Utilization of PET Plastic Bottle Strips in Soil Stabilization: A Methodological Study on Compaction Behaviour of Clayey/Silty Soils

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ABSTRACT

This study presents a structured and environmentally sustainable methodology to investigate the effects of PET plastic bottle strips on the compaction behaviour of locally sourced clayey/silty soils. Aimed at contributing to both geotechnical engineering and sustainable waste management, the methodology integrates controlled laboratory experiments adhering to IS 2720 (Part 7) and ASTM D698 standards. Soil samples were blended with uniformly shredded PET strips (5 mm × 50 mm) at varying concentrations (0% to 3%) and subjected to Standard Proctor Tests to analyze changes in Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). A total of 36 observation cycles, conducted over 18 hours, provided high-resolution data on compaction dynamics. The peak dry density of 1.61 gm/cc was recorded at 0.5% plastic content and 13.7% moisture, indicating an optimal stabilizer concentration. Beyond 1.5% plastic content, compaction efficiency declined, revealing a saturation point in the soil's ability to benefit from additional plastic reinforcement. The methodology's systematic structure and precision instrumentation ensured accurate, repeatable, and meaningful outcomes, offering a viable solution for incorporating waste plastic in soil stabilization efforts.

Key Words: *PET Plastic Strips, Soil Compaction, Standard Proctor Test, Sustainable Geotechnics.*

1. INTRODUCTION

Soil stabilization is a critical technique used to improve the properties of soil, such as strength, compaction, and resistance to erosion. One such innovative approach is the use of waste plastic, specifically plastic bottle strips, as a stabilizer in soil. By cutting plastic bottles into strips and incorporating them into soil, a composite material is formed that enhances the mechanical properties of the soil while also contributing to the reduction of plastic waste. This method represents a dual solution to two major issues: improving soil stability and tackling plastic pollution.

Fig: Soil Stabilization

The addition of plastic strips helps in minimizing the need for conventional stabilizers, which can be expensive and less sustainable. However, despite its promising advantages, the long-term durability of plastic-stabilized soil needs further investigation, especially regarding the degradation of plastic over time due to environmental factors such as UV radiation and moisture. Nevertheless, the stabilization of soil using plastic bottle strips represents a promising step toward sustainable construction practices that address both environmental and infrastructural challenges.

2. RESEARCH METHODOLOGY

This paper outlines the research methodology adopted to evaluate the impact of PET plastic bottle strips on the compaction behaviour of soil. Locally available clayey/silty soil was oven-dried and characterized using the Standard Proctor Compaction Test. Recycled PET strips, manually cut and uniformly blended in varying percentages (0%–3%), served as the stabilizing agent. Moisture content was adjusted using clean tap water, with values ranging from 12.8% to 19.9%. Standard lab equipment and instruments ensured precise measurements. Tests were conducted at 30-minute intervals over an 18-hour period. All procedures followed IS 2720 (Part 7) and ASTM D698 standards.

Soil Sample

Parameter	Specification
Soil Type	Locally available clayey/silty soil
Dry Soil Preparation	Oven-dried at 105°C for 24 hours
Initial Testing	Standard Proctor Compaction Test without plastic additives

The soil used in this study was a locally available clayey/silty type, selected due to its low natural bearing capacity and prevalence in construction regions. The soil was oven-dried at 105°C for 24 hours to eliminate moisture content and ensure uniformity during testing. Initial characterization of the soil was carried out using the Standard Proctor Compaction Test in accordance with IS 2720 (Part 7) guidelines to determine its baseline compaction properties without any additives. This control test provided the necessary reference data for evaluating the impact of varying plastic bottle strip content on soil behaviour.

Stabilizing Agent: PET Plastic Bottle Strips

Parameter	Specification
Material	Recycled PET plastic bottles
Cut Dimensions	Approx. 5 mm width × 50 mm length
Plastic Content Range	0% to 3% by weight of dry soil
Mixing Method	Manual uniform blending with soil before compaction
Source	Collected post-consumer PET bottles (cleaned and shredded)

Recycled PET plastic bottle strips were used as the stabilizing agent in this study to enhance the geotechnical properties of soil. The plastic was sourced from post-consumer PET bottles, thoroughly cleaned, and manually cut into uniform strips measuring approximately 5 mm in width and 50 mm in length. These strips were added to the dry soil at varying proportions ranging from 0% to 3% by weight. The blending of plastic with soil was performed manually to ensure uniform distribution prior to compaction. This eco-friendly approach helps in managing plastic waste while improving soil stability and compaction behaviour.

Water (for Moisture Content)

Parameter	Specification
Water Type	Clean tap water
Application	Added incrementally to reach different moisture content levels
Measured Moisture Range	~12.8% to 19.9%

Clean tap water was used in this experimental study to achieve the desired moisture content levels required for effective soil compaction. Water was added incrementally to each soil sample to simulate different field moisture conditions, enabling accurate determination of the Optimum Moisture Content (OMC) for each plastic content variation. The moisture content ranged from approximately 12.8% to 19.9%, depending on the proportion of plastic strips present. Proper hydration was critical to ensure uniform mixing and to replicate realistic soil compaction scenarios. The added water facilitated interaction between soil particles and plastic strips, influencing compaction and dry density outcomes.

Equipment and Apparatus

Equipment	Purpose
Standard Proctor Mould & Rammer	For conducting compaction test (IS 2720 Part 7)
Electronic Weighing Balance	Accurate measurement of soil, water, and plastic (±0.01g)
Graduated Cylinder	Water measurement
Mixing Tray & Trowel	Manual blending of soil, water, and plastic
Moisture Content Containers	For oven-drying and moisture content calculation
Drying Oven (105°C)	Pre-test soil drying
Stopwatch	For time-phased observational recordkeeping

A range of standard laboratory equipment was employed to conduct the compaction tests and record observational data accurately. The Standard Proctor Mould and Rammer, conforming to IS 2720 Part 7, were used to determine the compaction characteristics of soil. An electronic weighing balance (accuracy ±0.01g) ensured precise measurement of soil, water, and plastic strips. Water was measured using a graduated cylinder, and blending was done manually using a mixing tray and trowel. Moisture content containers and a drying oven (set at 105°C) facilitated moisture analysis. A stopwatch was used to maintain time-phased data intervals during each stage of testing.

Experimental Timeline & Observations

Parameter	Specification
Time Interval	30-minute intervals for each compaction test phase
Total Duration	~18 hours from 00:00 to 17:30
Test Conducted Per Step	Soil + specific % of plastic + specific moisture level
Output Recorded	Dry Density (gm/cc) at each stage

The compaction tests were carried out in a structured sequence with each phase conducted at 30-minute intervals, resulting in a total experimental duration of approximately 18 hours (from 00:00 to 17:30). At each interval, a unique combination of soil, a specified percentage of PET plastic strips (ranging from 0% to 3%), and a defined moisture level was tested. The primary output recorded at every step was the Dry Density (gm/cc), used to determine the compaction behaviour of the stabilized soil.

Test Standard

Standard/Reference	Description
IS 2720 (Part 7) – 1980	Indian Standard for Compaction Test of Soil
ASTM D698	Standard Proctor Test (ASTM equivalent)

The compaction tests adhered to IS 2720 (Part 7) – 1980, the Indian Standard for determining soil compaction characteristics. ASTM D698 was also considered as the equivalent international standard, ensuring consistency in the methodology and reliability of results in accordance with globally accepted Proctor compaction procedures.

3. RESULTS AND ANALYSIS

This chapter presents the comprehensive analysis of experimental results obtained through a systematic study of soil stabilization using PET plastic bottle strips. The observations were recorded during a series of time-phased compaction tests conducted at 30-minute intervals using the Standard Proctor Compaction method. The study aimed to examine the effect of varying plastic content, ranging from 0% to 3% by weight of dry soil, on the soil's compaction behaviour and strength characteristics.

Observational Data

Time	Plastic Content (%)	Moisture Content (%)	Dry Density (gm/cc)
00:00	0	14.25	1.49
00:30	0	14.3	1.52
01:00	0	14.35	1.54
01:30	0	14.4	1.57
02:00	0	14.45	1.55
02:30	0	14.5	1.46
03:00	0.5	13.5	1.57
03:30	0.5	13.6	1.59
04:00	0.5	13.7	1.61
04:30	0.5	13.8	1.6
05:00	0.5	14.1	1.56
05:30	1	12.8	1.5
06:00	1	12.9	1.54
06:30	1	13.1	1.57
07:00	1	13.2	1.55
07:30	1	13.3	1.54
08:00	1.5	18.4	1.46
08:30	1.5	18.5	1.47
09:00	1.5	18.6	1.51
09:30	1.5	18.7	1.5
10:00	1.5	18.8	1.49
10:30	2	18.6	1.45
11:00	2	18.7	1.46
11:30	2	18.9	1.49

12:00	2	19.1	1.49
12:30	2	19.3	1.47
13:00	2.5	19.1	1.46
13:30	2.5	19.2	1.48
14:00	2.5	19.4	1.5
14:30	2.5	19.6	1.49
15:00	2.5	19.8	1.47
15:30	3	19.2	1.44
16:00	3	19.3	1.45
16:30	3	19.5	1.46
17:00	3	19.7	1.45
17:30	3	19.9	1.43

The experimental results are based on a comprehensive time-phased observation of the compaction characteristics of soil treated with varying percentages of PET plastic bottle strips. The test was conducted using the Standard Proctor Compaction method at 30-minute intervals, covering plastic content from 0% to 3% by weight of dry soil. Each phase involved a specific moisture content level to determine the corresponding dry density.

The data reveal that the maximum dry density (1.61 gm/cc) was achieved at 0.5% plastic content and 13.7% moisture, indicating this combination as the most effective for compaction. Similarly, 1.0% plastic content also showed a high dry density of 1.57 gm/cc at 13.1% moisture, signifying good compaction with lower water demand. Beyond 1.5%, a consistent decline in dry density was observed with increasing plastic content, reaching 1.43 gm/cc at 3%, which implies diminished soil-particle bonding and greater void ratio due to excess plastic.

The optimum moisture content showed a rising trend with higher plastic percentages, peaking at 19.9% for 3% plastic. These results clearly suggest that small quantities of plastic strips can enhance compaction, while excessive content adversely affects soil density and moisture retention efficiency.

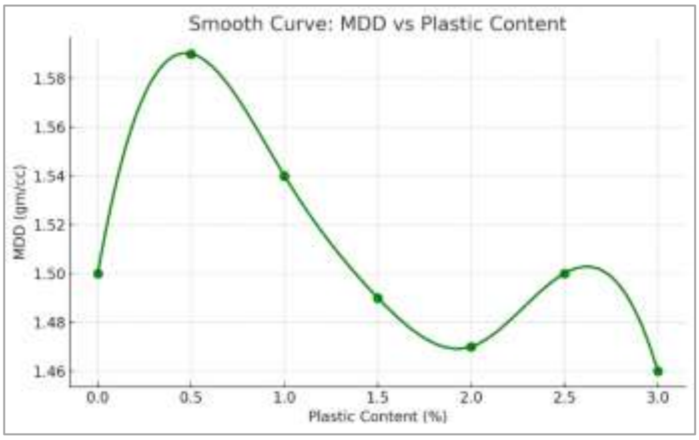

Fig: Maximum Dry Density

The graph illustrates the variation of Maximum Dry Density (MDD) with respect to plastic content in soil. As shown, the MDD increases initially, reaching its peak at 0.5% plastic content (1.59 gm/cc), indicating optimal compaction. Beyond this point, the MDD gradually declines, with a noticeable drop at higher plastic percentages. At 3% plastic content, the MDD reaches its lowest value of 1.46 gm/cc, highlighting a reduction in compaction efficiency due to excessive plastic interfering with soil particle bonding. This trend confirms that 0.5% plastic content offers the most favourable improvement in dry density for stabilized soil applications.

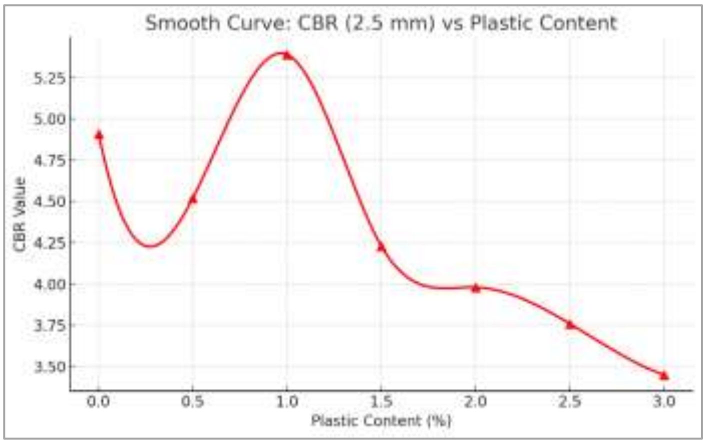

Fig: California Bearing Ratio

The graph presents a smooth curve showing the relationship between CBR (California Bearing Ratio) at 2.5 mm penetration and plastic content in soil. The CBR value initially increases with plastic addition, peaking at 1.0% plastic content (5.39), indicating enhanced load-bearing capacity. Beyond this point, CBR values decline steadily, dropping to 3.45 at 3.0% plastic, suggesting that excess plastic reduces soil strength due to interference with soil structure and compaction. This trend confirms that 1.0% plastic content offers the optimal improvement in strength, while higher percentages may weaken the soil's resistance to deformation under load.

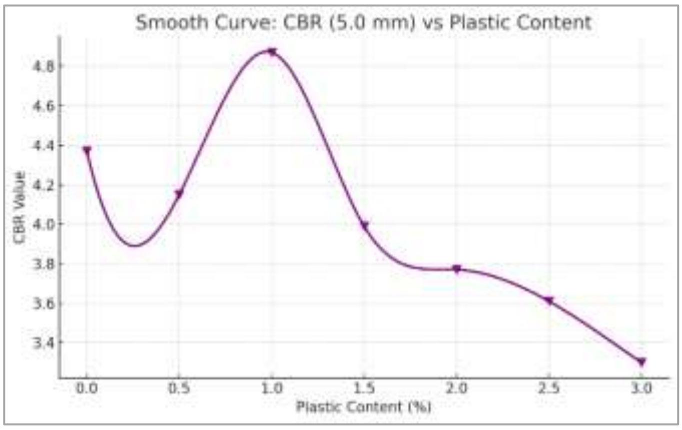

Fig: Smooth Curve CBR

The graph illustrates the variation of CBR values at 5.0 mm penetration depth with increasing plastic content in soil. The CBR initially increases, reaching its maximum value of 4.87 at 1.0% plastic content, indicating optimal reinforcement and improved subgrade strength. However, beyond this point, the CBR values steadily decrease, falling to 3.30 at 3.0% plastic, due to the disruption in soil structure caused by excessive plastic strips. This trend mirrors the behaviour seen at 2.5 mm depth and confirms that 1.0% plastic addition is the most effective dosage for enhancing both surface and deep-layer soil strength in stabilization applications.

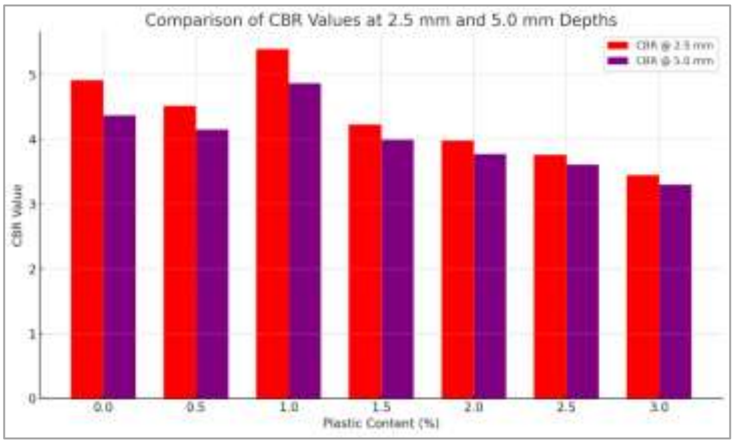

Fig: Compares the California Bearing Ratio

The bar graph compares the California Bearing Ratio (CBR) values at 2.5 mm and 5.0 mm penetration depths for varying percentages of plastic bottle strips used as a soil stabilizer. The results reveal a clear trend where CBR values initially increase with the addition of plastic, reaching a peak at 1.0% plastic content. At this point, the CBR value at 2.5 mm penetration is 5.39, and at 5.0 mm penetration, it is 4.87, indicating optimal enhancement of the soil's load-bearing capacity. This improvement can be attributed to better interlocking and distribution of stress due to the reinforcing effect of plastic strips. However, with further increase in plastic content beyond 1.0%, the CBR values show a steady decline for both depths. At 3.0% plastic, the CBR values drop to 3.45 (2.5 mm) and 3.30 (5.0 mm), highlighting that excessive plastic disrupts soil compaction and uniformity, reducing its strength characteristics. The consistent decline suggests that while small amounts of plastic contribute positively to soil strength, excess inclusion hampers compaction efficiency. Thus, the graph clearly establishes 1.0% plastic content as the most effective proportion for improving soil bearing capacity through stabilization with recycled PET plastic strips.

4. CONCLUSION AND FUTURE SCOPE

Conclusion

The research methodology adopted in this study provides a structured and practical approach to understanding the effects of PET plastic bottle strips on the compaction behaviour of clayey/silty soils. By using locally available soil and environmentally damaging plastic waste as stabilizing material, this study not only contributes to geotechnical engineering advancements but also aligns with sustainable development goals. The methodology involved a comprehensive sequence of experiments, including soil sample preparation, addition of different proportions of plastic strips, and incremental water addition to evaluate the compaction behaviour through the Standard Proctor Test.

The findings from the experimental observations confirmed that the methodology was effective in highlighting the influence of plastic content on the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soil. A total of 36 observation cycles were conducted over an 18-hour time span at 30-minute intervals. The highest dry density (1.61 gm/cc) was achieved at 0.5% plastic content and 13.7% moisture, validating the method's precision in detecting optimal stabilizer concentration. Additionally, the process allowed for precise tracking of how increasing plastic percentages impacted both compaction characteristics and strength properties like CBR values.

The test standards followed, namely IS 2720 (Part 7) and ASTM D698, ensured the accuracy, repeatability, and international relevance of the methodology. Standard laboratory equipment like Proctor moulds, electronic balances, and drying ovens were employed to maintain consistency and credibility across all trials. The systematic structure of the testing, supported by reliable instrumentation, was instrumental in capturing meaningful and reproducible data.

The use of PET plastic bottle strips in this research presents a unique method of soil stabilization that is both cost-effective and environmentally responsible. The methodology ensured that the shredded PET strips, with uniform dimensions of 5 mm width and 50 mm length, were thoroughly mixed into the soil samples at specified proportions (0% to 3%) before compaction. This uniform mixing played a key role in achieving consistent outcomes across varying plastic contents. Clean tap water was added incrementally, and moisture levels ranging from 12.8% to 19.9% were tested to determine the Optimum Moisture Content (OMC) for each configuration.

The time-phased testing schedule, combined with meticulous recording of observational data such as dry density and moisture content, enabled a thorough analysis of compaction trends. The comprehensive dataset provided insights into how different proportions of plastic content affected soil behaviour. Particularly, the methodology made it possible to identify the threshold beyond which plastic inclusion becomes counterproductive. As observed, plastic content beyond 1.5% started to show declining performance in terms of dry density and compaction efficiency.

Future Scope

This methodology can serve as a foundation for a variety of future research directions in the field of soil stabilization and sustainable construction materials. One potential area of future exploration is the use of different types of plastic waste, such as HDPE, LDPE, or mixed polymers, to assess comparative effects on soil properties. These alternative plastic types may offer different structural advantages and interact differently with soil under compaction.

The methodology can also be extended to different soil types, including sandy, loamy, or expansive soils, to examine the generalizability of plastic stabilization across diverse geotechnical conditions. A comparative study across multiple soil textures could provide valuable insights into where PET stabilization is most effective. Another future scope involves studying the long-term durability and environmental behaviour of plastic-stabilized soils under real-world field conditions. Factors such as temperature fluctuations, rainfall, leaching, and biodegradation resistance need to be investigated to determine the practical applicability of this approach in roads, embankments, or low-cost construction projects.

Additionally, future research could involve numerical modelling or simulation techniques to validate and predict compaction behaviour using finite element methods or machine learning algorithms trained on large experimental datasets. This would complement the physical testing methodology and expand its application into predictive design tools.

Further refinement of this methodology could also include additional laboratory tests such as unconfined compressive strength (UCS), permeability tests, and triaxial shear tests to provide a broader understanding of mechanical behaviour. The interaction of plastic strips with soil in terms of shear strength, pore pressure response, and tensile reinforcement could offer deeper engineering insights. From a sustainability perspective, future studies could evaluate the carbon footprint reduction and economic feasibility of largescale implementation of this method. Through quantifying the environmental benefits of reusing plastic waste in geotechnical applications, researchers can establish the ecological value of this stabilization technique.

REFERENCES

1. Shah, A., & Thaker, T. (2025) Enhancing Soil Subgrade Strength Using Waste Plastic Water Bottles as a Reinforcement. In *Geo-EnvironMeet 2025* (pp. 283-290).
2. Abdulwadood, H. W. (2025). Wasted Plastic Polypropylene Fibers as Gypseous Soil Stabilizer. *The Iraqi Geological Journal*, 231-244.
3. Kamil, I., Ahmad, R., Widyawati, D. D., Prihatin, K., & Wulandari, F. (2025) Application of Waste Pet (Polyethylene Terephthalate) Bottle-Derived Geocells For Stabilization of Unpaved Road.
4. Ngoma, M. C., Lin, J., Kolawole, O., & Ogunro, V. O. (2025). Potential of plastic-based waste in geomaterial stabilization, grouting, and geotechnology applications: retro and prospective insights. *Discover Civil Engineering*, *2*(1), 28.
5. Hassan, N. S. I. A., Hasbollah, D. Z. A., Muztaza, N. M., & Yuliana, Y. (2024). Peat soil stabilizer using plastic waste. *Smart and Green Materials*, *1*(1), 44-56.
6. Oguntayo, D. O., Aladegboye, O. J., Adeyemo, F. O., Aransiola, O., & Gbadamosi, N. A. (2024, April). Reinforcing effect of waste plastic bottle strips on lime-admixed clayey soil. In *2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG)* (pp. 1-5). IEEE.
7. Khalid, B., & Alshawmar, F. (2024). Comprehensive review of geotechnical engineering properties of recycled polyethylene terephthalate fibers and strips for soil stabilization. *Polymers*, *16*(13), 1764.
8. Azam, F. A. A., bte Roslan, R., Baharudin, I. N. Z., & Muchlas, N. H. M. (2024). Enhancing the soil stability using biological and plastic waste materials integrated sustainable technique. *Alexandria Engineering Journal*, *91*, 321-333.
9. Yohanna, P., Etim, R. K., Ekene, N. I., Toluwase, J. A., Mbah, E. O., Ayodeji, O. O., ... & Moris, K. I. (2024). Case evaluation of structural strength improvement of cement stabilized lateritic soil reinforced with sisal fibers and plastic waste strips. *Discover Civil Engineering*, *1*(1), 66.
10. Obianyo, I. I., Taiwo, I. A., Dayyabu, A., Mahamat, A. A., Amuda, A., Muoka, A., ... & Onwualu, A. P. (2024). Modification of Lateritic Soil Using Waste Plastics for Sustainable Road Construction. *Polymers*, *16*(19), 2689.
11. Kumar, S., & Mishra, M. K. (2023). Effect of NaOH treated polyethylene terephthalate (PET) plastic bottle strips on stabilization of Soil. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1273, No. 1, p. 012013). IOP Publishing.
12. SHOFIUL AZAM, M. O. H. A. M. M. A. D. (2023). *Use Of Alkali Activated Incineration Ash And Coal Based Flyash Along with Pet Bottle Strip Reinforcement In Stabilizing Road Subgrade Soil* (Doctoral dissertation, Department of Civil Engineering, MIST).
13. Sarkar, R. K., Mahi, R. F., Akter, M. M., Al Hussain, H., & Sarkar, H. C. (2023). Study of the Performance of Waste Plastic in Clay Soil Stabilization. *Malaysian Journal of Civil Engineering*, *35*(3), 25-28.