for Stabilization of Expansive Soil by Using Waste Materials—Brick Dust and Eggshell Powder, Geoenvironmental Engineering. 508 (2024). https://doi.org/doi.org/10.1007/978-981-97-3823-6_5.

[22] S.divya, K. Anusaya, P. P, V. Sobana, Stabilization of Black Cotton Soil using Groundnut, 6 (2023) 545–549.

[23] M. Kumar, Evaluation of experimental research on black cotton soil stabilization using stone powder, Materials Today: Proceedings. 37 (2020) 3490–3493. https://doi.org/10.1016/j.matpr.2020.09.389.

[24] ASTM D2487-10, Standard Practice for Classification of Soils for Engineering Purposes (unified Soil Classification System)., ASTM International, West Conshohocken, 2010. https://doi.org/10.1520/D2487-10.

[25] American Society for Testing and Materials (ASTM), D2487-17e1: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM International. (2020) 1–10. https://doi.org/10.1520/D2487-11.2.

[26] ASTM-D-2216-98, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, ASTM International. (1998) 1–5.

[27] ASTM-D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3)), (2012).

[28] ASTM-D1883, Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils, ASTM International, West Conshohocken, PA, 2016.

[29] J. Wei, J. Wei, Q. Huang, S.M.I.B.S. Zainal Abidin, Z. Zou, Mechanism and Engineering Characteristics of Expansive Soil Reinforced by Industrial Solid Waste: A Review, Buildings. 13 (2023) 1–17. https://doi.org/10.3390/buildings13041001.

[30] Ezreig, Ismail, Ehwailat, Hydrophobic effect of soil stabilization for sustainable subgrade soil improvement, Materials. 15 (2022) 3087. https://doi.org/10.3390/ma15093087.

[31] N.H.A. Rizal, M.A. Hezmi, R. Razali, N.A. Wahab, M.J. Roshan, A.S.A. Rashid, D.Z.A. Hasbollah, Effects of Lime on the Compaction Characteristics of Lateritic Soil in UTM, Johor, IOP Conference Series: Earth and Environmental Science. 971 (2022). https://doi.org/10.1088/1755-1315/971/1/012031.

[32] H. Güllü, H. Canakci, I.F. Al Zangana, Use of cement based grout with glass powder for deep mixing, 2017. https://doi.org/10.1016/j.conbuildmat.2017.01.070.

[33] M.S.I. Zaini, M. Hasan, Effect of Optimum Utilization of Silica Fume and Lime On the Stabilization of Problematic Soils, International Journal of Integrated Engineering. 15 (2023) 352–366. https://doi.org/10.30880/ijie.2023.15.01.032.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.