Re-Using Polyethylene Bag (A Plastic Waste) for Soil Stabilization

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Abstract: ***Soil plays a critical role in supporting structural loads. Weak soil with low bearing capacity poses challenges to construction stability. Soil stabilization provides an effective solution to this problem. In this study, waste polyethylene bags, a major source of plastic pollution, were used as reinforcement material to stabilize soil. Experimental investigations including water content, specific gravity, sieve analysis, compaction, permeability, and bearing capacity tests were conducted on soil samples with and without plastic waste. The results revealed that inclusion of 0.1% plastic waste enhanced the soil's safe bearing capacity from 43.15 kN/m² to 93.16 kN/m². Furthermore, improvements in consistency limits and density characteristics were observed. This indicates that plastic waste can be effectively used as a low-cost, eco-friendly material for ground improvement, providing dual benefits of waste management and enhanced soil strength.***

Keywords: Plastic Waste, Polyethylene Bags, Safe Bearing Capacity, Soil Stabilization

1. Introduction

Rapid urbanization and population growth have significantly increased plastic waste generation worldwide. Polyethylene bags, which are non-biodegradable, pose a major threat to the environment. Recycling of plastic is limited due to high costs and inefficiencies. However, reuse of plastic waste in civil engineering applications offers a sustainable alternative. Soil stabilization is a technique used to improve weak soils by altering their engineering properties. Traditionally, cement, lime, and fly ash have been used, but these materials are costly. Hence, researchers are exploring the use of alternative waste materials. This study investigates the feasibility of using polyethylene bag waste for soil stabilization.

The problem of plastic waste management has become a global concern due to its non-biodegradable nature. Among various types of plastics, polyethylene bags constitute a large proportion of the waste generated daily, especially in developing countries like India. With rapid urbanization and modernization, the demand for plastic products has increased exponentially, leading to billions of plastic bags being discarded every year. Improper disposal of these bags leads to clogging of drainage systems, pollution of land and water bodies, and hazards to wildlife. Hence, effective reuse of polyethylene waste is urgently required to minimize its harmful impact on the environment. Soil stabilization, on the other hand, is a well-established ground improvement technique that modifies the engineering properties of weak soils to make them suitable for construction purposes. Conventionally, stabilization has been achieved using materials such as lime, cement, bitumen, and fly ash. While effective, these stabilizers are costly and involve significant environmental drawbacks, including high energy consumption and CO_2 emissions. As a result, researchers are increasingly exploring alternative, eco-friendly stabilizers derived from waste materials. The idea of using plastic waste for soil stabilization has gained considerable attention in recent years. Plastic possesses qualities such as durability, tensile strength, and chemical resistance, making it suitable for engineering applications. When shredded into small pieces and mixed with soil, polyethylene bags can act as reinforcing elements within the soil matrix. This improves interlocking, enhances shear strength, reduces settlement, and increases the safe bearing capacity of soil. Thus, polyethylene waste, which is otherwise an environmental burden, can potentially serve as a sustainable engineering resource.

The improvement in strength can be attributed to the reinforcing effect of the plastic strips. When mixed with soil, the irregular surfaces of plastic pieces create interlocking within soil particles, resisting shear forces and improving load distribution. This mechanism is similar to that of fiber-reinforced soil, where randomly distributed fibers act as tension-resisting elements, bridging across potential failure surfaces.

From an environmental perspective, the reuse of polyethylene waste in soil stabilization provides a dual advantage. First, it reduces the reliance on traditional stabilizers like cement and lime, which have high carbon footprints. Second, it offers a sustainable way of disposing of non-biodegradable plastic, which is otherwise a major environmental pollutant.

Figure 1: Plastic Waste & Plastic Pieces

By incorporating plastic waste into geotechnical applications, this method helps reduce landfill burden, mitigate drainage clogging, and address ecological hazards associated with open dumping of plastics. Overall, the study demonstrates that waste polyethylene bags, when used in small proportions, can significantly enhance soil properties without any negative impact. However, large-scale field trials are recommended to assess the long-term performance of this method under varying climatic and loading conditions. The technique can be particularly useful in low-cost rural road construction, embankment strengthening, and other infrastructure projects where weak soils pose challenges to stability.

2. Materials and Methods

This study investigates the feasibility of reusing polyethylene bag waste in soil stabilization. Laboratory experiments were conducted on soil samples with and without polyethylene waste to evaluate key parameters such as water content, consistency limits, compaction behavior, permeability, and safe bearing capacity. The findings demonstrate how plastic waste can be transformed into a useful material for geotechnical applications, providing dual benefits: improving soil performance while reducing environmental pollution. This approach not only enhances construction practices but also contributes toward sustainable waste management.

2.1 Soil Sample collection

The soil sample used for this study was collected from Gopal Stadium, Adipur (Gujarat, India). The soil was classified as a well-graded brownish fill-up soil. Basic properties of the soil were determined in the laboratory before conducting stabilization experiments. The soil exhibited a specific gravity of 2.29 and a natural water content of 1.73%. Preliminary sieve analysis indicated that the soil contained about 3.9% gravel, 51.7% sand, and 4.1% silt and clay fractions, confirming it to be a well-graded soil suitable for compaction and stabilization studies.

2.2 Plastic Waste (Polyethylene Bags)

The plastic waste selected was high-density polyethylene (HDPE) bags, obtained from Yash Euro Acrylic Industries. The material properties were as follows: density = 0.94 g/cm³, thickness = 40 microns, melting point = 135 °C, and heat resistance up to 100 °C. The plastic was strong, durable, and 100% virgin material, which is recyclable and reusable. For experimental purposes, the polyethylene bags were manually cleaned, dried, and cut into small rectangular pieces before being mixed with soil. Plastic proportions ranging from 0.05% to 0.5% by weight of soil were initially tested, and based on results, 0.1% was identified as the optimum proportion for further analysis.

3. Experimental Procedure

A series of laboratory tests were conducted on soil samples with and without polyethylene waste to evaluate the effect of plastic on engineering properties of soil. All tests were performed in accordance with relevant Indian Standard (IS) codes. The natural moisture content of the soil sample is 1.73 %, specific gravity of the soil sample is 2.29. The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for construction, air field etc.

Grain size distribution: Grain size distribution shows the proportion of different-sized soil or aggregate particles present in a sample. It helps in classifying soil and determining its suitability for construction works.

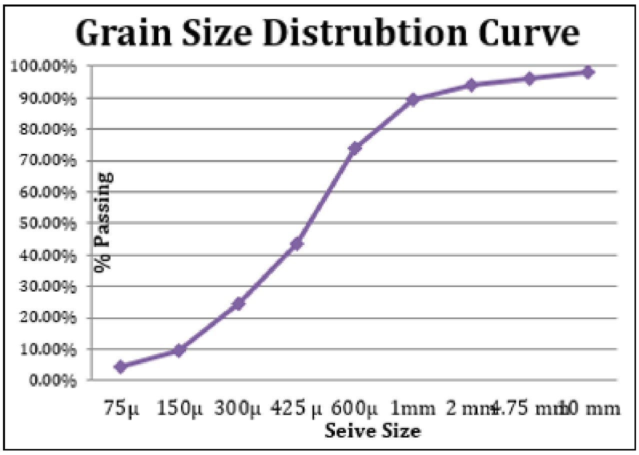

Figure 2: Grain size distribution

Permeability Test by Falling Head Method: The Falling Head Permeability Test is used to determine the coefficient of permeability of fine -grained soils. It measures the rate of water flow through soil when the water head decreases over time.

Table 1: Permeability Test by Falling Head Method

Sample	Time	Permeability (cm/sec)	Average (cm/sec)
Soil sample (without plastic)	T1 = 24 sec	2.04×10^{-3}	2.07×10^{-3}
	T2 = 22 sec	2.22×10^{-3}	
	T3 = 25 sec	1.96×10^{-3}	
Soil sample (with plastic) 0.5%	T1 = 15 sec	3.26×10^{-3}	3.42×10^{-3}
	T2 = 14 sec	3.50×10^{-3}	
	T3 = 14 sec	3.50×10^{-3}	
Sample (with plastic) 0.3%	T1 = 14 sec	3.50×10^{-3}	3.42×10^{-3}
	T2 = 14 sec	3.50×10^{-3}	
	T3 = 15 sec	3.26×10^{-3}	
Soil sample (with plastic) 0.1%	T1 = 27 sec	1.81×10^{-3}	1.88×10^{-3}
	T2 = 26 sec	1.88×10^{-3}	
	T3 = 25 sec	1.96×10^{-3}	
Soil sample (with plastic) 0.05%	T1 = 23 sec	2.13×10^{-3}	1.94×10^{-3}
	T2 = 26 sec	1.88×10^{-3}	
	T3 = 27 sec	1.81×10^{-3}	

Consistency Limits-Liquid Limit Test for soil: The Liquid Limit Test determines the moisture content at which soil changes from a plastic to a liquid state.

It helps in classifying soil and assessing its strength and compressibility.

Table 2: Water content for soil sample

S. No.	Details	Observations- Soil Sample with 0.1% plastic			
1	No. of blows	29	20	17	9
2	Container no.	E	G	Y	K
3	Wt. of empty container (gms)	16	18	18	18
4	Wt. of empty container + wet soil (gms)	52	84	79	77
5	Wt. of empty container + dry soil (gms)	46	72	68	65
6	Water content	20%	22.22%	22%	25.53%

Water content of a soil sample is the ratio of the weight of water present in the soil to the weight of dry soil. It indicates the soil's moisture condition, which greatly affects its strength and behavior. From the above result graph was plotted shown below

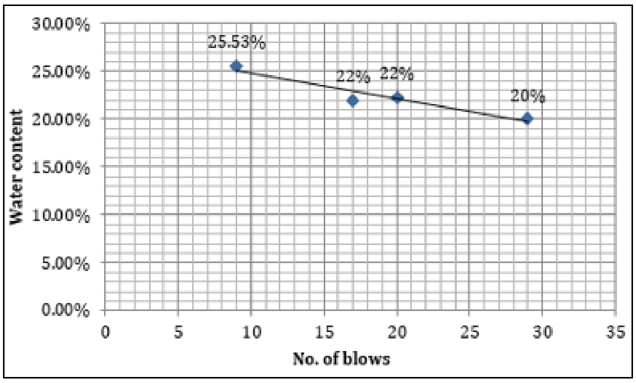

Figure 3: Water content result after adding 0.1% plastic in soil sample

Table 3: Consistency Limits-Liquid Limit Test for soil with 0.1% plastic

S. No.	Details	Observations- Soil Sample with 0.1% plastic			
1	No. of blows	20	17	10	9
2	Container no.	Y	B	R	M
3	Wt. of empty container (gms)	18	17	18	18
4	Wt. of empty container + wet soil (gms)	70	85	73	67
5	Wt. of empty container + dry soil (gms)	63	75	64	59
6	Water content	15.56%	17.24%	19.57%	19.50%

Dry density is the ratio of the mass of soil solids to the total volume of the soil. It indicates the degree of soil compaction and strength for construction purposes.

Table 4: Dry density for Soil Sample

Soil Sample				
Wt. of empty mould (gms)	2389	2389	2389	2389
Wt. of mould + compacted soil (gms)	4441	4570	4600	4535
Wt. of compacted soil (gms)	2052	2181	2211	2146
Bulk density $\gamma b = w/v$ (gm/cc)	2.09	2.22	2.25	2.18
Water content = w (%)	6.25%	5.71%	17.07%	14.89%
Dry density $\gamma d = \gamma b / (1+w)$ (gm/cc)	1.96	2.10	1.92	1.90

From the result obtain compaction curve is prepared shown below.

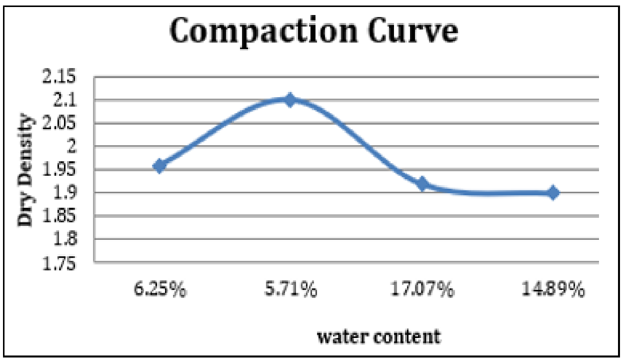

Figure 4: Compaction curve for soil sample

Paper ID: SR25822131453 DOI: https://dx.doi.org/10.21275/SR25822131453

From the graph maximum dry density = MDD= 2.1gm/cc and optimum moisture content= OMC=5.72%

Table 5: Dry density for soil sample with plastic

Soil Sample with 0.1% plastic				
Wt. of empty mould (gms)	2386	2386	2386	2386
Wt. of mould + compacted soil (gms)	4321	4536	4584	4517
Wt. of compacted soil (gms)	1935	2150	2198	2131
Bulk density γb = w/v (gm/cc)	1.97	2.19	2.24	2.17
Water content = w (%)	3.25%	9.52%	7.32%	9.38%
Dry density γd = γb / (1+w) (gm/cc)	1.91	2	2.08	1.98

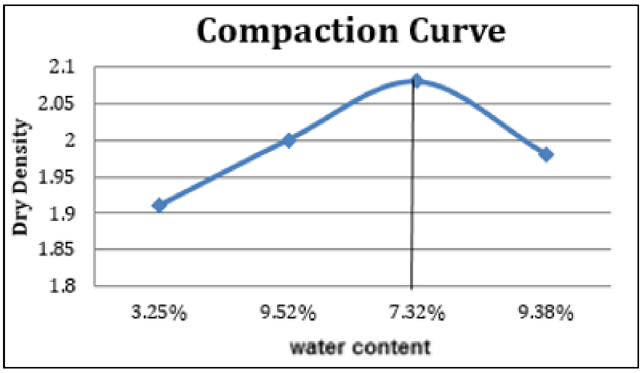

Figure 5: Compaction curve for soil sample with plastic

From the practical we get maximum dry density = MDD= 2.10 gms/cc and Optimum moisture content= OMC=7.30 %

4. Result & Discussion

Stage 1 (Trial Tests) result: Soil samples were mixed with plastic waste at varying percentages (0.05%, 0.1%, 0.3%, and 0.5%) to assess initial trends in permeability and strength.

Stage 2 (Final Testing) result: Based on results, **0.1% plastic waste** was identified as the most effective proportion. Detailed tests (consistency limits, compaction, permeability, and SBC) were then conducted for this proportion and compared with natural soil values.

This systematic approach ensured that the influence of polyethylene waste on soil properties was comprehensively assessed and validated.

4.1 Experimental Results

The consistency limits further validate these findings. The liquid limit decreased from 21.2% to 13.2% after the addition of plastic, while the plastic limit increased from 9.76% to 12%. A lower liquid limit suggests that the soil becomes less compressible and more workable, while a higher plastic limit indicates improved ductility and reduced brittleness. Together, these results imply that soil mixed with polyethylene waste is more stable under varying moisture conditions.

Compaction characteristics also revealed positive outcomes. The maximum dry density (MDD) of the soil remained nearly the same, but the optimum moisture content (OMC) increased from 5.72% to 7.30%. This indicates that the soil mixed with plastic requires slightly more water for compaction, but the final density achieved is not compromised. This makes the technique feasible for large-scale field applications where moisture control is critical.

The permeability results showed a slight reduction when polyethylene waste was added. Although this reduction is small, it is beneficial for construction purposes, particularly in preventing excessive seepage in embankments, subgrades, and retaining structures. Lower permeability implies higher resistance to water infiltration, reducing the chances of soil softening and loss of strength over time.

Table 6: Consolidated Result

Property	Soil sample	Soil sample with plastic pieces 0.1%
Type	Well graded soil	Well graded soil
Water content	1.73%	1.73%
Specific gravity	2.29	2.29
Bulk density	1.69 gm/cc	1.69 gm/cc
Dry density	1.66 gm/cc	1.66 gm/cc
Permeability	2.07×10^{-3} cm/sec	1.88×10^{-3} cm/sec
Liquid limit	21.20%	13.20%
Plastic limit	9.76%	12%
Maximum dry density (MDD)	2.1 gm/cc	2.10 gm/cc
Optimum moisture content (OMC)	5.72%	7.30%
Safe bearing capacity	43.15 kN/m²	93.16 kN/m²

5. Conclusion

The results obtained from the experimental program clearly indicate that the addition of polyethylene bag waste improves several engineering properties of soil. When 0.1% of shredded polyethylene waste was incorporated into the soil, there was a notable increase in the safe bearing capacity, nearly doubling from 43.15 kN/m² to 93.16 kN/m². This enhancement in load-bearing capacity highlights the potential of waste plastic to function as an economical soil stabilizer. This technique offers a sustainable approach to soil improvement, reduces construction costs, and simultaneously mitigates the adverse environmental effects of plastic waste. Further large-scale studies are recommended to validate the performance of this technique in real field conditions.

References

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