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Study the effect of waste plastic bottle strips in improvement of soil quality: A case study in Raipur district

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Abstract
With rapid advancements in technology globally, the use of plastics such as polyethylene bags, bottles etc. is also increasing. The disposal of thrown away wastes pose a serious challenge since most of the plastic wastes are non-bio degradable and unfit for incineration as they emit harmful gases. Soil stabilization improves the engineering properties of weak soils by controlled compaction or adding stabilizers like cement, lime etc. but these additives also have become expensive in recent years .In recent years, stabilizer such as lime, cement and fly ash have become prohibitively expensive for soil stabilization. In some circumstances, solid waste production, particularly garbage from plastic products, is increasing uncontrollably and continuously. Given the rapid increase in plastic waste and the rising expense of additives in recent years, the current study focuses on treating the soil with plastic waste as a soil stabilizer to enhance the soil's bearing capacity. This prospective study aimed to determine the index properties, review past research on the engineering properties and develop a hypothesis on the optimum proportion of plastic waste to be employed in the soil for engineering applications. This research paper examines the use of plastic waste from polyethylene terephthalate (PET) plastic bottle shreds as a stabilizer, which necessitates a review of previous research studies and several investigations following the British Standard (BS), many techniques are used to improve the Complexity of soil. This paper presents a detailed study on the behavior and use of waste plastic in soil improvement. Experimental investigation on reinforced plastic soil results showed that, plastic can be used as an effective stabilizer so as to encounter waste disposal problem as well as an economical solution for stabilizing weak soils. Plastic reinforced soil behaves like a fiber reinforced soil.

Keywords: Plastic waste, soil stabilization, bearing capacity, pet fibers, reinforced soil

1. Introduction

Soil is a fundamental component in civil engineering andgeotechnical applications, serving as a base for most infrastructure projects. However, in many regions, the naturally occurring soil lacks sufficient strength and stability to support structural loads, requiring modification or stabilization. Traditional methods of soil stabilization often involve the use of cement, lime, or other chemical additives, which may have economic and environmental drawbacks.

PET waste has become a major portion of plastic pollution (Kim *et al.*, 2020) [11], and is a semi-crystalline thermoplastic polyester. The bulk of the world's PET consumption is for synthetic polymers. PET is made up of a polymer matrix of ethylene terephthalate monomers with alternating (C10H8O4) units. PET bottles are commonly used for carbonated drinks. PET is very compact and can be semi-rigid or rigid. It is a strong gas and moisture blocker, and also a great deterrent to liquor and solvents. PET is steadily gaining market share as a garment fiber due to its reuse and recycling and the significant surplus of post-consumer waste in the form of bottles and cans. PET is produced from the polycondensation of ethylene glycol and terephthalic acid. PET can be processed using a common moulding method like injection moulding, blown moulding and extrusion. It is also suitable to be used to fabricate thin layer products like stretched film and thermo-forming, it was concluded that due to low specific gravity of plastic pieces there is decreases in MDD and OMC of the soil. The factors identified to have an influence on the efficiency of reinforcement material were the plastic properties (concentration, length, width of the strips) and the soil properties (gradation, particle size, shape).

In recent years, the reuse of waste plastic in civil engineering has gained popularity due to its environmental and economic benefits. (Choudhary *et al.* 2010) [12] conducted experiments using plastic strips from waste polyethylene bags in sub-grade soil. They found that the California Bearing Ratio (CBR) values increased significantly with 1.5% plastic content. (Khan and Sayyad 2014) [13] tested shredded plastic bottles mixed with black cotton soil and observed improved UCS and reduction in swelling potential. (Kumar and Saran, 2003) [14] noted that plastic strips enhanced the strength of sand, with the optimal results found at 1-2% strip content by weight. These studies confirm that plastic strips can serve as effective reinforcements, similar to conventional fibers, due to their tensile properties, lightweight nature, and non-degradable characteristics. The reuse of waste plastic in soil stabilization aligns with sustainable development goals. (Rokade *et al.* 2012) [15] highlighted the dual advantage of reducing plastic pollution and improving ground performance

2. Materials and Methods

2.1. Soil

G Type: Locally available clayey soil (Yellow Black Alluvial Soil)

Collection Site: Excavated from IGKV Campus at a depth of 1-1.5 meters to avoid organic content and surface disturbances.

Fig 1: Figure Showing collected Black yellow Alluvial soil

2.2 Plastic Strips

Source: Waste polyethylene terephthalate (PET) bottles.
Collection site: We are collecting the plastic which is being used in any function in your locality, because these functions are the major source of plastic waste. We have collected these plastics bottles from a function which is organized in our college campus

2.3 Preparation

Bottles cleaned, labels removed, and cut manually into strips.

Dimensions: Constant width of 5 mm; varying lengths of 10 mm, 20 mm, and 30 mm.
Percentage by Weight of Soil**:** 0%, 2.0% and 4%.

Fig 2: Showing prepared Plastics strip

2.3.1 Plastic Content Variations

The study examined different percentages of plastic strips: 0% (natural soil), 2% and 4% by weight of the soil. Sizes of plastic strips were tested: Uniform width of 5 mm and lengths of 10 mm, 20 mm, and 30 mm, to determine the effect of strip dimensions on soil properties.

2.3.2 Plastic Content Variation with soil sample

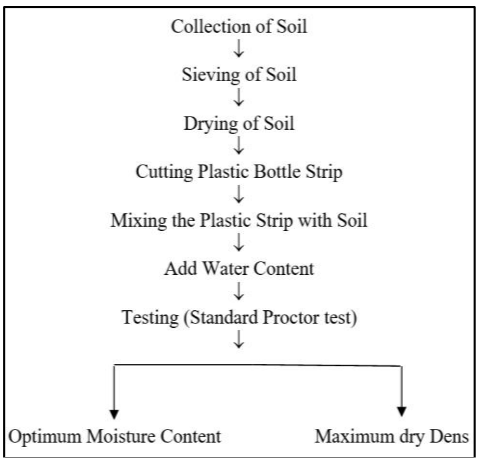
Sample No.	Amount of soil	Amount of Plastic
SN-1	1KG	0%
SN-2	2KG	2% = 20g
SN-3	3KG	4% = 40g

2.4 Experimental Tests Conducted:

2.4.1 Standard Proctor Compaction Test

To determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of both untreated and plastic-reinforced soil. By using IS 2720 (Part 7)-1980

2.5 Flow Chart of Experimental Study



Preparation of Waste Plastic Bottle Strips

1. **Collection:** We Used PET bottles were collected from a function which is organized in our college campus or from local areas.
2. **Cleaning:** Bottles were thoroughly washed to remove labels, adhesives, and other contaminants.
3. **Cutting:** Bottles were cut into strips with a uniform width of 5 mm and lengths of 10 mm, 20 mm, and 30 mm using scissors or a cutting tool.
4. **Weighing:** Plastic strips were weighed 250gm and added to the soil in percentages of 0%, 2% and 4% by the dry weight of soil.

Fig 3: Showing Soil samples containing **2** % plastic

Fig 4: Showing Soil samples containing 4% plastic

3. Results and Discussion

3.1. Standard Proctor Compaction Test (0% Plastic Strip)

S. No	Description	1	2	3	4	5	6	7
a	Wt. of Soil + Mould (gm)	5722	5780	5828	5878	5933	5973	5931
b	Wt. of Mould (gm)	4158	4158	4158	4158	4158	4158	4158
c	Wt. of Soil (a-b) (gm)	1564	1622	1670	1720	1775	1815	1773
d	Volume of Mould (cm^3)	944	944	944	944	944	944	944
e	BulkDensity = c/d(gm/cm^3	1.66	1.71	1.76	1.82	1.88	1.92	1.87
f	Container No.	1	2	3	4	5	6	7
g	Wt. of Soil + Container (gm)	42	51	71	60	68	42	48
h	Dry Soil + Container (gm)	40	47.5	65	54.2	61.35	37.2	42.2
i	Wt. of Water (g-h) (gm)	2	3.5	6	5.8	6.65	4.8	5.8
j	Wt. of Container (gm)	21	20	24	20	28	15	16
k	Wt. of Dry Soil (h-j) (gm)	19	27.5	41	34.5	33.35	22.2	26.2
l	Moisture Content = (h/j)×100	10.5%	12.5%	14.6%	17%	19.5%	21.5%	22%
m	Max Dry Density = e/(1+l/100)	1.50	1.52	1.53	1.55	1.57	1.58	1.56

OMC = 21.5%
MDD = 1.58 g/cc or kN/m^3

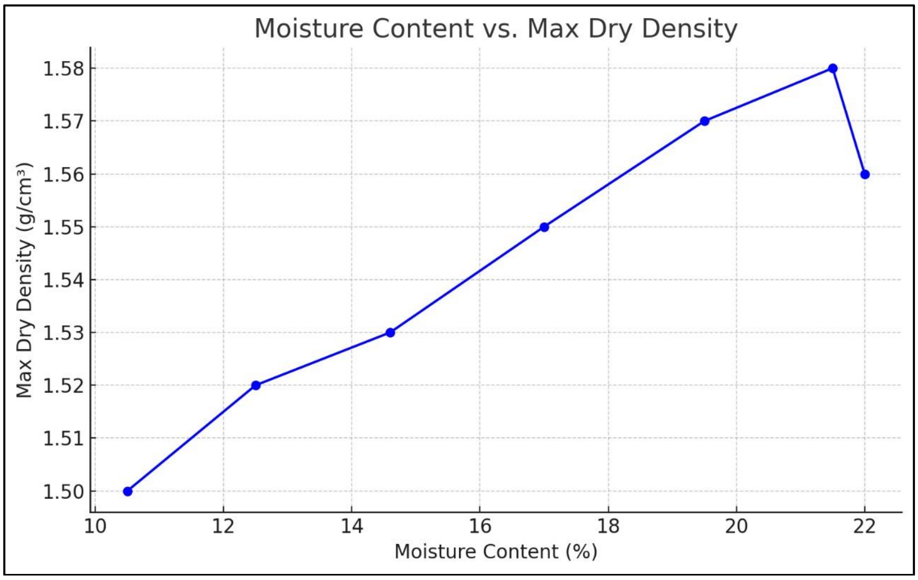


Fig 5: Showing Soil Graph Between MDD & Moisture content(%)

Table 1: Standard Proctor Compaction Test (2% Plastic Strip)

S. No	Description	1	2	3	4	5	6	7
a	Wt. of Soil + Mould (gm)	5620	5656	5707	5748	5776	5855	5833
b	Wt. of Mould (gm)	4154	4154	4154	4154	4154	4154	4154
c	Wt. of Soil (a-b) (gm)	1466	1502	1553	1594	1622	1701	1679
d	Volume of Mould (cm³)	944	944	944	944	944	944	944
e	Bulk Density = c/d (gm/cm³)	1.55	1.59	1.64	1.68	1.71	1.80	1.77
f	Container No.	1	2	3	4	5	6	7
g	Wt. of Soil + Container (gm)	33	34	36	47	39	29	54
h	Dry Soil + Container (gm)	30.9	31.5	33	43.8	35	27	50
i	Wt. of Water (g-h) (gm)	2.1	2.5	3	3.2	4	2	4
j	Wt. of Container (gm)	14	14	15	24	15	18	34
k	Wt. of Dry Soil (h-j) (gm)	16.9	17.5	18	19.8	20	9	16
l	Moisture Content = (h/j)×100	12.14%	14.3%	16.6%	18.8%	20%	22.2%	25%
m	Max Dry Density = e/(1+l/100)	1.37	1.39	1.40	1.41	1.425	1.47	1.41

OMC = 22.2 %
MDD = 1.47 g/cc or kN/m³

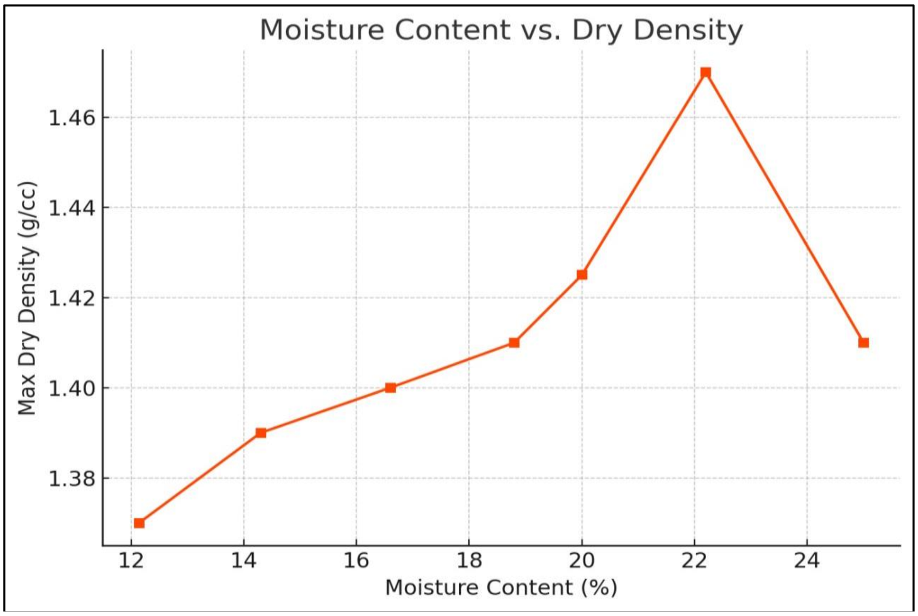


Fig 6: Showing Graph between MDD and Moisture content (2% plastic strip)

Table 2: Standard Proctor Compaction Test (4% Plastic Strip)

S. No	Description	1	2	3	4	5	6
a	Wt. of Soil + Mould (gm)	5578	5653	5688	5743	5809	5765
b	Wt. of Mould (gm)	4149	4149	4149	4149	4149	4149
c	Wt. of Soil (a-b) (gm)	1429	1504	1539	1594	1680	1616
d	Volume of Mould (cm³)	944	944	944	944	944	944
e	Bulk Density = c/d (gm/cm³)	1.54	1.59	1.63	1.69	1.78	1.71
f	Container No.	1	2	3	4	5	6
g	Wt. of Soil + Container (gm)	50	53	58	58	25	42
h	Dry Soil + Container (gm)	47.2	49	52.8	53	22.8	38
i	Wt. of Water (g-h) (gm)	2.74	4	5.2	5	2.2	4
j	Wt. of Container (gm)	24	20	20	28	14	23
k	Wt. of Dry Soil (g-i) (gm)	23.25	29	32.8	25	8.8	15
l	Moisture Content = (I/k)×100	11.5%	13.8%	15.85%	20%	25%	26.5%
m	Max Dry Density = e/(1+l/100)	1.35	1.39	1.40	1.41	1.42	1.35

OMC = 25%
MDD = 1.42 g/cc or kN/m³

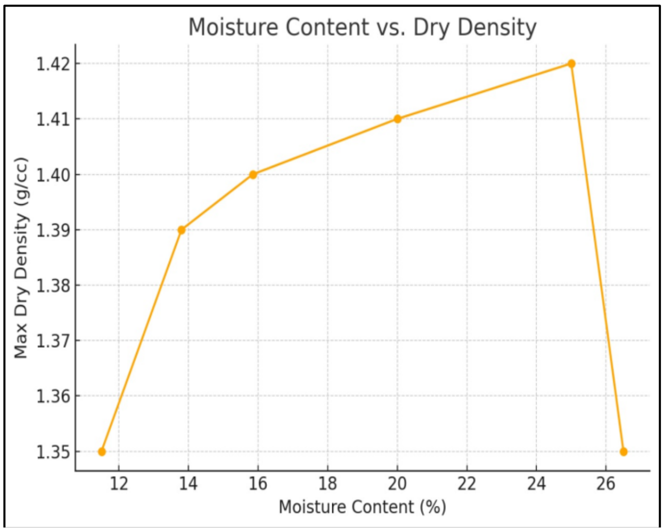


Fig 7: Showing Graph between MDD and Moisture Content (4%)

From the above tables and graphs we find that As the percentage of plastic strips increases, the MDD decreases. The reduction in density is due to the lower specific gravity and higher void ratio introduced by plastic strips. The OMC increases because more water is needed to lubricate the plastic-soil mix during compaction

4. Conclusion

This experimental study was conducted to evaluate the effect of incorporating waste plastic bottle strips into clayey soil (yellow black alluvial soil) to improve its geotechnical properties. A series of laboratory tests including Standard Proctor Compaction and were performed by varying the plastic strip content (0% to 4%) and lengths (10 mm, 20 mm)

- Standard Proctor Compaction test was conducted to determine Optimum Moisture Content and Maximum Dry density (MDD).
- We observed that MDD initially increased with small addition of plastic (0 to 4%) then decreased with higher percentages.
- Optimum Moisture Content (OMC) generally increased with higher plastic content due to reduced density and increased voids. We also find and conclude that:-
- With the inclusion of plastic strips, the Maximum Dry Density (MDD) decreased and the Optimum Moisture Content (OMC) increased due to the lightweight and non-absorbent nature of plastics.
- This study provides a sustainable and eco-friendly method of reusing non-biodegradable waste plastic, reducing environmental pollution and landfill pressure
- Plastic-reinforced soil can be effectively used in subgrade layers, embankments, low-volume roads, and temporary construction platforms where improved strength and durability are required.
- Low cost stabilization method compare to chemical additive or other reinforcement technique.
- The experiments were performed only on clayey soil. Results may vary for other types of soils such as sandy, silty, or expansive soils, which were not included in this study.
- Only PET (Polyethylene Terephthalate) from plastic bottles was utilized. The study does not examine the impact of other plastic types like HDPE, LDPE, or polypropylene.

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