Sustainable Ground Improvement Using Waste Plastic Bottle Mattresses Beneath Strip Footings

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Abstract

The persistence of plastic waste, particularly polyethylene terephthalate (PET) bottles, poses a major environmental concern due to its non-biodegradable nature. Repurposing these materials as ground improvement elements provides an environmentally friendly and cost-effective alternative to traditional geosynthetics. This study investigates the use of waste plastic bottle mattresses as reinforcement for sandy subgrades supporting strip footings. A series of physical model tests was conducted to evaluate how variations in mattress embedment depth, width, and height influence foundation performance. The results showed that the inclusion of bottle mattresses consistently improved both the load-bearing capacity and the initial stiffness of the foundation system. The degree of improvement was closely tied to the interaction between the stress influence zone and the confinement effect of the reinforcement, with efficiency stabilizing beyond certain geometric limits. The outcomes of this study provide practical guidance for optimizing reinforcement geometry in shallow foundation systems and underscore the value of integrating recycled materials into geotechnical design frameworks.

Keywords: Waste plastic bottles; Strip footing; Geocell reinforcement; Bearing capacity; Improvement factor.

1- Introduction

Improving the load-bearing performance of shallow foundations has been a persistent challenge in geotechnical engineering, given the inherent limitations of natural soils in sustaining applied loads. Historically, conventional ground improvement methods such as soil replacement with granular fills, installation of stone columns, chemical stabilization, and deep foundation systems have been implemented to enhance bearing capacity and control settlements [1,2]. While effective in certain contexts, these approaches often suffer from high costs, extended construction time, and environmental drawbacks.

The introduction of geosynthetics provided a cost-effective and versatile alternative. Planar reinforcements such as geotextiles and geogrids were widely adopted to improve subgrade response by mobilizing tensile resistance and reducing soil deformations [3- 5]. However, their two-dimensional nature restricts their ability to provide three-dimensional confinement and efficient stress redistribution. Cellular confinement systems, known as geocells, represented a paradigm shift by forming a three-dimensional honeycomb mattress that confines the infill soil and mobilizes multiple reinforcing mechanisms including lateral restraint, load distribution, and membrane tension. Extensive studies have confirmed the superior efficacy of geocell systems in improving bearing capacity, reducing settlement, and modifying failure mechanisms beneath strip footings compared to both unreinforced and planar-reinforced conditions [6- 9].

In recent years, there has been an increasing emphasis on the sustainable utilization of waste materials in civil engineering, particularly to address the environmental crisis posed by plastic waste. Plastic bottles, primarily composed of polyethylene terephthalate (PET), are one of the most ubiquitous pollutants due to their durability and non-biodegradability, with decomposition times reaching up to 450 years [10]. Conventional waste management strategies such as landfilling and incineration have proven environmentally hazardous, while recycling is limited by economic and quality-related challenges. Consequently, researchers have explored incorporating plastic waste into asphalt, concrete, and soil as fibers, strips, chips, and flakes, with notable improvements in mechanical performance [11- 14]. Despite these advances, the challenge of contamination and impracticality of separating shredded plastics from soil has limited their widespread adoption.

An alternative strategy is to use waste PET bottles (WPBs) in their original form, eliminating the need for shredding or crushing while reducing both energy demand and contamination risks. Several recent studies have demonstrated the potential of WPBs to act as low-cost geocell-like reinforcements. Dutta and Mandal showed that bottle-based mattresses filled with fly ash or supported by columns improved subgrade performance [15, 16]. Moghaddas Tafreshi et al. (2021) reported significant reductions in accumulated settlement when PET bottles were used under dynamic loading, while Shah et al. (2022) highlighted the comparable performance of WPB-based geocells and commercial HDPE geocells in CBR tests. However, most existing studies have focused on cohesive soils or pavement subgrades, leaving a gap in understanding the performance of WPB mattresses in granular soils [17, 18].

The increasing consumption of PET bottles, combined with the urgent need for sustainable ground improvement techniques, underscores the potential of WPBs as an eco-efficient reinforcement system. In this study, the performance of waste plastic bottle (WPB) mattresses arranged in a strip configuration beneath shallow strip foundations on loose sandy soils is investigated through laboratory model tests. The bottle ends were cut to enhance interfacial shear resistance, creating a confinement system resembling commercial geocells. The experimental program evaluates the influence of key parameters—including the depth of placement (u/B), the height of the mattress (h/B), and the mattress width (b/B)—on the load–settlement response of strip footings. The results are interpreted in terms of improvement factors at prescribed settlement levels, thereby providing new insights into the feasibility of WPBs as sustainable substitutes for commercial geocells in geotechnical engineering.

2. Physical Model Description and Testing Program

2.1 Test setup

The experimental investigations were conducted in a rigid steel test tank with internal dimensions of 110 cm (length), 100 cm (width), and 80 cm (height). The tank dimensions were selected in accordance with Boussinesq's stress distribution theory to minimize boundary effects. The foundation model consisted of a rigid strip steel plate with a width of 10 cm, length of 90 cm and thickness of 1 cm, representing a surface strip footing under plane strain conditions. The footing was connected to an electro-mechanical jack capable of applying monotonic vertical loading. The applied load was measured using a calibrated load cell positioned between the jack and the footing plate. Settlement of the footing was continuously recorded using a high-precision Linear Variable Differential Transformer (LVDT) attached to the loading shaft. A general view of the experimental setup is shown in Fig. 1.

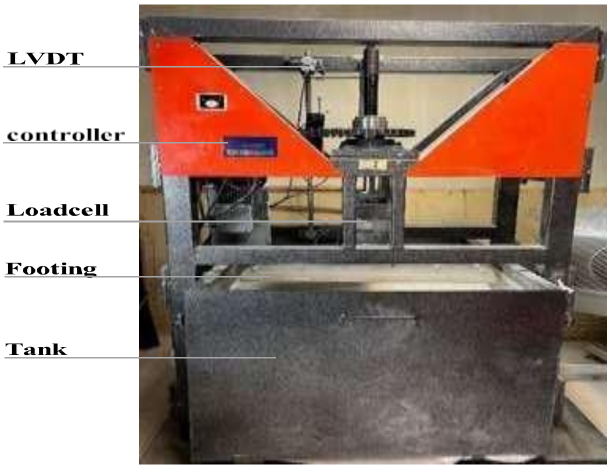

Fig. 1. General view of the experimental setup

2.2 Soil properties

The foundation soil comprised poorly graded silica sand obtained from a local crusher plant in Hamedan, Iran. The sand particles were predominantly angular and transparent. The particle size distribution curve and a close-up image of the sand grains are presented in Fig. 2. Basic physical and mechanical properties of the sand are summarized in Table 1.

The maximum and minimum dry unit weights were determined as 16.4 kN/m^3 and 12.8 kN/m^3, respectively, with a specific gravity of 2.85. The mean particle diameter (D_{50}) was measured as 1.45 mm, with coefficients of uniformity ($C_u = 1.65$) and curvature ($C_c = 0.9$), classifying the soil as poorly graded sand (SP) according to the Unified Soil Classification System (USCS).

To evaluate the shear strength parameters at the target relative density of 35%, a series of direct shear tests were performed. The results indicated an internal friction angle (φ) of 32°. The corresponding modulus of elasticity (E) was determined as 10 MPa. For the same density, the average dry unit weight (γ_d) of the test specimens was 13.8 kN/m^3.

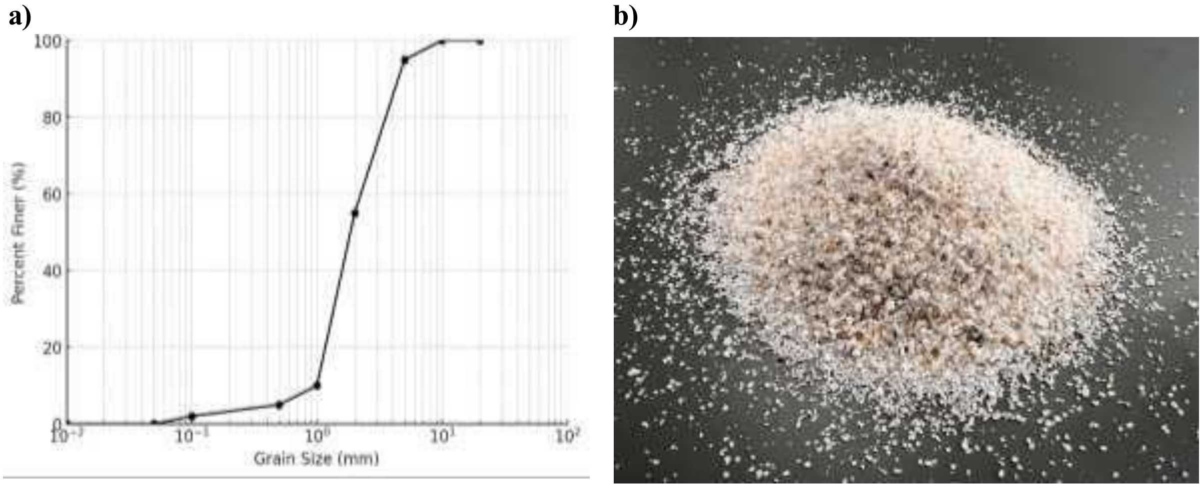

Fig. 2. (a) Particle size distribution curve and (b) close-up image of sand grains.

Table 1. Physical and mechanical properties of the tested sand

Soil Properties	Symbol	Unit	Value
Specific gravity	G_s	-	2.85
Maximum dry unit weight	$\gamma_{d\ max}$	$^{KN}/_{m^3}$	16.4
Minimum dry unit weight	$\gamma_{d\ min}$	$^{KN}/_{m^3}$	12.8
Dry unit weight *	γ_d	$^{KN}/_{m^3}$	13.8
Mean particle diameter	D_{50}	mm	1.45
Coefficient of uniformity	C_u	-	1.65
Coefficient of curvature	C_c	-	0.9
Soil friction angle *	φ	degree	32

Modulus of elasticity *	E	MPa	10

* for D_r =35%

2.3 Waste Plastic Bottle Mattress

The global consumption of bottled water has increased substantially in recent decades, largely driven by changes in lifestyle and urbanization. Consequently, enormous volumes of waste plastic bottles are generated worldwide, with approximately 1,500 bottles being discarded every second [19]. Most bottles are produced from polyethylene terephthalate (PET), Fig. 3 shown a thermoplastic polyester with the chemical formula $n(C_{10}H_8O_4)$ [10]. PET is characterized by low density, flexibility, and long-term durability. While its persistence in natural environments is a major environmental concern, these same properties can be advantageously exploited in civil engineering applications.

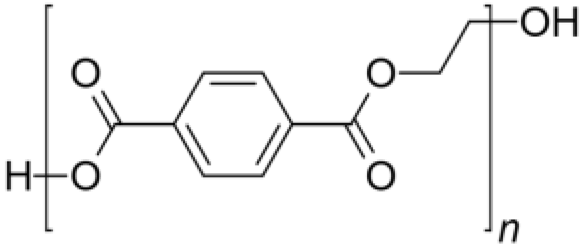

Fig. 3. Molecular model of polyethylene terephthalate (PET).

In this study, a WPB mattress was fabricated to function as a geocell-like confinement system. Each bottle had a nominal volume of 500 ml, a wall thickness of 0.25 mm, and an average diameter of 56 mm. The bottles were cut to the required height and arranged side by side to form a continuous mattress (Fig. 4). To enhance structural integrity, bottles were stapled together, with a thin PET sheet interposed between adjacent units to ensure uniform stress transfer and lateral confinement [15, 16].

Fig. 4. Assembled bottle mattress to a reinforcement mattress

The mechanical characterization of both the bottle body and bottle-to-bottle joints was carried out through tensile test using a universal testing machine (Fig. 5). For the bottle wall, specimens measuring 5 cm × 12 cm with a gauge length of 6 cm were tested in the radial direction, which is critical due to the dominance of hoop stresses in PET bottles under pressure. For evaluating the connections, two 5-cm-high bottle segments joined with staples were tested under tensile loading until failure. In all cases, a displacement-controlled loading rate of 1 mm/min was maintained. Similar methodologies have been employed in previous studies to evaluate WPB systems [17, 18].

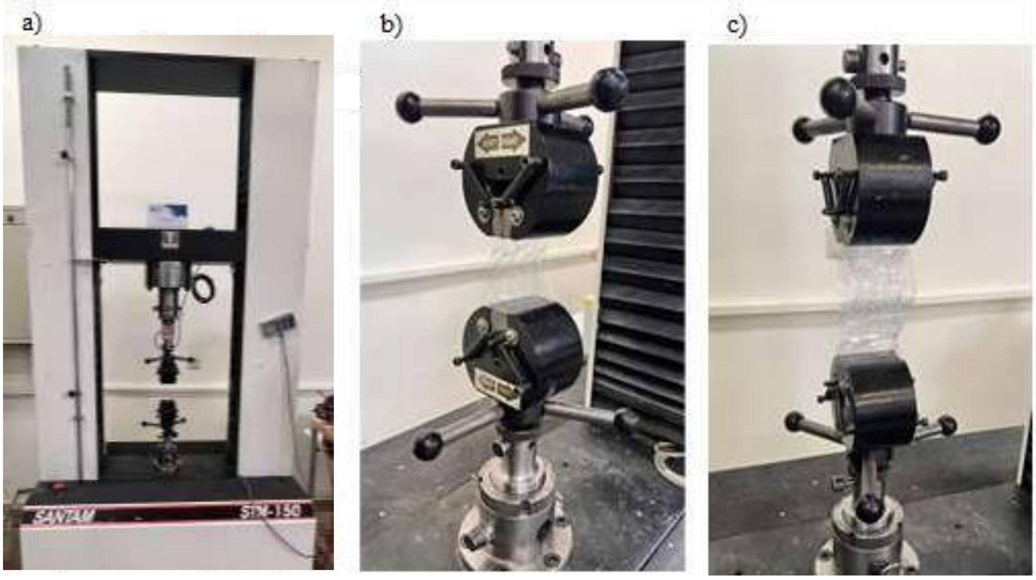

Fig. 5. Tensile testing of WPB materials: (a) general view of the universal testing machine, (b) bottle-to-bottle connection under tensile loading, and (c) tensile test of the bottle wall specimen.

Figure 6 illustrates the stress–strain behavior of the waste plastic bottle (WPB) specimens, including both the PET body and the stapled connections. The PET body exhibited a relatively steep initial slope, reflecting a high stiffness with a Young's modulus of 33.20 kN/m, and reached an ultimate tensile strength of 2.14 kN/m. In contrast, the stapled joints displayed lower stiffness (7.14 kN/m) and strength (0.71 kN/m), highlighting the joint as the critical element governing the overall tensile capacity of the WPB mattress. Despite this reduction, the combined system still demonstrated appreciable tensile resistance suitable for soil confinement applications. The unit weight of the PET material was 13.34 kN/m³, which is sufficiently low to make the system lightweight while retaining mechanical efficiency. These results are consistent with previous findings that reported comparable performance of PET-based reinforcements relative to conventional polymeric geocells [16, 18]. A detailed summary of the mechanical and physical properties of the WPBs is provided in Table 2.

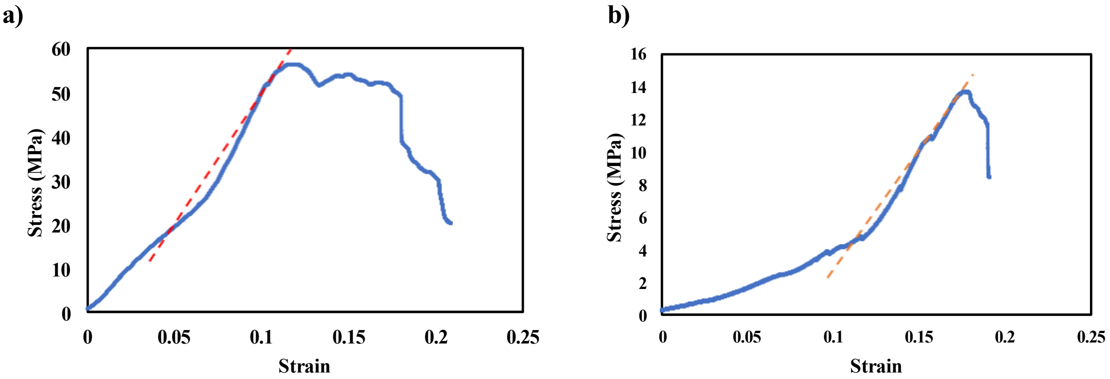

Fig. 6. Stress–strain curves of WPB: (a) PET body specimen and (b) stapled connection.

Table 2. Physical and Mechanical properties of WPB

Plastic Bottle Properties	Unit	Value
Bottle diameter	mm	56.00
Thickness of bottles	mm	0.25
Ultimate joint tensile strength	kN/m	0.71

Joint Young modulus	$\mathrm{kN}/_{\mathrm{m}}$	7.14
Ultimate body tensile strength	$\mathrm{kN}/_{\mathrm{m}}$	2.14
Body Young modulus	$\mathrm{kN}/_{\mathrm{m}}$	33.20
Unit weight (γ)	$\mathrm{KN}/_{\mathrm{m}^3}$	13.34

2.4 Test Procedure

In this investigation, the model subgrade was prepared at a target relative density of 35%. To ensure uniformity across the entire surface of the soil tank, the sand raining (air pluviation) method was employed, a technique widely adopted in physical modeling studies for its ability to produce reproducible density conditions [6, 7]. In this method, the relative density of the deposit is controlled by adjusting both the falling height and the raining rate of the sand. For the present study, approximately 1,000 kg of natural silica sand was deposited in successive layers from a constant fall height of 20cm until the desired dimensions of the soil bed—110 cm in length, 100 cm in width, and 65 cm in height—were achieved.

The WPB mattress was placed at the designated embedment depth within the prepared soil bed. The bottles were carefully filled with sand identical to that of the surrounding subgrade to ensure continuity and effective confinement. Once the mattress was installed, after filling all cells, the surface of the sand bed was leveled to accommodate the foundation model. A rigid footing fabricated from steel, was positioned at the centerline of the test tank. Special care was taken to align the footing to ensure that the vertical load from the electro-mechanical jack was applied concentrically along the footing's axis, thereby minimizing eccentricity effects.

Vertical loading was applied under displacement control at a rate of approximately 1 mm/min, in accordance with established procedures for shallow foundation modeling [9]. The applied load was monitored through a pre-calibrated S-shaped load cell positioned between the jack and the foundation plate. Footing settlements were measured using a high-precision LVDT mounted on the loading shaft. Both load and settlement data were captured continuously and displayed in real time on a computer interface through dedicated acquisition software. This setup enabled accurate tracking of the load–displacement response throughout the testing sequence.

2.5 Testing Program

The primary objective of this study is to investigate the effect of WPB mattresses on the load–settlement behavior and bearing capacity of strip footings resting on sand beds. In particular, the influence of three key geometrical parameters was evaluated: the embedment depth (u), the mattress width (b), and the mattress height (h). To ensure generality and facilitate comparison with previous studies, all parameters were expressed in non-dimensional form relative to the footing width (B), namely u/B, b/B, and h/B [6, 7].

A baseline test (Test No. 00) was first performed on an unreinforced sand bed in order to provide a reference for quantifying the improvement achieved by the inclusion of WPB mattresses. Subsequently, a comprehensive series of reinforced tests was carried out, in which the mattress geometry was systematically varied. The schematic representation of the experimental configuration is shown in Fig. 7.

Due to physical limitations of the model tank and the uniformity of the bottles used, the average bottle diameter was maintained at approximately 0.5 times the footing width, ensuring a consistent scale between the footing and reinforcing elements. Similar constraints and design considerations have been reported in prior studies on geocell-reinforced footings [9].

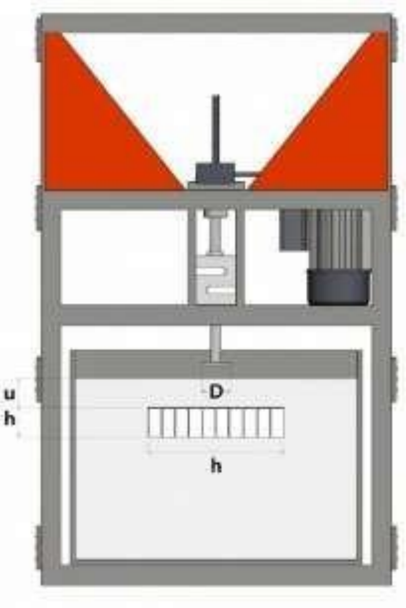

Fig. 7. Schematic of the test setup

The nomenclature of the tests conducted on footing follows the pattern illustrated in Fig.8. This naming convention consists of four components. The first component denotes the footing type, where Str refers to the strip footing. The second component indicates the embedment depth of the reinforcement (u). The third component represents the mattress width (b), while the fourth specifies the mattress height (h). The complete details of the experimental program and the ultimate bearing capacity of each test are summarized in Table 3.

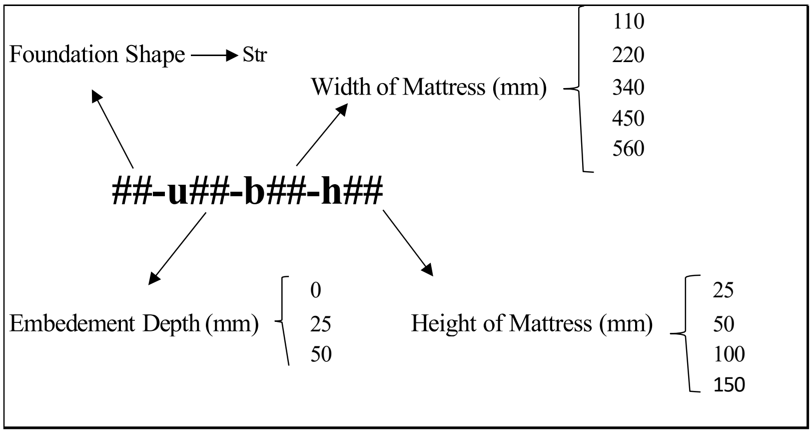

Fig. 8. Parameter ranges for strip footing tests: embedment depth (u), mattress width (b), and mattress height (h).

Table 3. Details of model tests

Test No.	Test Code	Type of reinforcement	u/B	b/B	h/B
00	Str-unrein	Unreinforced	-	-	-
01	Str-u0-b450-h100	Reinforced	0.0	4.5	1.0
02	Str-u25-b450-h100	Reinforced	0.25	4.5	1.0
03	Str-u50-b450-h100	Reinforced	0.5	4.5	1.0

04	Str-u0-b110-h100	Reinforced	0.0	5.6	1.0
05	Str-u0-b220-h100	Reinforced	0.0	3.4	1.0
06	Str-u0-b340-h100	Reinforced	0.0	2.2	1.0
07	Str-u0-b560-h100	Reinforced	0.0	1.1	1.0
08	Str-u0-b450-h25	Reinforced	0.0	4.5	1.5
09	Str-u0-b450-h50	Reinforced	0.0	4.5	0.5
10	Str-u0-b450-h150	Reinforced	0.0	4.5	0.25

The experimental program for footing was designed in three independent series to systematically evaluate the influence of each reinforcement parameter. In each series, one parameter was varied while the other two were kept constant to isolate the effect of the variable under investigation.

Series I (Effect of embedment depth, u): The WPB mattress was embedded at three depths of 0, 25, and 50 mm. In this series, the mattress width and height were held constant at 450 mm and 100 mm, respectively.

Series II (Effect of mattress width, b): The mattress width was varied at five levels, namely 110, 220, 340, 450, and 560 mm, while the embedment depth and mattress height were kept constant at 0 mm and 100 mm, respectively.

Series III (Effect of mattress height, h): The mattress height was investigated at four levels, i.e., 25, 50, 100, and 150 mm, with the embedment depth and mattress width fixed at 0 mm and 450 mm, respectively.

This systematic experimental framework enabled a clear evaluation of the role of each parameter (u, b, and h) in enhancing the bearing capacity of strip footings reinforced with WPB mattresses.

3. Results and discussion

3.1 Effect of Embedment Depth (u/B)

Figures 9 and 10 illustrate the load–settlement response and improvement factors of strip footings with different embedment depths (u/B = 0, 0.25, and 0.5). The results confirm that the inclusion of WPB mattresses markedly improved both the ultimate bearing capacity and the initial stiffness relative to the unreinforced condition. The optimum performance was observed at u/B = 0.25, where the reinforced system mobilized maximum confinement within the stress influence zone of the footing. At this depth, the ultimate bearing capacity increased by nearly four times relative to the unreinforced case, with the initial load–settlement response indicating a stiffness improvement of about 70%.

At u/B = 0, where the mattress was placed directly beneath the footing, the system still provided significant gains over the unreinforced condition. The mattress effectively restricted lateral soil displacement at shallow depth, leading to a steeper initial stiffness and higher resistance at small settlements. However, because the reinforcement was exposed to concentrated shear stresses immediately beneath the footing, premature local deformations reduced its long-term efficiency. In addition, as the top surface of the mattress was not fully embedded in the soil, its pull-out resistance was lower compared with the embedded condition, which further limited the ultimate bearing capacity.

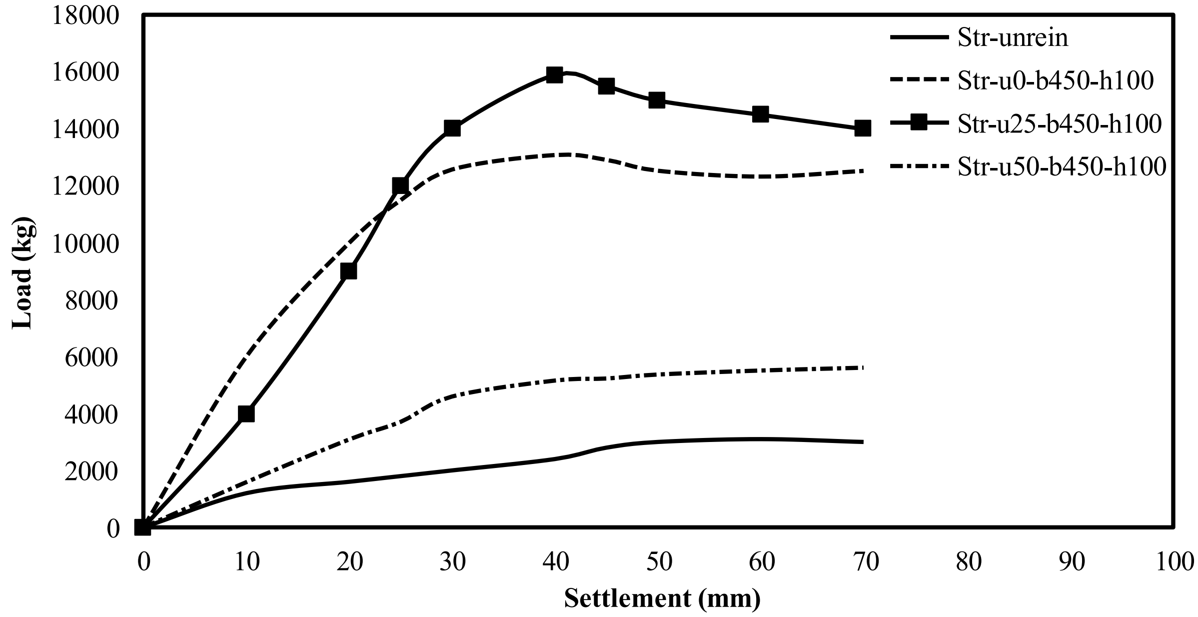

Fig. 9. Load-Settlement curves of strip footings with different embedment depths (u/B)

When the mattress was placed deeper (u/B = 0.5), the confinement mechanism became less effective. Although the reinforced soil bed continued to exhibit higher strength than the unreinforced case, the IF decreased substantially compared with u/B = 0.25. This reduction can be attributed to the limited overlap between the stress bulb of the footing and the reinforcement zone at greater embedment depths. This behavior is explained by the fact that at greater embedment depths, a significant portion of the WPB mattress is located outside the active stress bulb beneath the footing, thereby reducing the soil–reinforcement interaction and limiting the ability of the mattress to effectively confine the surrounding soil. As a result, the initial stiffness improvement dropped to approximately 20–25% above the unreinforced case, and the bearing capacity gains at serviceability settlements were modest.

The I_f curves (Fig. 10) provide additional insights. For u/B = 0.25, the I_f values increased sharply with settlement, reaching more than three at s/B = 0.1, and nearly four at larger settlements. In contrast, the I_f for u/B = 0 grew more gradually, while for u/B = 0.5 the curve flattened beyond s/B = 0.05, indicating limited contribution of the mattress to settlement resistance at greater embedment depths.

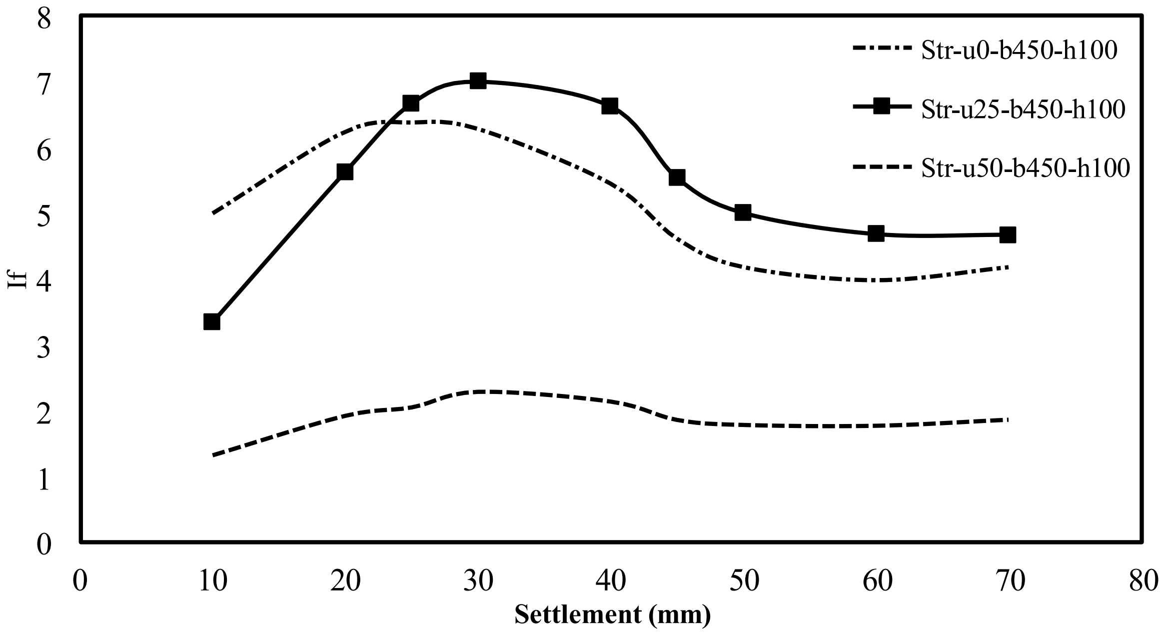

Fig. 10. I$_f$–Settlement curves for varying embedment depths (u/B)

When the mattress was placed deeper (u/B = 0.5), the reinforcement efficiency diminished. Although confinement was still provided, the greater depth caused the overlying soil to deform before the reinforcement could be fully mobilized, which explains the lower initial stiffness and reduced resistance at small settlements observed in this study. As a result, the gains at serviceability settlements were modest. In previous investigations, the optimum embedment depths have typically been reported in the range of 0.2–0.4B [6, 7].

The I$_f$–settlement response of WPB-reinforced footings does not follow a single monotonic trend across the entire deformation range; instead, the curves typically exhibit three stages: a rapid mobilization at small normalized settlements, a peak near serviceability levels, and a gradual softening at larger settlements.

3.2 Effect of Mattress Width (b/B)

The influence of mattress width on the behavior of footings is illustrated in Figures 11 (load-settlement) and 12 (I$_f$ – settlement). As expected, increasing b/B enhanced both the bearing capacity and the initial stiffness of the footing–soil system. At small mattress widths (b/B $\leq$ 2.2), the reinforcement effect was limited because the stress bulb beneath the footing extended beyond the lateral boundaries of the mattress, allowing shear stresses to dissipate into the surrounding unreinforced soil. With further increases in width, the WPB mattress was able to more effectively distribute, resulting in a steeper initial slope of the load–settlement curve and a substantial increase in the ultimate bearing capacity. The maximum benefits were observed in the range b/B $\approx$ 3.4–4.5, where the I$_f$ increased rapidly, reflecting the mattress's full engagement in resisting lateral deformation. At b/B = 4.5, the initial stiffness was nearly doubled compared with the unreinforced footing, underscoring the efficiency of the confinement mechanism in redistributing vertical stresses over a wider zone.

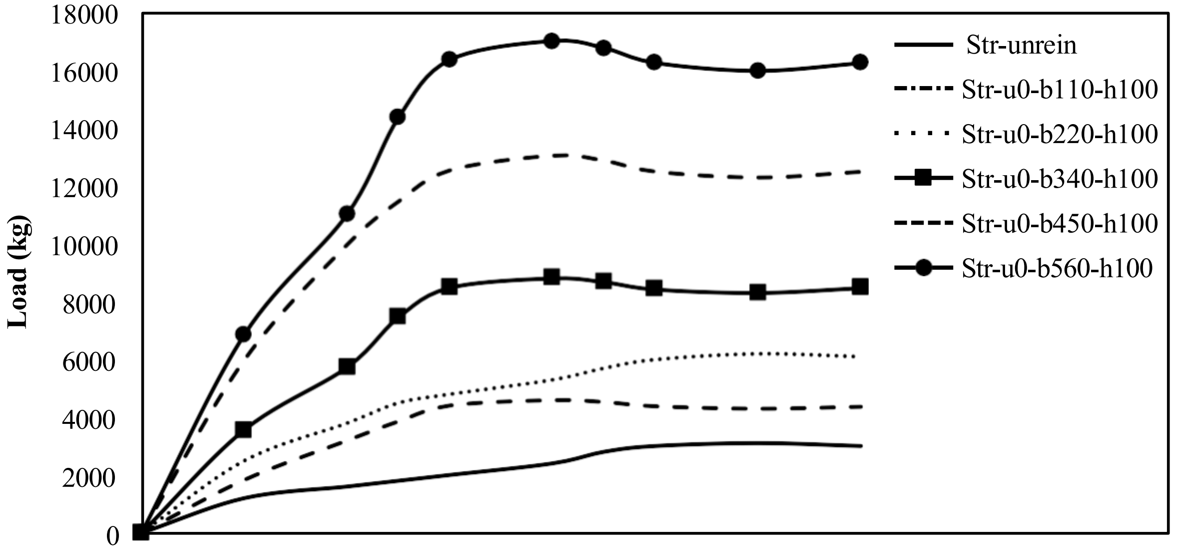

Fig. 11. Load-Settlement curves of strip footings with different mattress widths (b/B).

Beyond b/B = 4.5, the incremental gains diminished, and the I$_f$–settlement curves displayed clear signs of stabilization. For b/B $\geq$ 5.6, both the bearing capacity and initial stiffness approached a plateau, suggesting that the reinforcement width had already encompassed the full stress influence zone beneath the footing. In this condition, additional width does not contribute significantly to load transfer or settlement reduction, indicating that the reinforcement had reached its effective limit. Based on the previous studies the optimum widths in the range of 4–6B were reported [9]. The observed plateauing behavior highlights that reinforcement efficiency is not governed solely by mattress size but also by the extent of overlap with the active shear zone. Thus, while width expansion enhances the confinement effect up to a critical threshold, the design of WPB mattresses should focus on optimizing this parameter within the effective range rather than pursuing unnecessary increases.

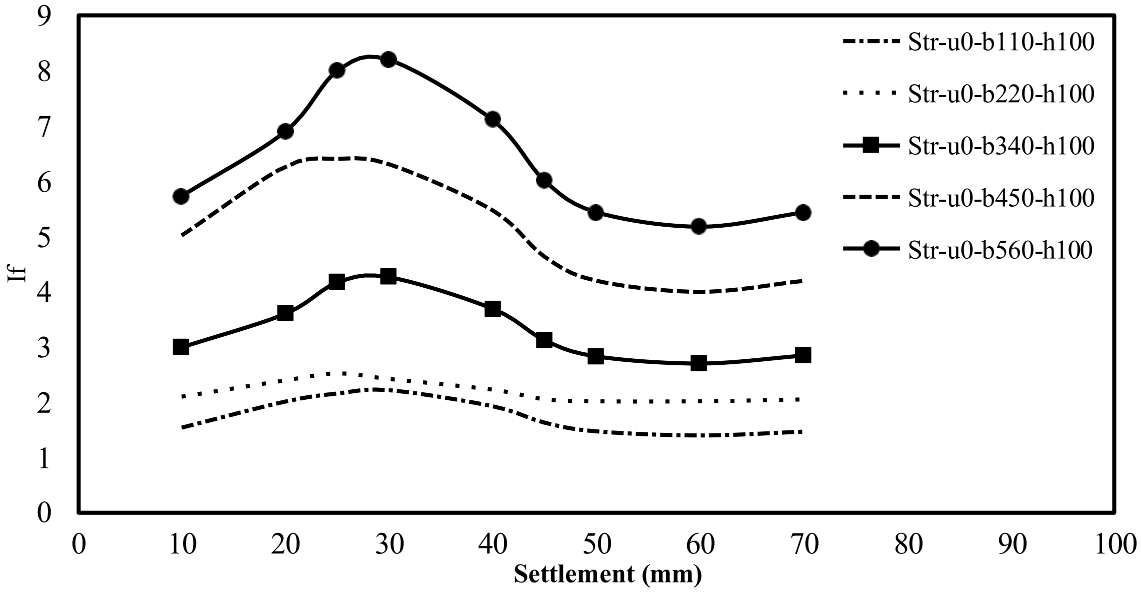

Fig. 12. I_f–Settlement curves for varying mattress widths (b/B).

4.3 Effect of Mattress Height (h/B)

Figures 13 and 14 demonstrate the influence of mattress height on the load–settlement response and improvement factors of strip footings. Increasing h/B markedly enhanced both the ultimate bearing capacity and the initial stiffness, confirming the critical role of vertical confinement. The most notable gains occurred between h/B = 0.25 and h/B = 1.0. In this range, the WPB mattress provided sufficient depth to confine the soil beneath the footing and to resist lateral displacement, leading to sharper load-settlement curves and higher I_f values. At h/B = 1.0, the initial stiffness was approximately 2.3 times greater than that of the unreinforced case, reflecting the effective mobilization of the confinement mechanism along the full depth of the mattress.

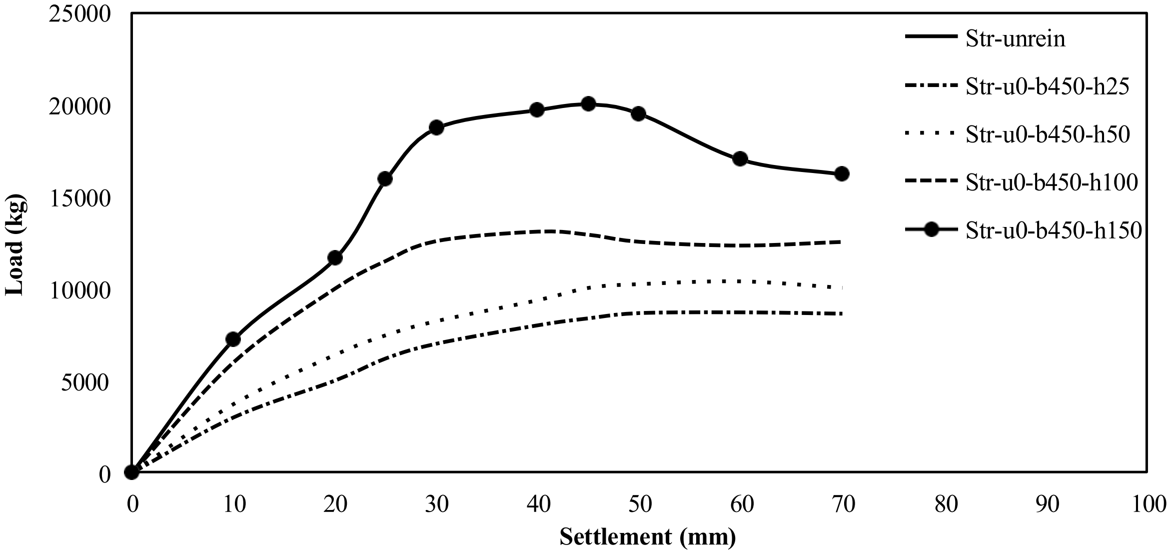

Fig. 13. Load-Settlement curves of strip footings with different mattress heights (h/B).

Beyond the initial gains, increasing mattress height continued to enhance footing performance. At h/B = 1.5, the load–settlement curve demonstrated a substantial increase in both stiffness and ultimate bearing capacity compared with h/B = 1.0, highlighting that additional depth of confinement was still effective in mobilizing resistance. This behavior suggests that the influence zone beneath the footing was not yet fully encompassed at h/B = 1.0, and extending the mattress height provided greater vertical confinement and improved load transfer. Nevertheless, the rate of improvement is expected to diminish once the reinforcement depth exceeds the active shear zone, at which point further increases would contribute only marginally.

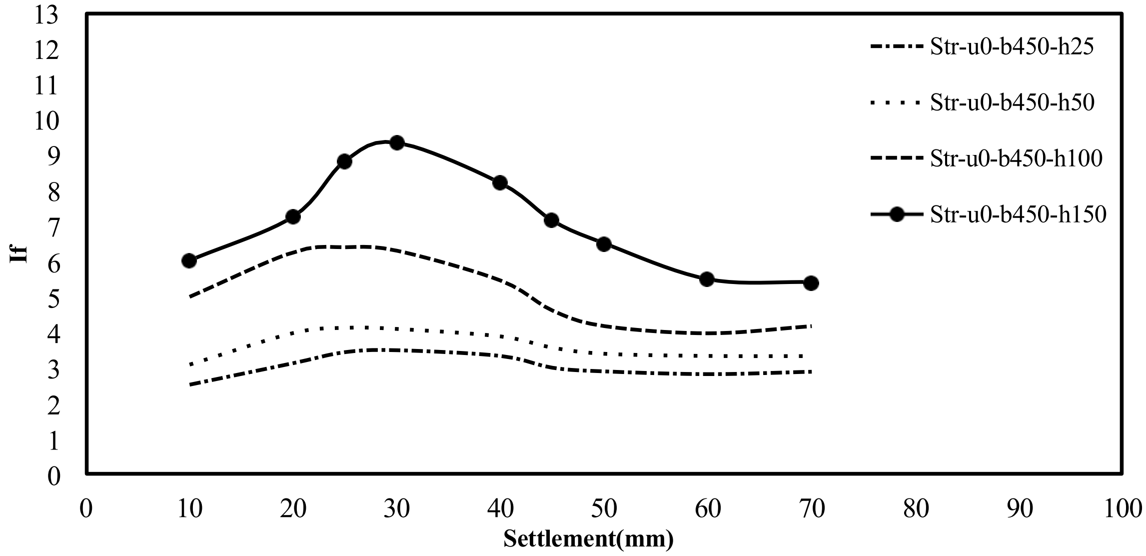

Fig. 14. I_f–Settlement curves for varying mattress heights (h/B).

The I_f–settlement curves further confirm the role of mattress height in improving foundation performance. Sharp gains in IF were evident at low to intermediate settlements across all reinforced cases, with the most pronounced enhancement observed for h/B = 1.5. Compared with h/B = 1.0, the h/B = 1.5 configuration provided a distinctly higher peak IF, indicating that additional vertical confinement was still effective in mobilizing resistance. This trend suggests that the influence zone beneath the footing was not yet fully stabilized at h/B = 1.0, and extending the reinforcement depth continued to yield tangible benefits. Nevertheless, as highlighted in earlier studies on geocell reinforcement, a plateau in reinforcing efficiency is expected once the mattress depth extends beyond the active shear zone [7, 20]. Collectively, the results demonstrate that mattress height plays a decisive role in the overall improvement, although practical design should balance these gains against constructability and material considerations.

4. Conclusion

This study evaluated the performance of strip footings on sand reinforced with waste plastic bottle (WPB) mattresses through a series of controlled small-scale physical model tests. The effects of embedment depth (u/B), mattress width (b/B), and mattress height (h/B) on load–settlement response and improvement factor (IF) were systematically investigated. Based on the findings, the following conclusions can be drawn:

- **Effect of embedment depth (u/B):** Reinforcement improved both stiffness and bearing capacity at all embedment depths. The best performance was obtained at an intermediate depth (u/B ≈ 0.25), where the reinforcement overlapped effectively with the active stress zone. At u/B = 0, improvements were evident but limited due to reduced pull-out resistance and concentration of shear stresses beneath the footing. At u/B = 0.5, the reinforcement was mobilized only after deformation of the overlying soil, resulting in lower efficiency.

- **Effect of mattress width (b/B):** Increasing mattress width consistently enhanced footing performance across the entire test range. The bearing capacity and I_f improved markedly with wider reinforcements, and at b/B = 5.6, the performance surpassed that of b/B = 4.5. This indicates that, within the range tested, the effective influence zone of the footing had not yet been fully encompassed, and wider mattresses continued to provide tangible benefits.
- **Effect of mattress height (h/B):** Larger mattress heights significantly increased stiffness and bearing capacity. While substantial gains were achieved up to h/B = 1.0, extending the height to h/B = 1.5 resulted in a distinct further improvement, with higher stiffness and ultimate capacity than h/B = 1.0. This shows that the active shear zone was not yet fully engaged at h/B = 1.0 and that additional confinement at h/B = 1.5 was still effective in mobilizing resistance.

The results of this study demonstrate that WPB mattresses can deliver substantial enhancements in the performance of strip footings on sand. Both bearing capacity and initial stiffness were significantly improved, with reinforcement efficiency governed by the interaction between the stress distribution beneath the footing and the geometry of the mattress. Optimum behavior was observed at intermediate embedment depths, while increases in mattress width and height beyond the expected limits continued to provide measurable benefits within the tested range. These findings confirm the ability of WPB mattresses to act as effective confinement systems, enhancing load transfer and reducing settlement in shallow foundations. Beyond their mechanical performance, WPB mattresses also represent a sustainable ground improvement technique. By reusing non-biodegradable plastic bottles without the need for energy-intensive processing, this method offers an environmentally responsible and cost-effective alternative to conventional geosynthetics. Integrating structural efficiency with waste reduction, WPB mattresses present a practical pathway toward sustainable and resilient foundation engineering.

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