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Original article

Effects of PET Strip Content, Dimensions, and Cement Stabilization on Clay Soil CBR: Experimental and Numerical Study

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Abstract
This study investigates the California Bearing Ratio (CBR) behavior of a low-plasticity clay reinforced with recycled polyethylene terephthalate (PET) bottle strips, focusing on the effects of PET content, strip dimensions, and moisture condition. PET strips measuring 1 × 2 cm and 2 × 2 cm were incorporated at contents of 0.3%, 0.4%, 0.6%, and 1.2% by dry soil mass. CBR tests were conducted under different moisture conditions, including unsoaked specimens prepared at the natural-soil optimum moisture content (OMC), specimens prepared at the individual OMC of each mixture, and specimens subjected to 96 h of soaking. The untreated soil exhibited CBR values of 3.83% and 3.24% under unsoaked and soaked conditions, respectively. At the natural-soil OMC, PET inclusion improved CBR up to 0.6%, with the 2 × 2 cm strips producing the highest PET-only value of 6.63%, whereas the 1.2% mixtures showed lower values than the untreated soil. Under the individual-OMC condition, a measurable CBR of 2.06% was obtained only for the 0.3% PET mixture with 1 × 2 cm strips. Following 96 h of soaking, none of the PET-only specimens exhibited a measurable CBR response. In a subsequent stage, the selected mixture containing 0.6% PET with 2 × 2 cm strips was treated with 4% and 6% cement and tested after soaking, yielding CBR values of 35.94% and 64.21%, respectively. The results demonstrate that PET content, strip dimensions, and moisture condition govern the bearing response, while cement stabilization substantially improves performance under prolonged soaking.
Keywords. California Bearing Ratio; Recycled PET; Plastic Strips; Clay Soil; Cement Stabilization; Soaking.

Introduction

Weak soils with limited bearing resistance can adversely affect the performance of foundations, earthworks, and pavement subgrades. The California Bearing Ratio (CBR) test is widely used to evaluate the penetration resistance of compacted soils and to provide an indication of their suitability as supporting or subgrade materials [1,2]. Improving the mechanical response of weak soils is therefore an important consideration in geotechnical engineering. Conventional stabilization techniques commonly involve the use of cementitious binders such as cement to improve soil strength and stability. At the same time, recycled plastic materials have attracted attention as alternative reinforcement because they offer a potential engineering use for plastic waste while introducing discrete reinforcing elements into the soil matrix [3]. Recycled polyethylene terephthalate (PET) bottle strips may modify soil behavior through interaction with surrounding soil particles, although their effectiveness depends on reinforcement configuration, soil characteristics, compaction state, and moisture condition. Moisture condition is particularly important in fine-grained soils because increasing water content can reduce stiffness and penetration resistance. Under prolonged soaking, the contribution of discrete PET strips may also become limited if the surrounding soil matrix loses sufficient strength and confinement. In such cases, combining PET reinforcement with cement stabilization may provide a more stable response under wet conditions.

This study investigates the CBR behavior of low-plasticity clay reinforced with recycled PET bottle strips under different moisture conditions. The study also examines the use of cement as a complementary stabilizing material for the selected PET-reinforced mixture under soaked conditions. The main objective is to evaluate the influence of PET reinforcement, moisture condition, and cement stabilization on the bearing response of the investigated soil. In addition to the laboratory program, an axisymmetric finite-element model was developed in PLAXIS 2D to reproduce the CBR response of the natural soil and PET-reinforced mixtures. The numerical CBR values at 2.5 and 5.0 mm penetration were compared with the corresponding laboratory measurements.

The remainder of the paper is organized as follows. Section II reviews the relevant literature, Section III describes the materials and experimental procedures, Section IV presents the experimental and numerical results, Section V discusses the findings in relation to previous studies, and Section VI summarizes the main conclusions.

A considerable body of research has examined the use of recycled plastic materials to enhance the California Bearing Ratio (CBR) of weak soils and other geomaterials. Different reinforcement forms have been investigated, including PET bottle strips, plastic chips, fragments, granules, and larger bottle-derived elements. In several studies, plastic reinforcement was also combined with supplementary materials such as stone dust, fly ash, quarry dust, and waste marble dust. The overall findings indicate that the effectiveness of recycled plastic is not governed by plastic content alone; it is also influenced by soil type, reinforcement geometry, particle interaction, moisture condition, and the presence of additional stabilizing materials [4–16].

Dutta and Sarda investigated the use of waste-plastic strips in stone dust and fly ash placed over saturated clay [5]. Their experimental program considered both strip size and reinforcement content and evaluated performance using CBR and secant modulus. The results showed progressive improvement as the plastic content increased up to approximately 2%, while further increases produced only limited additional benefit. The study also showed that the stone-dust system developed a more favorable response than the corresponding fly-ash system, highlighting the importance of the surrounding material in controlling reinforcement efficiency.

Peddaiah et al. studied PET bottle strips in silty sand and found that the reinforcement response varied with both PET content and strip dimensions [4]. Among the tested combinations, the most favorable performance was obtained at 0.4% PET with 15 × 15 mm strips. Honnalli et al. examined the combined use of quarry dust and plastic strips for CBR improvement and demonstrated that the contribution of plastic reinforcement should be assessed together with the soil-additive system in which it is incorporated [10]. Poweth

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et al. evaluated plastic granules in intermediate-compressibility clay through compaction, direct-shear, and CBR testing and identified 0.25% plastic content as the most favorable overall proportion within the range considered [16].

The behavior of plastic reinforcement in cohesive soils has also been investigated. Saha et al. incorporated plastic-bag strips into clayey soil and observed that the CBR increased as the plastic content was raised to 1% using 1 × 1 cm strips [6]. Beyond this content, however, the CBR decreased, indicating that excessive plastic inclusion can reduce the effectiveness of reinforcement. Mai et al. examined PET bottle strips in subgrade soil at 1% and 2% contents [7]. Both mixtures produced improvements in strength and CBR, although the larger increase was associated with the 2% PET mixture.

Research on granular and industrial materials has likewise shown that reinforcement geometry can strongly affect performance. Mahali and Sinha investigated PET strips in stone dust and reported that variations in strip content and dimensions produced noticeable changes in CBR [8]. The maximum CBR recorded in their study was approximately 2.79 times the value of the untreated material. Paramkusam et al. studied PET fragments in red mud, fly ash, and different combinations of the two materials [9]. Their results showed substantial improvement as the PET content increased up to about 2%, whereas higher contents produced comparatively small additional gains. Other researchers have focused on the arrangement and physical form of bottle-derived reinforcement. Saravanan and Ravindraraj evaluated raw plastic bottles using both CBR and plate-load testing [11], while Ashraf et al. investigated weak soil reinforced using different arrangements of bottle layers and strips [12]. These studies indicated that the benefit of plastic reinforcement is strongly related to how the material is positioned within the soil and how effectively it interacts with the surrounding matrix. Therefore, reinforcement form and placement can be as important as the total plastic content.

Kirubakaran et al. examined PET bottle waste in black cotton soil using contents of 3%, 5%, and 7% [13]. Among the proportions considered, the 5% mixture produced the most favorable overall response. Amena and Kabeta investigated expansive soil reinforced with plastic strips in combination with waste marble dust, providing further evidence that recycled plastic may be used together with another stabilizing material when a stronger or more durable soil matrix is required [14]. Singh et al. reviewed previous investigations involving PET strips in clay subgrade and reported a favorable configuration consisting of 6% PET with strips measuring 25 × 5 mm [15]. Because it is a review article, this configuration represents the result of the primary study summarized by the authors rather than a separate experimental result generated within the review itself [15].

The available literature therefore demonstrates that the response of plastic-reinforced soil varies considerably between studies. No single reinforcement content, strip size, or configuration can be regarded as universally optimum because the resulting CBR depends on the interaction between the plastic reinforcement and the specific soil or geomaterial being treated. Differences in soil texture, plastic form, reinforcement content, strip geometry, moisture condition, compaction state, and the use of supplementary stabilizers all contribute to the observed variation in performance. In particular, findings obtained from silty sand, stone dust, red mud, expansive clay, or composite soil–additive systems cannot be directly transferred to fines-rich, low-plasticity clay. Comparatively limited attention has been given to the combined influence of relatively large PET-strip dimensions, specimen moisture condition, and prolonged soaking. The present investigation addresses these aspects by evaluating PET-reinforced low-plasticity clay under different moisture conditions and by extending the experimental program to include cement stabilization when PET reinforcement alone does not maintain an adequate response under soaking.

Methods

This section describes the natural soil and PET-strip mixtures investigated in the study, together with the procedures adopted for specimen preparation, compaction, and CBR testing. Both unsoaked and soaked conditions were considered, and the selected PET mixture was subsequently evaluated with cement stabilization. The methods used to calculate and compare the measured CBR values are also presented.

Soil

The natural soil was collected from a site near Al-Bayada Fuel Station in eastern Libya. The bulk sample was transported to the laboratory, air-dried, and prepared for testing. Its principal index and compaction properties are summarized in Table 1. Based on the measured fines content and Atterberg limits, the soil was classified as low-plasticity inorganic clay (CL) according to the Unified Soil Classification System (USCS). The sampling location is shown in Figure 1.

Table 1. Index and compaction properties of the natural soil.

Property	Value	Unit	Test standard
Percentage passing No. 200 sieve	54.2	%	ASTM D1140/D1140M
Liquid limit (LL)	31.14	%	ASTM D4318-17
Plastic limit (PL)	21.87	%	ASTM D4318-17
Plasticity index (PI)	9.27	%	ASTM D4318-17
Natural water content	4.32	%	ASTM D2216-71
Specific gravity (Gs)	2.53	—	ASTM D854-98
Maximum dry density (MDD)	1.752	g/cm^3	ASTM D698
Optimum moisture content (OMC)	15.11	%	ASTM D698
USCS classification	CL	—	USCS

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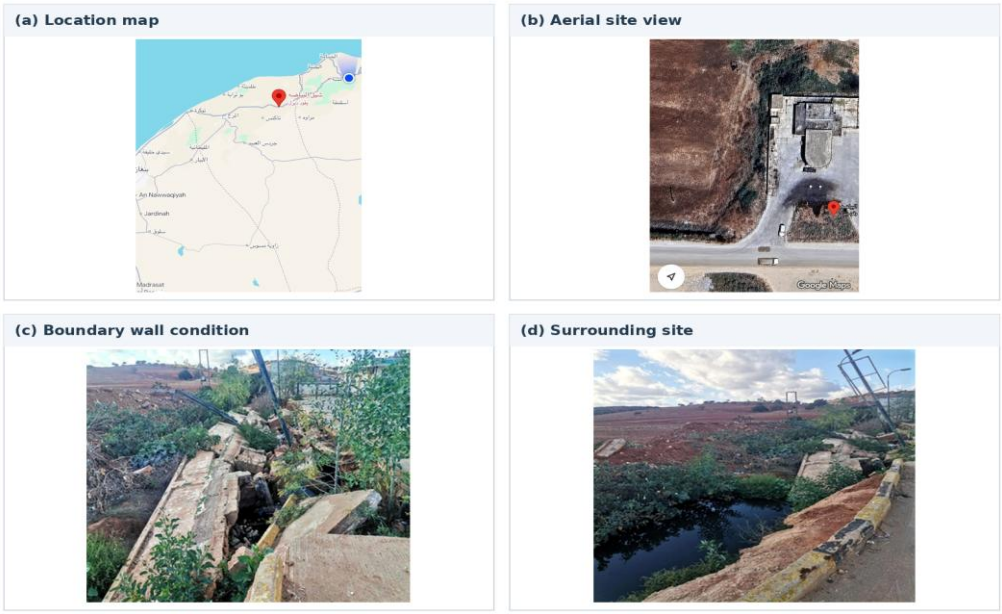


Figure 1. Soil sampling area: (a) location map; (b) aerial view; (c) damaged boundary wall; (d) surrounding site condition.

Recycled PET strips

Discarded polyethylene terephthalate (PET) drinking-water bottles were cleaned, dried, and cut into rectangular strips for use as soil reinforcement. Two strip dimensions, 1 × 2 cm and 2 × 2 cm, were investigated at PET contents of 0.3%, 0.4%, 0.6%, and 1.2% by dry soil mass. The original bottles and the prepared PET strips are shown in (Figure 2).

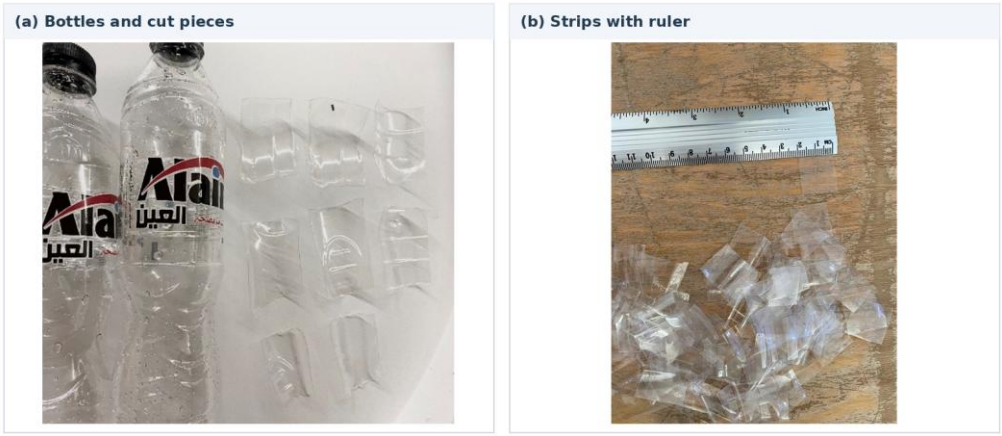


Figure 2. PET reinforcement material: (a) recycled bottles and cut pieces; (b) prepared strips with a ruler for dimensional reference.

CBR specimen preparation and testing

CBR testing was conducted generally in accordance with ASTM D1883. Soil passing the No. 4 (4.75 mm) sieve was mixed with the required PET content and water, and then compacted in a 152.4 mm diameter CBR mold in three approximately equal layers using 56 blows per layer. The main PET-only series was prepared at the natural-soil optimum moisture content (OMC) of 15.11%. An additional unsoaked series was prepared at the individual OMC determined for each PET mixture to examine the influence of mixture-specific moisture conditions. A surcharge mass of approximately 4.5 kg was applied during penetration testing. CBR values were determined at penetrations of 2.5 and 5.0 mm using the corresponding standard reference loads [2,17].

For soaked testing, PET-only specimens were prepared at the natural-soil OMC by mixing the soil, PET strips, and water, followed by compaction and immersion in water for 96 h. After draining for 15 min, penetration testing was conducted. Following evaluation of the PET-only soaked series, the mixture containing 0.6% PET with 2 × 2 cm strips was selected for cement stabilization. Cement was added at 4% and 6% of the dry soil mass, using the optimum moisture content determined for each cement content. The soil, PET strips, cement, and water were mixed, compacted, and immersed in water for 96 h. After draining for 15 min, penetration testing was conducted.

CBR reporting and comparison

The untreated soil was adopted as the reference condition. For the unsoaked tests, CBR values were calculated at both 2.5 and 5.0 mm penetrations. Since the 2.5 mm CBR value was higher than the corresponding 5.0 mm value for all tested mixtures, the 2.5 mm value was adopted for the comparative results presented in (Table 2). The percentage change relative to the untreated soil was calculated as:

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Percentage change (%) = [(CBRtreated - CBRnatural) / CBRnatural] × 100
For soaked PET-only specimens with no measurable penetration load, no numerical CBR value was assigned. These outcomes are marked N/M (not measurable) and should not be interpreted as a measured CBR of zero.

Numerical modelling using PLAXIS 2D
The laboratory CBR test was modelled in PLAXIS 2D using an axisymmetric geometry representing the specimen (radius 0.076 m; effective height 0.118 m) and central plunger (radius 0.0248 m). The 4.5 kg surcharge was represented by a uniform pressure of 2.72 kN/m^2 on the exposed annular soil surface. The soil was described by the Mohr–Coulomb model, with c = 15.33 kPa, ϕ = 25.44°, γ = 19.79 kN/m^3, and ν = 0.30. The natural-soil modulus was calibrated as E = 5500 kPa. A fine mesh (element-size factor 0.25) and sequential initial-stress, surcharge, and plunger-penetration phases were used; maximum prescribed penetration was 10 mm. For the PET mixtures, the soil–strip system was represented as an equivalent homogeneous composite, and case-specific E and c values were calibrated to the laboratory response while the model geometry and loading sequence were held constant. The full plunger load was obtained from the axisymmetric reaction using Q = 2π|Fy|, and CBR was calculated at 2.5 and 5.0 mm using the standard reference loads. Numerical analyses covered the unsoaked specimens compacted at the natural-soil OMC; soaked PET and PET–cement specimens were not modelled.

Results

Natural soil CBR
The untreated soil was first used to establish the reference CBR response under the unsoaked and soaked conditions. A measurable response was obtained in both cases, with the soaked value lower than the unsoaked reference. These baseline results are included in (Tables 2 and 5) for comparison with the reinforced mixtures.

Effect of PET content on unsoaked CBR
At the common natural-soil optimum moisture content, PET inclusion increased the CBR as the reinforcement content rose from 0.3% to 0.6% for both strip dimensions. The highest response occurred at 0.6% PET, whereas the 1.2% mixtures fell below the untreated-soil response (Table 2). The overall variation with PET content is shown in (Figure 3).

Table 2. Unsoaked CBR values at the natural-soil optimum moisture content (15.11%).

Strip dimension	PET content (%)	CBR at 2.5 mm (%)	CBR at 5.0 mm (%)	Reported CBR (%)
Natural soil	0.0	3.83	3.71	3.83
1 × 2 cm	0.3	5.30	5.18	5.30
1 × 2 cm	0.4	5.60	5.47	5.60
1 × 2 cm	0.6	6.48	6.06	6.48
1 × 2 cm	1.2	2.06	1.97	2.06
2 × 2 cm	0.3	5.89	5.86	5.89
2 × 2 cm	0.4	6.04	5.31	6.04
2 × 2 cm	0.6	6.63	5.86	6.63
2 × 2 cm	1.2	2.50	2.34	2.50

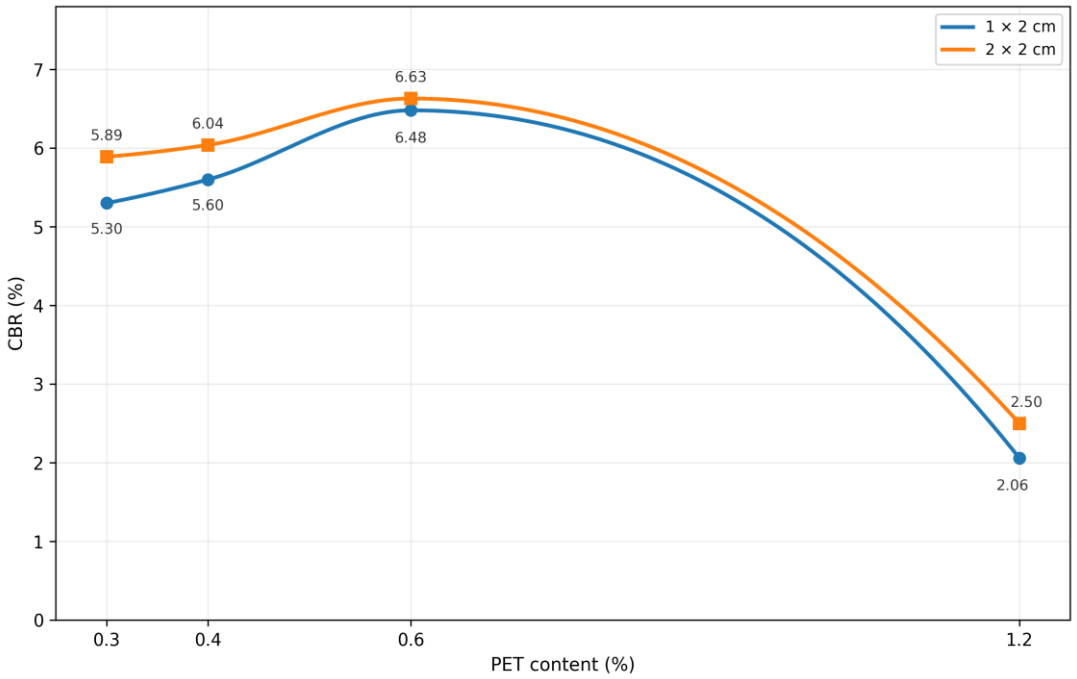


Figure 3. Variation of unsoaked CBR with PET content for both strip dimensions. Smooth lines are guides to the eye.

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Effect of PET strip dimensions on unsoaked CBR

Strip dimensions also affected the measured response. The 2 × 2 cm strips produced higher CBR values than the 1 × 2 cm strips at each PET content investigated. The difference between the two sizes became relatively small at 0.6% PET, where both reached their maximum response, while both configurations declined markedly at 1.2% PET (Figure 4).

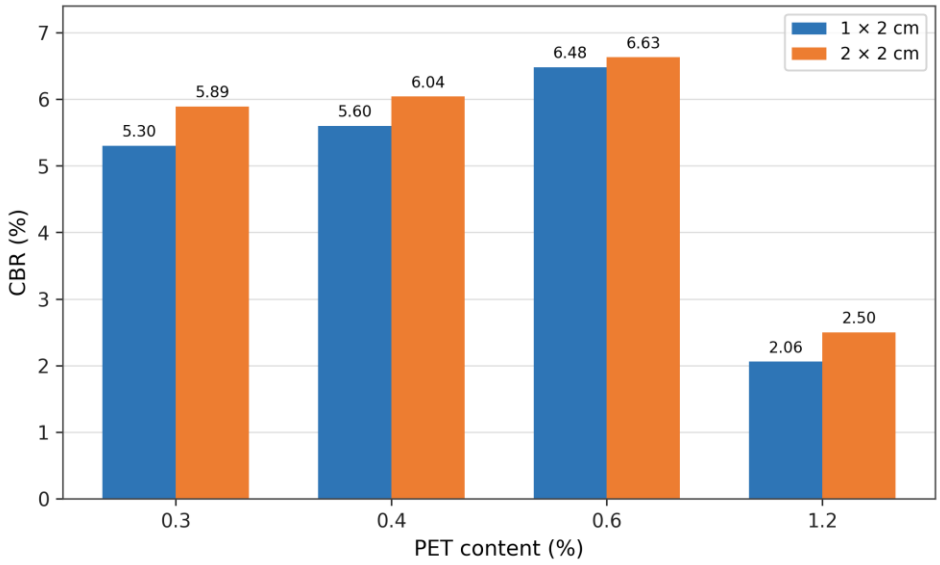


Figure 4. Comparison of unsoaked CBR values for 1 × 2 cm and 2 × 2 cm PET strips.

Effect of soaking on PET-reinforced soil

After 96 h of soaking, all PET-only mixtures showed no measurable CBR response, irrespective of PET content or strip dimensions. The natural soil, by contrast, retained a measurable soaked response. During penetration testing, the soaked PET–soil matrix was visibly soft, and the plunger penetrated easily without developing a measurable resistance. PET strips were also observed to separate from the surrounding soil, with some moving upward to the specimen surface. These observations suggest that softening of the clay matrix weakened soil–PET interaction and the confinement needed for effective load transfer. This interpretation is based on the observed specimen behavior; the underlying failure mechanisms were not independently measured.

Effect of mixture-specific moisture content

The additional unsoaked series prepared at the individual optimum moisture content of each PET mixture produced substantially lower responses than the series prepared at the common natural-soil OMC. A measurable CBR was obtained only for the mixture containing 0.3% PET with 1 × 2 cm strips, while the remaining combinations showed no measurable response (Table 3). The higher mixture-specific moisture contents may have softened the clay matrix sufficiently for the plunger to penetrate without developing a measurable resistance. Reduced interaction between the softened soil and PET strips is a plausible explanation, although the failure mechanism in this unsoaked series was not independently measured.

Table 3. Unsoaked CBR response when PET mixtures were prepared at their individual optimum moisture contents.

PET content (%)	Strip dimension	Individual OMC (%)	Reported CBR (%)	Response
0.3	1 × 2 cm	17.10	2.06	Measurable
0.4	1 × 2 cm	17.81	N/M	Not measurable
0.6	1 × 2 cm	18.17	N/M	Not measurable
1.2	1 × 2 cm	22.21	N/M	Not measurable
0.3	2 × 2 cm	20.06	N/M	Not measurable
0.4	2 × 2 cm	21.84	N/M	Not measurable
0.6	2 × 2 cm	21.20	N/M	Not measurable
1.2	2 × 2 cm	20.50	N/M	Not measurable

Note: N/M indicates that no measurable CBR response was obtained; no numerical CBR value was assigned.

Load–penetration response

The load–penetration curves provide a direct comparison between the untreated soil and the PET mixtures representing the highest and lowest unsoaked responses (Figure 5). The 0.6% PET mixture with 2 × 2 cm strips remained above the natural-soil curve throughout the recorded penetration range, whereas the corresponding 1.2% PET mixture remained below it. The curves are consistent with the CBR trends obtained at the standard penetration points.

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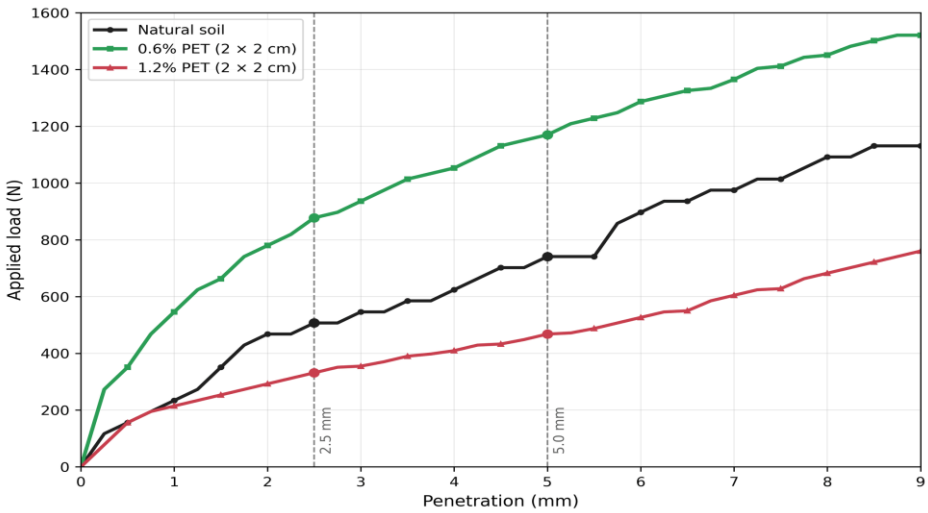


Figure 5. Load–penetration curves of natural soil, 0.6% PET with 2 × 2 cm strips, and 1.2% PET with 2 × 2 cm strips.

Percentage change relative to the natural soil

The percentage-change comparison further illustrates the effect of PET content (Table 4 and Figure 6). Positive changes were obtained from 0.3% to 0.6% PET for both strip dimensions, with the greatest improvement occurring at 0.6%. At 1.2% PET, the relative change became negative for both strip sizes, while the 2 × 2 cm strips generally maintained the highest response.

Table 4. Percentage change in unsoaked CBR relative to natural soil (CBR = 3.83%).

PET content (%)	1 × 2 cm strips (%)	2 × 2 cm strips (%)
0.3	+38.38	+53.79
0.4	+46.21	+57.70
0.6	+69.19	+73.11
1.2	−46.21	−34.73

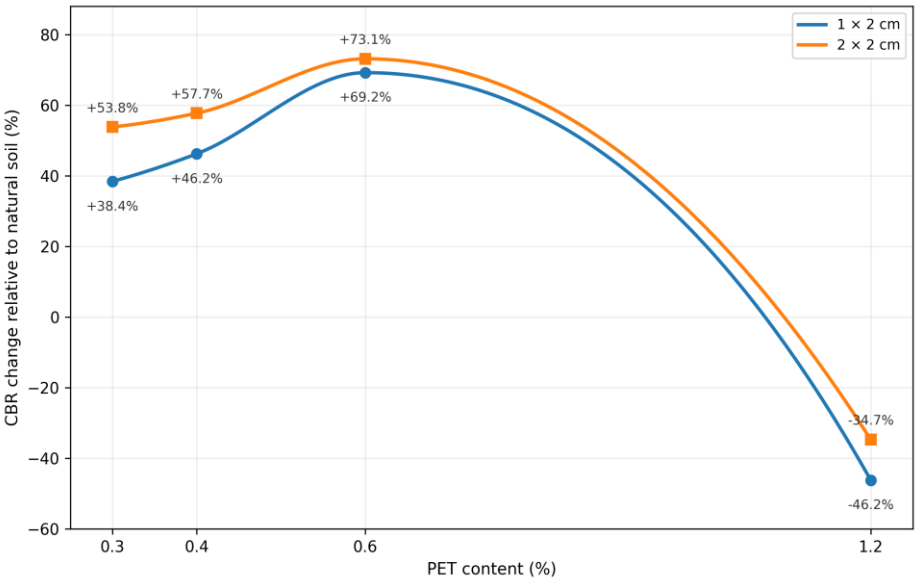


Figure 6. Percentage change in unsoaked CBR relative to natural soil for both PET strip dimensions. Smooth lines are guides to the eye.

Cement stabilization under soaked conditions

Because the PET-only specimens did not develop a measurable CBR response after soaking, the mixture containing 0.6% PET with 2 × 2 cm strips, which had produced the highest unsoaked CBR, was selected for the subsequent cement-stabilization stage.

Cement addition restored a measurable soaked CBR response, and the response increased further as the cement content was raised from 4% to 6% (Table 5 and Figure 7). Among the cement-treated mixtures investigated, the 6% cement mixture produced the highest soaked response.

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Table 5. Soaked CBR after 96 h for natural soil, PET-only soil, and PET–cement mixtures.

Mixture	PET content (%)	Strip dimensions (cm)	Cement content (%)	Soaked CBR (%)
Natural soil	0.0	—	0	3.24
Soil + PET	0.6	2 × 2	0	N/M
Soil + PET + cement	0.6	2 × 2	4	35.94
Soil + PET + cement	0.6	2 × 2	6	64.21

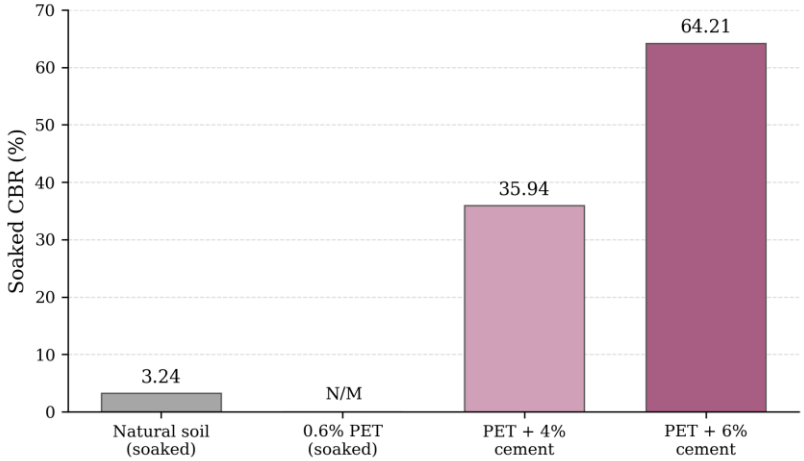


Figure 7. Comparison of soaked CBR values for natural soil, PET-reinforced soil, and mixtures containing 4% and 6% cement.

The corresponding load–penetration curves show a consistently higher response for the 6% cement mixture than for the 4% mixture throughout the recorded penetration range. The separation between the two curves became more pronounced as penetration increased (Figure 8).

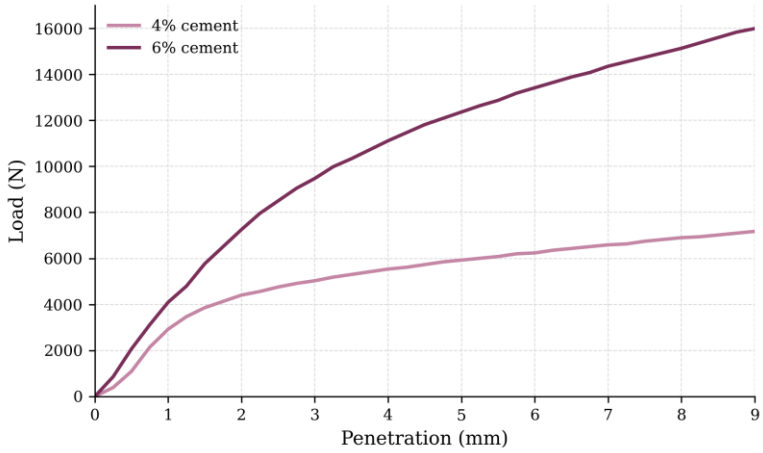


Figure 8. Load–penetration curves of soaked PET–cement mixtures containing 4% and 6% cement.

Numerical modelling results and comparison

The natural-soil model produced numerical CBR values of 3.77% and 3.71% at 2.5 and 5.0 mm, respectively, compared with experimental values of 3.83% and 3.71%; the mean relative error was 0.78%. For the eight PET-reinforced mixtures, the numerical response followed the measured trend, with CBR peaking at 0.6% PET for both strip sizes and declining at 1.2% (Table 6). Using the rounded values shown in (Table 6), the mean absolute percentage error (MAPE) across 16 comparisons is 0.77%, and the maximum absolute percentage error is 2.05%.

Table 6. Experimental and PLAXIS CBR values with absolute percentage errors for PET-reinforced mixtures.

Size	PET %	Exp. 2.5 mm (%)	PLAXIS 2.5 mm (%)	APE 2.5 mm (%)	Exp. 5.0 mm (%)	PLAXIS 5.0 mm (%)	APE 5.0 mm (%)
1 × 2	0.3	5.30	5.35	0.94	5.18	5.14	0.77
1 × 2	0.4	5.60	5.62	0.36	5.47	5.48	0.18
1 × 2	0.6	6.48	6.44	0.62	6.06	6.05	0.17
1 × 2	1.2	2.06	2.03	1.46	1.97	1.97	0.00
2 × 2	0.3	5.89	5.89	0.00	5.86	5.74	2.05
2 × 2	0.4	6.04	6.00	0.66	5.31	5.35	0.75
2 × 2	0.6	6.63	6.60	0.45	5.86	5.85	0.17
2 × 2	1.2	2.50	2.45	2.00	2.34	2.38	1.71

Note: Specimens were unsoaked and prepared at the natural-soil OMC (15.11%). APE = |CBR numerical − CBR experimental| / CBR experimental × 100; the reported MAPE and maximum APE were calculated from the rounded values shown here.

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The experimental and PLAXIS load–penetration responses are compared for all PET contents in (Figures 9 and 10). The comparisons are grouped by strip dimension, with panels (a)–(d) representing PET contents of 0.3%, 0.4%, 0.6%, and 1.2%, respectively.

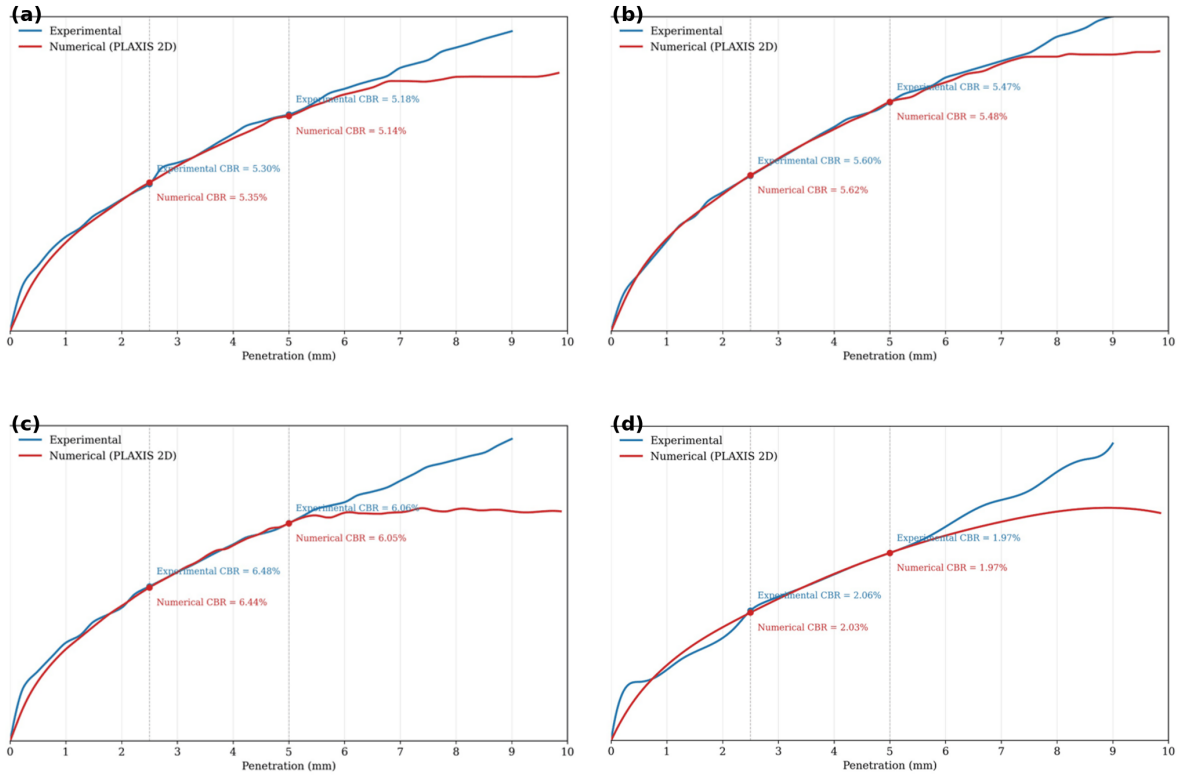


Figure 9. Experimental and PLAXIS load–penetration responses for soil reinforced with 1 × 2 cm PET strips at: (a) 0.3%; (b) 0.4%; (c) 0.6%; and (d) 1.2% PET content.

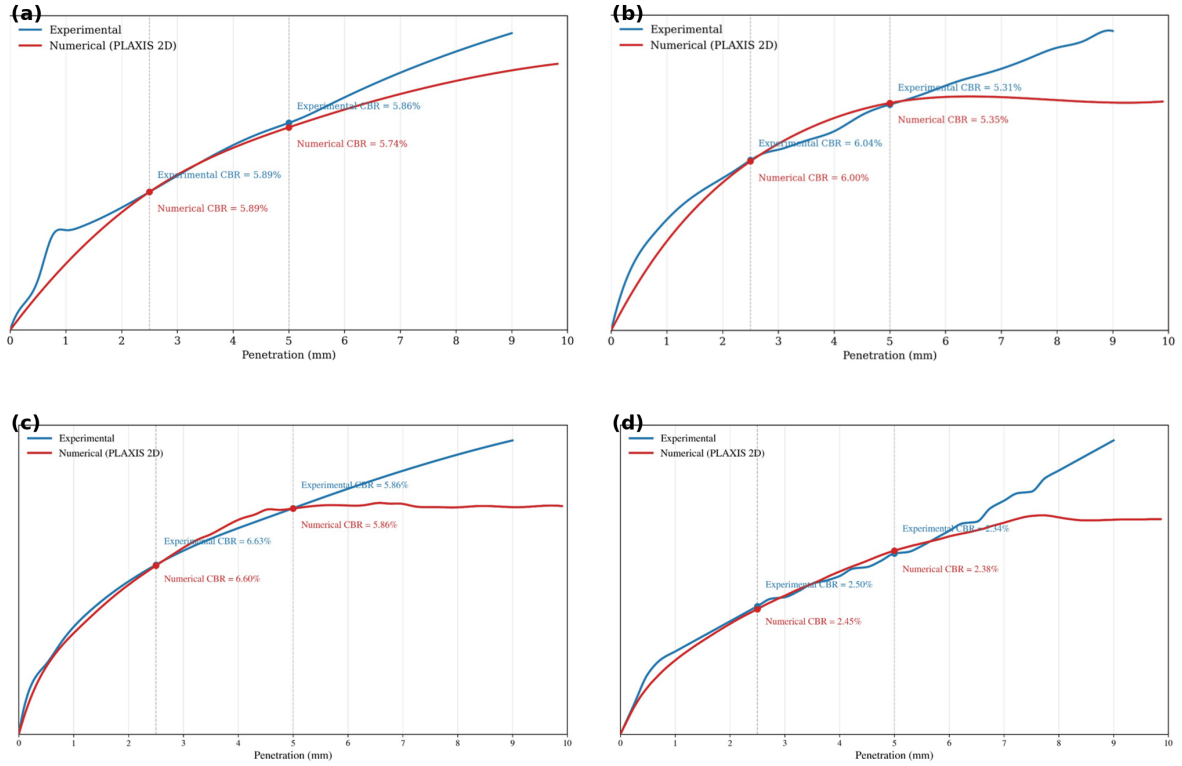


Figure 10. Experimental and PLAXIS load–penetration responses for soil reinforced with 2 × 2 cm PET strips at: (a) 0.3%; (b) 0.4%; (c) 0.6%; and (d) 1.2% PET content.

Discussion

The improvement observed at moderate PET contents can be attributed to the interaction between the strips and the surrounding soil, which increases resistance to particle movement during penetration. The larger 2 × 2 cm strips provide a greater contact area with the soil and therefore may develop more effective frictional and interlocking resistance. However, when the PET content becomes

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excessive, as at 1.2%, the larger number of strips can reduce direct soil-to-soil contact and disturb the continuity of the compacted matrix. This can create a less dense and less efficiently interlocked structure, explaining the reduction in CBR beyond the favorable PET content. Similar dependence on reinforcement amount and geometry has been reported in previous PET-reinforced soil studies [4–6].

The strong reduction in CBR at the individual OMCs and after soaking is mainly related to the influence of water on the fine-grained soil matrix. Increased moisture reduces interparticle friction and weakens the confinement surrounding the PET strips, making it more difficult for the soil to transfer load effectively to the reinforcement. Prolonged soaking further softens the clay matrix and reduces its ability to hold the strips in position. The observed upward movement and separation of PET strips after soaking support this interpretation. Similar moisture-related deterioration in bearing performance has been reported for stabilized expansive soils and pavement materials [18].

The substantial recovery in soaked CBR after cement addition can be explained by the formation of a stronger bonded soil structure. Cement hydration products bind soil particles, reduce the loss of integrity caused by water, and improve confinement around the PET strips. Increasing the cement content from 4% to 6% strengthens this cemented matrix further, which explains the higher penetration resistance obtained with 6% cement. Comparable improvements in strength and water resistance have been reported for cement-stabilized soils containing PET or other plastic waste materials [19–21].

The finite-element results reproduced the experimental trend across the tested PET contents and strip sizes. This agreement represents calibration consistency rather than independent predictive validation because the equivalent E and c parameters were fitted to the same laboratory CBR results; the model's applicability is therefore limited to the unsoaked mixtures compacted at the natural-soil OMC evaluated here. No separate experimental dataset was reserved for out-of-sample validation; the reported numerical agreement should therefore not be interpreted as evidence of predictive accuracy for other soil conditions, moisture states, or PET–cement mixtures.

Conclusion

The CBR response of the investigated low-plasticity clay was strongly governed by PET content, strip dimensions, and moisture condition. Under the common natural-soil OMC, PET reinforcement improved the unsoaked bearing response up to 0.6% PET, with the 2 × 2 cm strips producing the highest PET-only CBR. Increasing the PET content to 1.2% reduced the effectiveness of the reinforcement. When the mixtures were prepared at their individual OMCs, the improvement was not maintained, and prolonged soaking resulted in no measurable CBR response for all PET-only specimens. In contrast, cement stabilization substantially restored the soaked bearing resistance of the selected PET mixture, with 6% cement producing a higher response than 4%. Overall, PET reinforcement was beneficial under the investigated unsoaked condition, but its effectiveness was highly sensitive to moisture, while cement stabilization provided the necessary improvement for maintaining bearing resistance after prolonged soaking. The calibrated PLAXIS 2D model reproduced the natural-soil CBR with a mean relative error of 0.78% and the eight PET-reinforced cases with an overall MAPE of 0.77% (maximum absolute percentage error, 2.05%, based on the rounded values in Table 6). It also captured the measured increase at 0.6% PET and decline at 1.2% for the unsoaked mixtures prepared at the natural-soil OMC, supporting the model as a representation of the tested conditions.

Author contributions

Thekra Khalil Moftah conducted the laboratory investigation, analyzed the data, and prepared the original draft. Dr. Enas Abdulnabi Omar supervised the study and reviewed and edited the manuscript. Both authors approved the final manuscript.

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Conflicts of Interest

Enas Abdulnabi Omar and Thekra Khalil Moftah declare no conflicts of interest.

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