Evaluation on Use of Waste Plastic for Soil Stabilization: A Review

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Abstract: Plastic has become an integral part of daily life; however, its widespread use has created significant environmental challenges due to improper disposal. One effective and sustainable approach to managing plastic waste is its use in soil stabilization. This paper provides a comprehensive review of the use of waste plastic bottle fibers for reinforcing soils. It examines the effectiveness of plastic as a soil reinforcement material and suggests suitable fiber dimensions and proportions for optimal performance. The study highlights that waste plastic bottles can be efficiently recycled for soil stabilization applications by considering key soil properties such as optimum moisture content, maximum dry density, California Bearing Ratio (CBR), and unconfined compressive strength (UCS).

Keywords: Plastic waste, stabilization, black cotton soil

I. Introduction

Buildings in the modern world require sufficient strength, durability, and freedom from cracks or defects. The stability of the soil beneath a structure is crucial for supporting heavy loads safely. Since soil serves as the foundation for all construction, understanding its properties and the factors influencing its behaviour is essential [1]. The foundation transfers the superstructure's weight to the underlying soil in a safe and sustainable manner. However, weak soils are often used in construction, reducing bearing capacity and causing excessive settlement. This can lead to structural damage, decreased performance, and diminished durability [2].Soil stabilization techniques provide effective solutions to these challenges. Soil stabilization, also referred to as soil improvement, involves enhancing the engineering properties of soil and reducing its shrink-swell behaviour, thereby increasing its load-bearing capacity [3]. Historical civilizations, such as the Chinese, Romans, and Incas, applied various soil-strengthening methods, some of which remain effective today, with structures and roads still standing [4]. Modern stabilization methods include mechanical, chemical, polymer, and plastic-based techniques. While widely used in construction, many of these methods are not environmentally sustainable [5].Environmental concerns, particularly related to waste management, are growing globally. Plastic waste represents a significant portion of solid waste, accounting for 12.3% of total waste, largely originating from discarded Polyethylene Terephthalate (PET) bottles [6]. In the United States alone, 35 billion plastic bottles are discarded annually [7], contributing to more than 32.5 million tons of plastic waste, or 12.8% of all municipal solid waste [8]. The International Bottled Water Association reported that plastic usage for bottled water has increased by 500% over the past decade, with more than 1.5 million tons used annually [9]. Despite this rise in production, large quantities of plastic waste are incinerated each year, contributing to climate change and global warming. Plastics are widely used across numerous applications due to their low density, ease of handling, chemical resistance, mechanical strength, thermal and electrical insulating properties, and low cost. Manufacturing and service industries also generate significant quantities of plastic waste. Proper disposal of solid waste, particularly PET, is a critical environmental challenge; PET constitutes 9.2% of all plastic waste [10]. In 2015, approximately 5,971 million pounds of PET bottles were introduced into the U.S. economy [11]. PET bottles are preferred over glass for water storage due to their lightweight and transportable nature [12]. In the UK, 3 million tons of plastic were used and discarded in 2001, with only 7% recycled and the remainder burned or land filled [13].A practical solution to both environmental concerns and soil improvement is fibre-reinforced soil (FRS). Soil reinforcement involves enhancing soil engineering properties, such as shear strength and bearing capacity, by incorporating fibres, strips, geogrids or other materials. Using discarded plastic bottles as fibre material offers an economical and environmentally friendly solution. This paper presents a comprehensive review of studies on soil reinforcement with waste plastic bottles, analysing the ideal fibre dimensions, percentages, and overall effectiveness for improving soil properties.

II. Literature Review

(Shelema Amena, 2022) conducted research on expansive clay soil using the soil classification system developed by the American Association of State Highway and Transportation Officials (AASHTO). In geotechnical laboratory tests, plastic strips of various sizes were added at proportions of 0%, 0.25%, 0.5%, 1%, 1.5%, and 2%. The study found that increasing the percentage of plastic waste strips led to reductions in swelling percentage and compaction parameters. CBR values increased with higher plastic strip content, and unconfined compressive strength reached its highest value at 0.5% plastic strip addition before slightly decreasing. Adding plastic strips enhanced soil cohesion up to 1.5%. The study recommends using plastic waste in subgrade road construction. [14]

(Hussein Jalal Aswad Hassan et al., 2021) demonstrated through CBR test results that incorporating plastic fibres into clayey soils improves their strength and deformation characteristics. The greatest improvement occurred at 4% fibre content for fibre lengths of 1.0 cm and 2.0 cm, yielding CBR increases ranging from 185% to 150% for polypropylene (PP) and polyethylene (PE), respectively. At 4% fiber content, the resilient modulus of PE increased by 120%. [15]

(Hassan Biu SANI, 2021) reported that adding lime sludge reduces the free swell index of clay to zero. With the optimal amount of lime sludge, the clay becomes non-plastic, and its plastic limits decrease. When both additives—plastic bottle waste (0.25%, 0.5%, 0.75%, and 1.0%) and lime sludge (3%, 6%, 9%, and 12%)—were introduced, compaction tests showed an increase in optimum moisture content (OMC) and a reduction in maximum dry density (MDD). Unconfined compressive strength tests revealed a significant increase in shear strength when the optimal amount of the additives was applied, either individually or in combination. [16]

(Ahmed ELTAYEB et al., 2021) investigated a mechanical stabilization method using shredded plastic water bottle waste with a length of 1.0 cm and width of 2.0–3.0 mm. Two clayey soil types were selected based on their plasticity indices. Initial soil properties were determined using ASTM standard procedures. The plastic bottles were cut into small pieces and mixed with the soils in six ratios—1.0%, 1.5%, 2.0%, 2.5%, and 3.0%—by dry weight. The soil–plastic mixtures were subjected to standard compaction and unconfined compression tests. Results showed that adding shredded plastic decreased both maximum dry density and optimum moisture content, while significantly increasing unconfined compressive strength. However, the failure strain decreased with plastic addition. [17]

(P. R. K. Chakravarthy et al., 2020) mixed various proportions of raw plastic—5%, 10%, 15%, 20%, and 25%—into clayey soil. The optimal moisture content dropped by 8% at 20% plastic content in the natural soil sample. Cohesion and unconfined compressive strength increased by 70% at 20%, and dry density rose by 5% at the same percentage. The study recommends a 20% raw plastic content for low-plastic clay. [18]

(Dinis Gardete et al., 2020) used specific plastic waste crushed plastic bottles and shredded packaging labels—for soil stabilization. Shredded package labels (WA), with over 50% passing through sieve No. 200, were added to a reddish clay soil. For a grey shale soil containing 25% passing through sieve No. 200, ground plastic bottles (WB) were used. CBR values increased by nearly 20% compared to the untreated soil. The optimal results were obtained with 1% WA and 2% WB additions. [19]

(Rebecca Belay Kassa et al., 2020) investigated the stabilization and improvement of expansive clay soil using plastic bottle strips. Three strip sizes—5 mm × 7.5 mm, 10 mm × 15 mm, and 15 mm × 20 mm—were tested at three mixing proportions of 0.5%, 1%, and 2% by weight. The greatest reduction in OMC (31%) occurred with the 5 × 7.5 mm strip size at 2% plastic content. The same combination also resulted in a 30% reduction in swelling. For the strip size of 15 × 20 mm at 0.5%, the highest cohesion (C = 8.980 kPa) and angle of internal friction (ϕ = 62.67°) were recorded, corresponding to improvements of 57% and 26%, respectively. With a 15 × 20 mm strip at 1% content, the CBR value reached 3.23, representing a 104% increase. [20]
(R. Saravanan et al., 2020) presented results from stabilizing and reinforcing clay soil using waste synthetic strips. These strips were prepared in three aspect ratios—8 × 8 mm, 8 × 16 mm, and 8 × 24 mm—and mixed with the soil in proportions of 0.5%, 1%, and 1.5% by weight. The best compaction result (26% improvement) was achieved using the 8 × 16 mm strip size at 0.5% content. In UCS testing, the maximum strength recorded was 0.391 N/mm², representing a 56% increase. The CBR value improved by 107%, leading to reduced pavement thickness and cost savings. As plastic strips have a lower density than soil particles, the maximum dry density decreased as the strip content increased. [21]

1.1 CBR vs Plastic Content

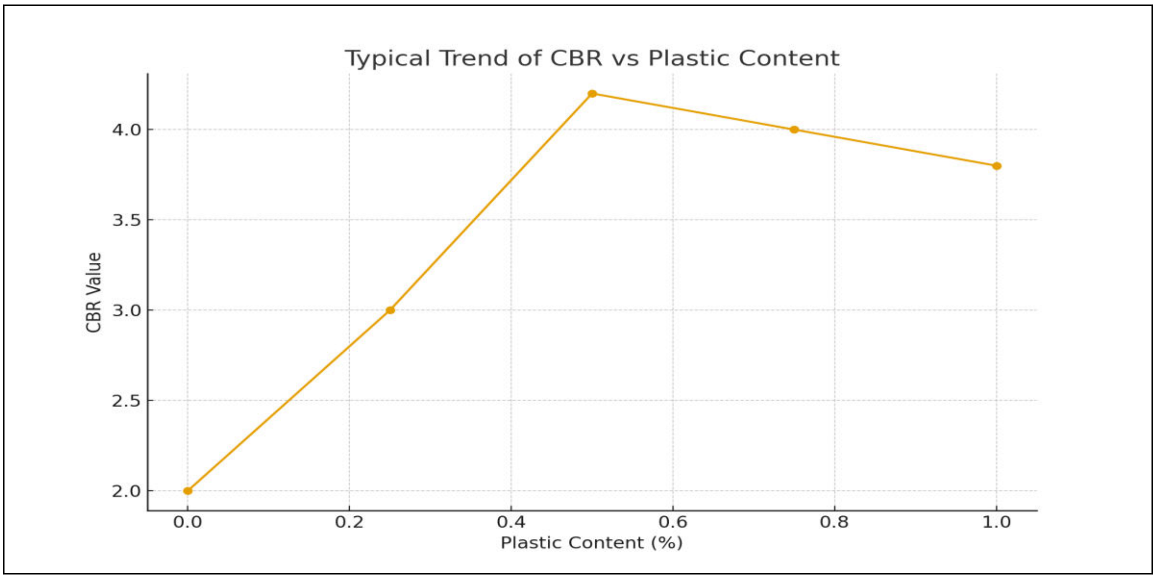

Figure 1. Shows a typical increase in CBR value up to an optimum plastic content (0.5–0.75%)

1.2 Maximum Dry Density vs Plastic Content

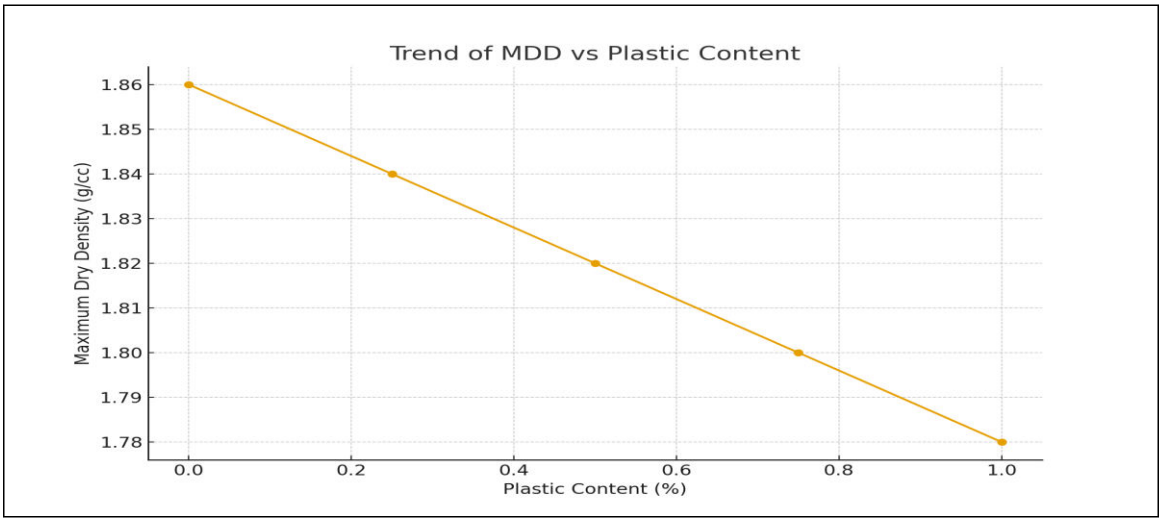

Figure 2. Demonstrates a decreasing MDD trend with increasing plastic content due to lower density of plastic fibers

1.3 Optimum Moisture Content vs Plastic Content

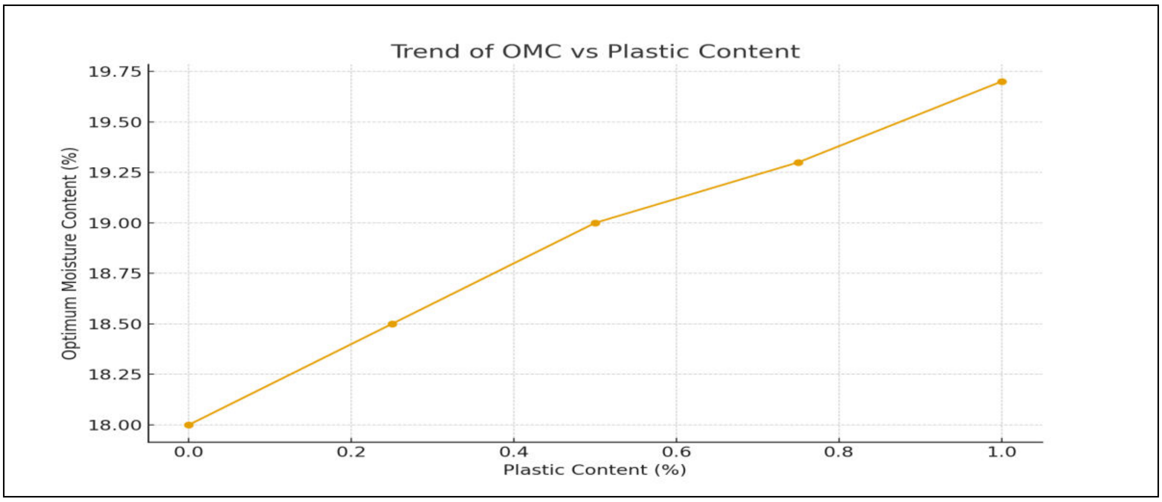

Figure 3. Shows the typical increase in OMC as plastic content increases

Table 1: Interpretation from graph above

Parameter	Behavior	Reason	Typical Optimum
CBR	Increases then decreases	Improved interlock and ductility	0.5–1.0%
MDD	Decreases	Low density of plastic fibers	—
OMC	Increases	Higher void ratio due to fibers	—

(K. D. Mayee et al., 2020) prepared soil specimens by mixing different proportions of leftover plastic strips with a two-aspect ratio. Strips measuring 2 cm × 1 cm were added at 0%, 0.2%, 0.4%, and 0.6% of the dry soil weight. The study concluded that the highest CBR value was achieved at 0.4% plastic content. [22]

(Mohd Furkhan et al., 2019) conducted CBR tests on red soil, black cotton soil, and loamy soil by adding plastic strips at 0.7% and 0.5% proportions. The results showed improved soil strength, with bearing ratios of 2.9 for red soil and 3.3 for black cotton soil. Loamy soil also showed enhanced strength with a 0.7% plastic addition, achieving a bearing ratio of 2.5. The study emphasized that using plastic waste for soil stabilization is cost-effective and low risk, making it an efficient recycling method. [23]

(Hotti et al., 2019) examined the influence of waste plastic bottle granules on the index properties of black cotton soil by stabilizing it with 2%, 4%, 6%, and 8% granules by soil weight. Tests conducted included compaction characteristics, differential free swell, and Atterberg limits. The findings confirmed that black cotton soil is inherently weak, and adding plastic granules enhances its stability, reduces swelling, and improves bearing capacity. All tests showed an overall enhancement in the soil's properties. [24]

(Phonsa and Singh, 2019) used stone dust and plastic bottle fibres as waste-based stabilizing materials for clayey subgrade soil. Plastic strips were added at 0.4%, 0.8%, 1.2%, 1.6%, and 2.0%, while stone dust was included at 2%, 4%, 6%, 7%, 8%, 10%, 12%, 16%, and 20%. The mixtures were analysed for their effects on maximum dry density, CBR, and optimum moisture content. The study revealed that adding stone dust and plastic strips increased maximum dry density, reduced optimum moisture content, and significantly enhanced CBR values. [25]

(Manickam et al., 2019) evaluated the stabilization of clay and red soils using plastic bottle fibres. Waste plastic fibres (0.25%, 0.50%, 0.75%, 1.00%, and 1.25% at 10 mm length) and quarry dust (10%, 20%, 30%, 40%, and 50%) were incorporated into the soil. Results showed that waste plastic fibres substantially improved soil strength, and the combination of quarry dust and plastic fibres further enhanced compressive strength. The study concluded that these materials could serve as effective stabilizing agents for pavement construction. [26]

(Solanki and Bhattarai, 2019) focused on evaluating the properties of stabilized soil produced by melting post-consumer polyethylene terephthalate (PET) bottles. Five soil–plastic composite mixes were prepared with PET contents of 20%, 25%, 30%, 45%, and 50%. Tests conducted included three-dimensional swelling, moisture susceptibility, and compressive strength. Compared to untreated soil, the PET-stabilized specimens demonstrated improved compressive strength. Among all mixes, the 25% PET blend yielded the highest strength and enhanced both moisture resistance and swell resistance. PET contents of 25% or higher were found to significantly reduce 3D swelling. Moisture and density results also showed that the 25% PET composite offered the strongest and densest structure. [27]

(Jin et al., 2019) used waste plastic fibres to reinforce flat sand and performed multiple direct shear tests to determine the effectiveness of plastic waste chips in improving engineering properties. PET fibres with diameters of 2 mm, 4.75 mm, and 5.6 mm were randomly mixed into the soil at proportions ranging from 2.5% to 20% of dry soil weight. The addition of PET fibres noticeably increased shear strength, cohesion, and friction angle. The greatest improvement in friction angle occurred with 5.6 mm fibres at 10% and 12.5% fibre content. [28]

(Gardete D et al., 2019) stabilized soil using fibres obtained from waste tires and plastic waste. Stabilization was carried out using 1%, 2%, and 3% of plastic and tire fibres, with the optimal content found to be between 0.5% and 1.5%. CBR values improved significantly: from 14% to 19% (a 36% increase) at 5.0 mm penetration and from 11% to 14% (a 27% increase) at 2.5 mm penetration when 1% plastic waste was added. [29]

(M. Sai et al., 2019) reported on randomly mixing plastic debris and granules with soil. Their results showed that adding plastic waste increased maximum dry density by 0.5%, improved bearing capacity by 1%, and enhanced compressive strength by 0.5% in UCS tests. [30]

(S. Peddaiah et al., 2018) investigated how plastic bottle strips affect the behaviour of silty sand by conducting compaction, direct shear, and CBR tests with different strip sizes, aspect ratios, and percentages. They concluded that soil type, plastic content, strip dimensions, and strip surface characteristics—such as smooth, plain, corrugated, or undulating—significantly influence soil reinforcement performance. The best improvement in silty sand properties was achieved using 0.4% plastic content and strip dimensions of 15 mm × 15 mm. [31]

(Nader Hataf et al., 2018) examined the effects of chitosan concentration, curing time, and specimen moisture content, and explored the feasibility of using chitosan as an alternative soil stabilizer to conventional materials. Unconfined compressive strength tests and direct shear tests were conducted for mechanical assessment, while optical microscopy and moisture retention analyses were used for physical evaluation. The study concluded that chitosan could serve as an effective temporary stabilizer for wet soils. Additionally, the mechanical behaviour of chitosan-treated soils remained consistent across dry, optimum moisture, and saturated conditions. [32]

(Pal et al., 2018) investigated the stabilization of clayey alluvial soils using waste plastic bottle strips of various lengths and proportions by weight. Plastic bottles were cut into three sizes—1 × 1 cm, 2 × 1 cm, and 3 × 1 cm—and mixed with dry soil at 0.25%, 0.5%, and 0.75% by weight. Compaction and strength properties were evaluated. The researchers found that the maximum dry density of the plastic-reinforced soil increased with rising plastic strip content up to an optimal level, while optimum moisture content decreased as plastic content increased. The highest CBR value was obtained using 1 × 1 cm strips, and CBR continued to increase with higher plastic fibre percentages. [33]

(Mohammed et al., 2018) conducted laboratory triaxial and compaction tests using plastic bottle fibers measuring 5–10 mm in length. These fibers were added to the soil at proportions of 0.5%, 1%, 3%, 6%, and 15% by weight. The study found that increasing PET content resulted in a decrease in maximum dry density and cohesion (C). Based on the results, the researchers recommended using 1.5% PET bottle waste for effective soil stabilization. [34]

(Vinoth et al., 2018) incorporated waste plastic bottle fibres with dimensions of 20 × 3 × 0.5 mm into soil samples at proportions of 0.25%, 0.50%, 0.75%, and 1%. The results showed that adding these fibres enhanced both the CBR value and the overall stability of the soil. [35]

(N. Prakhash et al., 2018) carried out testing in Melakaraikatu near Amman Kovil in Thottiam, where soil was mixed with 0%, 2%, 4%, and 6% of randomly distributed plastic strips. The California Bearing Ratio (CBR) test was used to assess strength. The findings indicated that CBR values increased up to 4% plastic content, after which they began to decline as plastic content continued to rise. [36]

(Z. Sabzi, 2017) reviewed various materials—such as cement, lime, bitumen, fly ash, pozzolana, nano clay, expanded polystyrene geofoam, and agricultural waste products—that can be used to enhance the engineering properties of soft soils. The study emphasized that stabilized soil plays a crucial role in supporting sustainable development, which is a key national priority in Iran. [37]

(Karmacharya and Acharya, 2017) explored the feasibility of using discarded plastic bottles as soil reinforcement materials. Three soil samples were subjected to triaxial testing, with waste plastic fibres added in proportions ranging from 0.5% to 1.5% by dry soil weight. The results indicated that the inclusion of plastic waste fibres increased soil shear strength by 25% to 125%. [38]

(Alshkane, 2017) added waste plastic bottle fibres to sandy soil (passing sieve No. 4) in proportions of 1%, 2%, and 4% by dry weight, using fibres of 8 mm and 16 mm lengths. The study found that plastic fibres enhanced soil cohesion and internal friction angle. When equal proportions of long and short fibres were used, short fibres produced similar peak stress values but exhibited less ductility. With 1% fibre content, soil cohesion, bearing capacity, and stiffness improved, while settlement and compressibility decreased. [39]

(Habiba Afrin, 2017) discussed the increasing use of chemical additives to improve the strength, durability, and compaction characteristics of subgrade soils as technological and economic conditions advance. The study noted that more performance-based evaluations are needed to validate the effectiveness of stabilizing agents. Although several chemical compounds from the petrochemical industry are available, their potential in soil stabilization remains underexplored. Additionally, treatment methods such as spray-on and injection techniques require further study to determine their cost-effectiveness. The impact of climate change on stabilizer performance was also highlighted as an important factor for future soil stabilization strategies. [40]

(Mai et al., 2017) conducted laboratory tests—including specific gravity, sieve analysis, swell index, unconfined compressive strength, Proctor compaction, and CBR tests—on clayey subgrade soil samples measuring 10 × 1 mm. Plastic bottle strips were added at

1% and 2% by soil weight. The results showed that unconfined compressive strength increased by 70.8% with 1% fibres and by 115% with 2% fibres. Specific gravity, dry density, and optimum moisture content also increased with fibre content, and the free swell index rose as more fibres were added. [41]

(Gowtham and Sumathi, 2017) investigated expansive black cotton soil (high-plasticity clay) by adding PET fibres—passing through a 10 mm sieve—at contents of 0.5%, 1.0%, 1.5%, and 2.0%. Tests performed included Atterberg limits, compaction, swell index, CBR, and UCS. The results showed significant reductions in liquid limit, plastic limit, and plasticity index. Maximum dry density increased while optimum moisture content decreased with higher fibre content. Additionally, both CBR and unconfined compressive strength improved as PET fibre content increased. [42]

(Seyed Abolhasan Naeini et al., 2017) examined the strength behaviour of silty soil reinforced with randomly distributed plastic bottle chips using consolidated undrained (CU) triaxial tests. Plastic chips with fixed width and thickness but varying lengths (4 mm, 8 mm, and 12 mm) were added at proportions of 0.25%, 0.50%, 0.75%, 1.0%, and 1.25% by dry soil weight. The study concluded that both the length and content of plastic chips enhanced the cohesion and internal friction angle of the reinforced silty soil. [43]

(Endaryanta et al., 2017) evaluated the use of plastic waste as reinforcement for clay through unconfined compressive strength tests. Plastic waste pieces sized 1 × 1 inch and 1 × 0.5 inch were mixed with the soil. The results indicated that adding larger plastic pieces (1 × 1 cm) increased the unconfined compressive strength (qu) by 3% at 3% fibre content, while the internal friction angle (ϕ) also improved. Smaller plastic pieces (0.5 × 1 cm) increased soil friction by 2%. [44]

(Gangadhara et al., 2017) reinforced red soil—a low-compressibility silt—using leftover plastic bottle strips at percentages of 0%, 1%, 2%, and 3%. The study showed that the inclusion of plastic strips improved the engineering properties and overall strength of the red soil. [45]

(Deekonda Gowthami et al., 2017) presented laboratory investigations on the strength characteristics of reinforced expansive soil. Tests such as UCS, CBR, swell index, Atterberg limits, and compaction were performed using various reinforcement ratios to determine the optimal mix. Black cotton soil was blended with polypropylene fibres at contents of 0.5%, 1.0%, 1.5%, and 2.0% by weight. The test results were analyzed to evaluate the effectiveness of plastic fibre waste in improving the strength properties of expansive soils. [46]

(Arpitha G. C. et al., 2017) mixed soil with plastic strips produced from waste plastic materials and performed a series of California Bearing Ratio (CBR) tests using different strip lengths and percentages. The findings showed that, when added in suitable proportions, waste plastic strips improved the strength and deformation behaviour of subgrade soil. [47]

(Osman Gunaydin et al., 2016) reported that PET waste can be incorporated into soil up to 45% by weight. However, higher PET mixing ratios may cause problems in the fill soil. The study proposed that future research should include image analysis of thin sections after strength testing of the improved soil samples, which would provide valuable insights into the interaction between PET waste and soil failure surfaces. [48]

(Gangadhara et al., 2016) investigated the effects of adding shredded plastic strips to poorly graded sand. The study found that as the plastic content increased, shear strength parameters—including cohesion and internal friction angle—also improved. The addition of plastic fibres enhanced the shear stress–strain behaviour, producing higher peak stresses at lower strains. Footing load-bearing capacity increased with rising plastic content up to an optimal point, after which it decreased. [49]

(V. Mallikarjuna et al., 2016) conducted an experimental study using plastic waste as a stabilizer for black cotton soils in the Amaravathi region of Andhra Pradesh. Soil samples containing 2%, 4%, 6%, and 8% plastic strips were tested for CBR. The results showed that CBR values increased with up to 4% plastic content, after which they began to decline. [50]

(Harish C et al., 2016) conducted a study by chopping plastic bottles into thin strips and mixing them with soil in varying proportions. For the CBR test, plastic strips were added at 0.7% for red soil and 0.5% for black cotton soil. The study concluded that the bearing ratios increased with soil reinforcement, reaching 2.9 for red soil and 3.3 for black cotton soil. [51]

(Singh and Sonthwal, 2016) incorporated waste plastic bottle fibres of different sizes—25 × 5 mm, 35 × 10 mm, and 50 × 15 mm—into low-plasticity inorganic clay (CL) at proportions of 2%, 4%, and 6% by weight. The study observed a decrease in maximum dry density (MDD) and an increase in optimum moisture content (OMC) with increasing plastic content. CBR values improved with higher fibre content, with a maximum increase of 27.33% for 6% of 25 × 5 mm fibres, potentially reducing pavement thickness and overall construction costs. [52]

(Mahali and Sinha, 2015) reinforced subgrade soil using stone dust combined with PET strips from plastic water bottles. CBR tests were performed with fibre contents ranging from 0.25% to 2%. Results showed that adding PET strips increased subgrade strength, with maximum dry density rising and optimum moisture content decreasing as fiber content increased. The CBR value of reinforced soil increased up to 2.79 times that of plain soil. [53]

(Khan and Pachghare, 2015) added waste plastic fibers of dimensions 12 × 12 mm, 24 × 12 mm, and 36 × 12 mm to subgrade soil at proportions of 1%, 2%, 3%, 4%, 5%, and 6%. The study found that adding plastic fibres improved the soil's internal friction angle and increased maximum shear stress by 5% before declining. CBR values also increased with fibre content, while OMC and maximum dry unit weight decreased. The optimal fibre size was 36 × 12 mm. [54]

(Laskar and Pal, 2013) investigated the effect of waste plastic fibres on compaction and consolidation behaviour of local clay-rich sandy-silt soil. Fibers measuring 10 × 5 mm, 10 × 2.5 mm, and 10 × 1.25 mm were added at 0%, 0.25%, 0.50%, and 1% by dry weight. Compaction tests showed that maximum dry density decreased as fibre content increased, with an optimum moisture content of 17.10%. Increasing fiber content up to 0.50% reduced the compression index and coefficient of volume change. The study concluded that plastic fibres enhance soil strength and reduce settlement. [55]

(Paramkusam, 2013) investigated the reinforcement of red mud with waste plastic fibres. CBR and dry density tests were conducted on samples containing plastic fibres sized 4.75 mm to 20 mm at proportions of 0.5%, 1%, 2%, 3%, and 4% by weight of the soil. The study found that increasing fibre content improved both dry density and CBR up to 2%, beyond which no further improvements were observed. [56]

(Babu and Chouksey, 2011) incorporated used plastic bottles into sand and red soil as reinforcement. Fiber contents of 0.5%, 0.75%, and 1% were tested through triaxial compression (UCC & CU) and one-dimensional compression tests. Results indicated that the addition of plastic fibres significantly reduced soil compressibility while increasing its strength. [57]

(Anas Ashraf et al., 2011) performed plate load tests on soil reinforced with layers of plastic bottles filled with sand, with half-cut bottles positioned in the middle and one-third of the tank to examine the effect of waste plastic bottles on soil stabilization. The study showed that placing cut bottles at the center was most effective in increasing soil strength. When 0.6% plastic strips were mixed with the soil, the soaked CBR increased from 1.96 to 2.47 before decreasing at higher contents. [58]

(Consoli et al., 2002) studied the influence of waste plastic fibres on uniform fine sand using compression, tensile, and drained triaxial tests. Fibers up to 36 mm in length and 0.9% by weight were added. Results indicated that PET fibres enhanced both peak and ultimate soil strengths without significantly affecting the original stiffness of the soil. [59]

Table 2: Properties of Soil Reinforced with Different Waste Plastic Bottles Fibers Percentages

Fibers	Direct	CBR	Compaction	Compaction	UCS	Settlement	Reference
(%)	Shear %	%	OMC %	MDD %	%	%	
0.1	-	-	-	-	+12.4	-	[59]
0.25	-	+ (20 -35)	(-4.7) -(+16)	(-1.2) -(+0.6)	-	-	[33] [26]
0.4	-	+3	-38	+8	-	-	[25]
0.5	+(9.1-44.4)	+(6.7-130)	(-8.3) -(+25)	(-2.7) -(+1.5)	+(13-40)	-60	[16], [17] [18] [9] [19] [35] [33] [31]
0.8	-	+4.8	+6.1	+2.9	-	-	[29]
0.75	+43.9	+ (6.9-	- (8.8-16.6)	-0.6	-	-	[9] [23] [35]
		170)					[31]
1	+ (13-144)	+ (53-150)	(-17) -(+50)	(-9.2) -(+17)	+ (18-175)	-20	[14], [16] [17] [9] [19] [20] [21] [22] [24] [35] [34] [33] [31]
1.25	-	-	-33.3	-32	+30.7	-	[31]
1.5	+ (76-189)	+120	(-29) -(+5)	(-1.7) -(+1)	+ (23-66)	-77	[16] [17] [19] [35] [33]
2	+ (9.4-167)	+ (1.5-36)	(-46) -(+20)	(-17) -(+3.3)	+ (6.1-28)	-30	[15], [16] [19] [21] [22] [24] [35] [32]
3	+21.7	-	(-6.5) -(+50)	- (25-11)	-	-50	[17] [21] [24]
4	+ (27.3-32)	+ (1.3-16.6)	- (27-8)	+ (28-4)	+18.1	-	[15] [22] [24] [32]
5	56.9		-10.5	-31	-	-	[24]
6	+52.5	+ (1-37.5)	(-36) -(+72)	(-35) -(+4.7)	+20.3	-	[15] [17] [24] [32]
8	-	+18.8	-36.4	+1.3	+8.8	-	[32]
9	-	-	+66.6	-16.6	-	-	[34]
12	-	-	+77.7	-19	-	-	[34]
15	-	-	+94.4	-23.8	-	-	[34]

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