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Experimental Study on Soil Stabilization Using Waste Plastic Bottle Strips

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Abstract: ***Soil stabilization is commonly adopted when locally available soil does not satisfy engineering requirements for foundations, embankments, pavements, or fills. At the same time, the disposal of non-biodegradable plastic waste presents an environmental challenge. This study investigates the use of waste plastic bottle strips as a randomly distributed soil additive. Plastic bottles were cut into approximately 15 mm × 15 mm strips and mixed with a locally collected soil at selected percentages. The soil was characterized by sieve analysis and specific-gravity testing, and Standard Proctor compaction tests were conducted on virgin soil and on soil containing 0.6%, 0.8%, and 1.0% plastic strips. The soil was reported as poorly graded sand with a specific gravity of 2.68. Maximum dry density increased from 1.80 g/cm³ for virgin soil to 1.83 g/cm³ at 0.6% plastic and 1.90 g/cm³ at 0.8%, then decreased to 1.87 g/cm³ at 1.0%. The corresponding optimum moisture contents were 14%, 16%, 14%, and 14%. The reported optimum dosage is therefore 0.8%, producing an approximately 5.6% increase in MDD relative to untreated soil. The results indicate that waste plastic strips can influence the compaction characteristics of sandy soil and may offer a useful reuse route for discarded plastic.***

Index Terms: soil stabilization, waste plastic, plastic bottle strips, Standard Proctor test, maximum dry density, optimum moisture content.

I. Introduction

Soil is one of the most extensively used materials in civil engineering. It forms the supporting medium for foundations and is widely used in pavement subgrades, embankments, earth fills, and other geotechnical works. The performance of a structure depends substantially on the strength, density, compressibility, and moisture response of the supporting soil. When soil available at a construction site is inadequate to carry

the intended load or meet serviceability requirements, its engineering properties may be modified through stabilization.

Conventional soil-stabilization methods include cementation, bituminous treatment, chemical additives, silicification, electrochemical processes, thermal treatment, and other techniques. Although these methods may be effective, the use of commercial additives can increase cost and may introduce additional environmental impacts. The source study therefore considers waste plastic as an alternative additive. The approach is especially relevant because plastic waste is non-biodegradable and can accumulate in drainage systems, open land, and disposal sites when it is not managed properly.

Waste plastic can be reused in civil-engineering applications as discrete reinforcement. Plastic strips introduced into soil may interact with particles through friction and mechanical interlocking and can influence compaction and strength. The source report identifies applications such as pavement base or subbase improvement, embankment reinforcement, and reduction of foundation settlement. It also proposes plastic as a comparatively inexpensive substitute for certain conventional admixtures where technically appropriate.

The objectives of the present investigation are threefold: to use plastic waste as a stabilizing admixture, to determine the maximum dry density of soil with different percentages of plastic strips, and to identify the percentage that gives the most favorable compaction response. The study is confined to the experimental information reported in the source document and does not extend the findings beyond the tested material and procedures.

II. Literature Review

Earlier research cited in the source document indicates that waste plastic can modify several geotechnical properties, although the direction and magnitude of the effect depend on soil type, plastic form, percentage, and testing method. Choudhary et al. investigated reclaimed HDPE strips in subgrade soil and reported improvement in CBR behavior, supporting the potential of plastic strips as reinforcement for highway applications [1]. Patidar, Kaur, and Poweth reviewed the use of waste plastic for improving geotechnical properties and highlighted its potential in soil improvement [2].

Chebet and Kalumba examined strips cut from polythene bags and attributed improved strength to tensile stresses mobilized in the plastic reinforcement [3]. Nagle et al. reported increases in MDD and CBR and improvements in load-bearing and settlement behavior for several soils reinforced with waste plastic [4]. Dhatrak and Konmare investigated randomly oriented plastic waste for flexible-pavement applications and described the

technique as an economical and environmentally beneficial alternative for subgrade improvement [5].

Other studies cited in the report show that plastic reinforcement does not produce a single universal trend. Fauzi et al. reported increased MDD and CBR when cut HDPE and crushed glass were added to subgrade soil [6]. Research on plastic fibers in clayey and expansive soils reported changes in OMC, MDD, CBR, UCS, shear strength, cohesion, and friction angle depending on fiber content and geometry [7]-[10]. Work on PET-soil composites and combined quarry-dust/plastic systems similarly showed that suitable proportions can improve selected strength or density characteristics [11], [12]. These findings support the need to determine an optimum plastic content experimentally for each soil-plastic combination.

III. Materials and Methodology

3.1 Waste Plastic Strips

The reinforcing material used in the investigation was obtained from discarded plastic bottles. The bottles were cut into small strips of approximately 15 mm × 15 mm. These discrete pieces were mixed with the soil in different percentages by weight. The study focuses on the use of raw plastic strips rather than melted plastic or chemical modification, keeping the preparation method simple and directly linked to reuse of post-consumer plastic waste.

3.2 Soil Sample

The soil sample was collected from the college ground at a depth of approximately 2 m below the ground surface. It was described as red-orange in color. The preliminary characterization included sieve analysis, specific-gravity determination, and Standard Proctor compaction. The particle-size distribution data showed that 100% of the soil passed the 1 mm sieve, 71.15% passed the 425 µm sieve, 7.8% passed the 150 µm sieve, and 1.35% passed the 75 µm sieve. Based on the reported gradation curve, the soil was classified as poorly graded sandy soil. The specific gravity determined using a pycnometer was 2.68.

3.3 Experimental Procedure

The methodology consisted of collecting the soil, conducting preliminary tests, and then performing Standard Proctor compaction tests after adding different percentages of plastic strips. The documented plastic contents used in the detailed experimental tables were 0.6%, 0.8%, and 1.0%, along with virgin soil as the 0% control. The source methodology diagram follows the sequence: soil collection, preliminary testing by sieve analysis, specific gravity and Proctor test, determination of MDD at the selected plastic percentages, and final conclusion.

For the Standard Proctor test, the reported mould diameter was 10 cm, height 12.7 cm, mould weight 3230 g, and mould volume 981.25 cm³. Compaction was performed over a range of moisture contents to establish the dry-density curve for each mixture. The MDD and OMC were then obtained from the peak of the respective compaction curve.

IV. Experimental Investigation

4.1 Virgin Soil

For virgin soil, the dry density increased from 1.53 g/cm³ at 6% moisture content to 1.61 g/cm³ at 8%, 1.69 g/cm³ at 10%, 1.76 g/cm³ at 12%, and 1.80 g/cm³ at 14%. At 16% moisture content the dry density decreased to 1.76 g/cm³. The source therefore reports an OMC of 14% and an MDD of 1.80 g/cm³ for the untreated soil.

4.2 Soil with 0.6% Plastic Strips

With 0.6% plastic strips, the dry density values reported for water contents of 6%, 8%, 10%, 12%, 14%, 16%, and 18% were 1.54, 1.59, 1.67, 1.74, 1.79, 1.83, and 1.70 g/cm³, respectively. The peak occurs at 16% water content, giving an MDD of 1.83 g/cm³ and an OMC of 16%.

4.3 Soil with 0.8% Plastic Strips

For the 0.8% mixture, the corresponding dry densities were 1.21, 1.60, 1.79, 1.87, 1.90, 1.80, and 1.52 g/cm³ at water contents from 6% to 18%. The maximum value of 1.90 g/cm³ occurred at 14% moisture content. Thus, the reported OMC is 14% and the MDD is 1.90 g/cm³.

4.4 Soil with 1.0% Plastic Strips

At 1.0% plastic, dry density was reported as 1.13, 1.29, 1.50, 1.78, 1.87, 1.79, and 1.60 g/cm³ at 6%, 8%, 10%, 12%, 14%, 16%, and 18% water content, respectively. The maximum dry density was 1.87 g/cm³ at an OMC of 14%. The detailed table and section heading identify this test as the 1.0% series even though the figure caption in the source mistakenly repeats 0.8%.

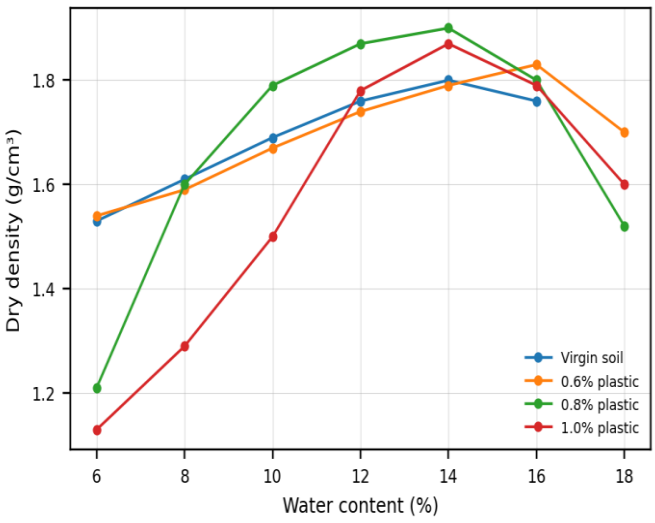

Figure 1. Compaction curves reconstructed from the numerical values reported in the source tables.

Table 1: Compaction results for virgin and plastic-reinforced soil.

Plastic (%)	OMC (%)	MDD (g/cm³)
0.0	14	1.80
0.6	16	1.83
0.8	14	1.90
1.0	14	1.87

V. Results and Discussion

The comparison of the maximum dry densities shows a clear optimum within the reported test series. Virgin soil had an MDD of 1.80 g/cm³. The value increased slightly to 1.83 g/cm³ with 0.6% plastic and then reached the highest recorded value, 1.90 g/cm³, when 0.8% plastic strips were used. Increasing the plastic content further to 1.0% reduced the MDD to 1.87 g/cm³. The source therefore fixes the optimum plastic-strip percentage at 0.8%.

The improvement at the optimum dosage is 0.10 g/cm³ compared with the untreated soil. Expressed as a percentage of the virgin-soil MDD, the increase is approximately 5.6%. This change is important in the context of the reported experiment because dry density is a primary compaction parameter and reflects how densely the soil mass can be arranged under the applied compactive effort. A denser compacted state may be beneficial for certain earthwork applications, although density alone does not establish complete structural performance.

The trend is non-linear. A small quantity of plastic may assist rearrangement or interlocking within the soil matrix, whereas a higher amount may introduce more low-density plastic surfaces and interfere with soil-to-soil contact. The test series suggests that the beneficial effect reaches a peak near 0.8% for the particular soil and strip geometry used. This observation is consistent with the literature reviewed in the source, where the effectiveness of plastic reinforcement depends on concentration, length, width, gradation, particle size, and soil type [3].

The optimum moisture content does not follow the same monotonic pattern. The virgin soil, 0.8% mixture, and 1.0% mixture all show an OMC of 14%, whereas the 0.6% mixture shows an OMC of 16%. Therefore, the increase in MDD cannot be interpreted simply as a progressive change in water requirement. The combined effects of particle packing, plastic distribution, local friction, and the low specific gravity of plastic may influence the shape and peak position of each compaction curve.

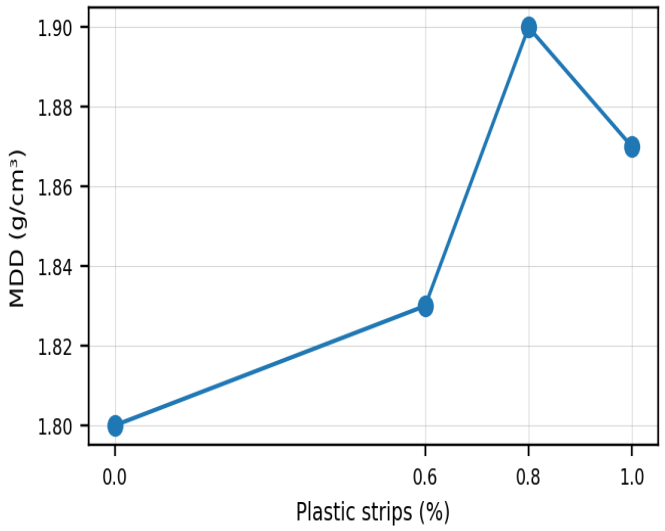

Figure 2. Variation of maximum dry density with plastic-strip content.

5.1 Sustainability and Practical Relevance

From an environmental perspective, using waste plastic in soil stabilization provides a potential secondary use for a material that otherwise persists for long periods in the environment. The method described in the source requires only collection, cutting, proportioning, mixing, and compaction. This simplicity could make it attractive in situations where a suitable local application is confirmed by engineering tests. The source also notes that reuse of plastic strips may reduce dependence on relatively expensive stabilizing materials such as cement or lime.

However, the experimental evidence reported here is specifically related to sieve analysis, specific gravity, and Standard Proctor compaction. The source literature discusses CBR, UCS, direct shear, triaxial behavior, and other strength parameters, but those tests were not reported for the present soil-plastic specimens. Consequently, the measured increase in MDD should not be treated as direct proof of improved CBR, shear strength, durability, or long-term pavement performance for this particular material.

5.2 Limitations of the Reported Dataset

The source conclusion mentions plastic percentages of 0.4%, 0.6%, 0.8%, and 1.0%, but the detailed methodology and Proctor tables provide numerical results only for 0%, 0.6%, 0.8%, and 1.0%. No 0.4% compaction dataset is included, so this paper does not create or infer one. The results and figures are therefore restricted to the documented test series. In addition, repeated-test variability, strip-thickness information, polymer type confirmation, and long-term environmental behavior are not supplied in the source.

Future experimental work could extend the present study by testing CBR, UCS, direct shear strength, resilient modulus, permeability, swelling or settlement, cyclic response, and durability. It would also be useful to compare different plastic geometries and percentages around the observed optimum and to evaluate field-scale mixing and compaction. Such work is required before the technique can be recommended for a specific structural application.

VI. Conclusion

The study demonstrates the effect of waste plastic bottle strips on the compaction characteristics of a locally collected poorly graded sandy soil. The soil had a specific gravity of 2.68, and the plastic bottles were cut into approximately 15 mm × 15 mm strips. Standard Proctor tests showed an MDD of 1.80 g/cm³ for virgin soil, 1.83 g/cm³ at 0.6% plastic, 1.90 g/cm³ at 0.8%, and 1.87 g/cm³ at 1.0%. The corresponding OMC values were 14%, 16%, 14%, and 14%. Based on these reported values, 0.8% is the optimum plastic-strip content for the compaction response, increasing MDD by approximately 5.6% compared with untreated soil. The result supports the potential reuse of waste plastic as a soil additive while also showing that excessive plastic content can reduce the achieved density. Broader strength, durability, and field tests are necessary to establish suitability for practical geotechnical construction.

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