STUDY ON STABILIZATION OF SOIL USING POLYPROPYLENE FIBER WASTE

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Abstract - *The main objective of this project is to investigate the effect of waste polypropylene fiber as a reinforcement by conducting compaction characteristics, Unconfined compressive strength, Direct shear test, and California bearing ratio for soil with randomly distributed small percentages (0%, 0.10%. 0.20%, 0.30%, 0.40% & 0.50%) of fiber. There is a rapid increase in plastic waste generation all over the world and the correct manner of disposing is very challenging as it is non-biodegradable and have very low recycling ratio ultimately causing ecological hazards. Soil stabilization by conventional methods using cement, lime fly ash as an admixture is not economical in recent years, so there is a need to look after for an alternative such as plastic. Fiber reinforcement emerged as an important method for improving the properties of soil. So, in this study we use waste polypropylene fiber and conducted various experiments to find optimum amount which will give the maximum enhancement in the strength of soil.*

Key Words: **Waste polypropylene fiber, non-biodegradable, Ecological hazard, randomly distributed, Unconfined Compressive strength, Direct shear test, California bearing ratio.**

1. INTRODUCTION

The foundation for any land-based structure is the most important part of the entire structure. The strength of the foundation is determined by the soil around it. To improve soil strength, we must first have a thorough understanding of its properties and the elements that govern its behavior. Soil stabilization is a powerful tool for improving soil properties [1,10]. Increase in population, consumerism and development led to very rapid increase in accumulation of plastic waste. There day to day uses contribute to a huge increase in volume of wastes [2]. It is commonly known that the planet Earth is confronting environmental issues, including a waste disposal dilemma. These issues arise as a result of garbage, and one of the most commonly produced wastes is plastic, which accounts for 12.3% of total waste produced [3]. This create the need for encouraging the use of plastic waste in geotechnical engineering is necessary to keep the development path sustainable [4].
Modernization raises demand for fuels and construction materials, resulting in scarcity and price increases. With rising population and a scarcity of land with good engineering properties, it is vital to investigate cost-effective stabilization methods [5].
Various conventional methods of stabilization such as mechanical, chemical and reinforcing by steel or other admixtures are very costly so for both economical and preventing ecological hazards by reducing plastic waste by using it for improving soil properties [6]. The majority of recent discoveries and approaches have been polymer-based in nature, such as processed polymer fiber or waste products such as polythene bags, plastic bottles, and recycled plastic pins. These new polymers and compounds have a number of important advantages to mechanical methods, including being less expensive and more effective in general, as well as being substantially less hazardous to the environment than conventional chemical solutions [7].
The term "soil stabilization" refers to the use of controlled compaction, proportioning, or the addition of a suitable admixture or stabilizer to improve the stability or bearing power of soil [8-9]. Methods of soil stabilization are:

Mechanical method: Soil of different gradations are mixed and compacted to reduce the voids and achieve required density. Cohesionless soil by vibratory roller and cohesive soil by sheep foot roller.

Chemical Method: Certain additives are added in proper quantities to enhance the engineering properties of the soil. Some of the chemical additives are- cement, lime, bitumen, fly ash etc.

Polymer method: To improve the physical qualities of soil, polymers are added. Various polymers have been found to promote water retention and prevent erosion, as well as boost soil shear strength and structure, at very low concentrations within soils.

According to the previous studies, polypropylene fiber as a soil reinforcement increases direct shear strength parameters (cohesion and angle of internal friction), unconfined compressive strength, and the soil's California Bearing ratio [10-12].

In this study soil stabilization using randomly distributed polypropylene fibers in varying percentages obtained from waste sources and results obtained are studied to get the maximum enhancement in properties.

1.1 Advantages of stabilization:

- Increases strength of soil i.e., Increases the bearing capacity of soil.
- Economical in both terms cost and energy.
- Also provides stability of soil in slopes.
- Soil stabilization also helps in preventing soil erosion in dry and arid areas.
- It is also used for preventing entry of water into the soil i.e., soil water proofing.
- Reduces the change in volume of soil due to swelling and shrinkage.
- Stabilization improves the durability and stability of soil.

1.2 Scope and Objective

In this study, the analysis is being made for clay of low compressibility with 12mm fibers and the various geotechnical properties such as shear strength parameters, Optimum moisture content (OMC), Maximum Dry Density (MDD), Unconfined compressive strength (UCS) and California Bearing ratio (CBR) was computed for different percentage of fibers and the results were analyzed for maximum increase in properties of soil.

Objectives of this study are:

- To compare MDD and OMC values of unreinforced soil and reinforced soil.
- The effect of polypropylene fiber on strength and compressibility based on shear parameters and compaction results.
- Increase the bonding between grains = increasing in shear strength.
- To improve the CBR value of the soil, hence decreasing the subgrade thickness.
- To take care of economy of the construction.
- To use inferior quality of locally available materials.

2. MATERIALS AND METHODS

- Soil sample: Location – SL2 Water tank, Sindri, Dhanbad

- Reinforcement: Waste polypropylene fiber (12mm)

From: JOGANI REINFORCEMENT ENGINEERING FIBERS

Index and strength parameters of PP-fiber

Behavior parameters	Values
Fiber type	Single fiber
Unit weight	0.91 g/cm^3
Average diameter	0.034 mm
Average length	12 mm
Breaking tensile strength	350 MPa
Modulus of elasticity	3500 MPa
Fusion point	165 °C
Burning point	590 °C
Acid and alkali resistance	Very good
Dispersibility	Excellent

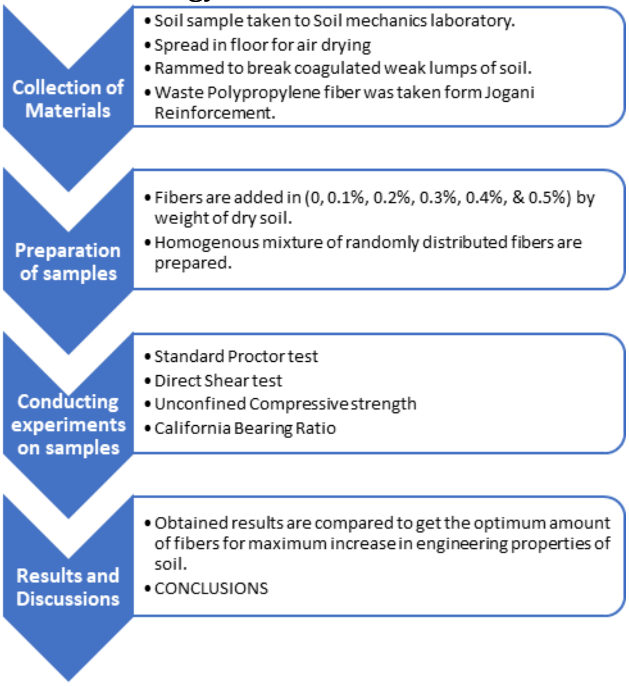
Table -1: Index and strength parameters of Polypropylene fiber

Fig. 1. Waste Polypropylene Fiber

Polypropylene fiber: Polypropylene is obtained as a by-product of petroleum refinery during production of petroleum or gasoline. It is thermoplastic. It is formed by the polymerization of propylene monomer. It is manufactured by propylene gas with titanium chloride as a catalyst.

It is very light is weight, high strength, hydrophobic in nature, resistant to chemical attack and low thermal conductivity.
It has low melting point and flammable in nature.

2.1 Methodology



3. RESULTS AND DISCUSSIONS

3.1 Properties of soil sample (unreinforced soil)

Sl. No.	Properties	Results
1	Specific Gravity	2.42
2	Sieve Analysis	56.60% passing through 75-micron
3	Liquid Limit, LL	31.73%
4	Plastic Limit, PL	17.10%
5	Classification of soil	Clay of low compressibility (CL)
6	Maximum Dry Density, MDD	1.87 g/cc
7	Optimum Moisture Content, OMC	13.93%
8	Unconfined Compressive Strength	0.21809 Kg/cm²
9	Cohesion, C	0.1133 Kg/cm²
10	Angle of internal friction, ϕ	18.78˚
11	California Bearing Ratio, CBR	1.87%

Table -2: Properties of soil sample

3.2 Engineering property tests:

These tests are conducted on unreinforced and reinforced soil with 0.10%, 0.20%, 0.30%, 0.40% & 0.50% fibers

1) Determination of Compaction Characteristics

Sl. No.	Description	OMC (%)	MDD (g/cc)
1	100% Soil	13.93	1.87
2	99.90% Soil + 0.10% fiber	13.65	1.88
3	99.80% Soil + 0.20% fiber	13.42	1.90
4	99.70% Soil + 0.30% fiber	13.08	1.91
5	99.60% Soil + 0.40% fiber	12.50	1.94
6	99.50% Soil + 0.50% fiber	13.56	1.89

Table 3: MDD and OMC values of soil for different percentage of fiber

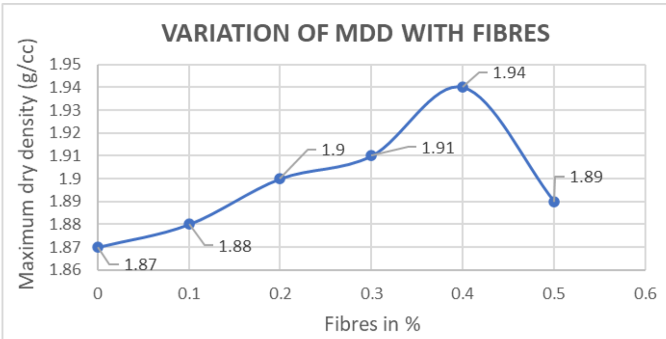


Fig. 2. Variation of MDD with fibers

➢ The variation of MDD with addition of different percentages of fibers by weight of soil shows that it increases up to 0.4% fiber then decreases.

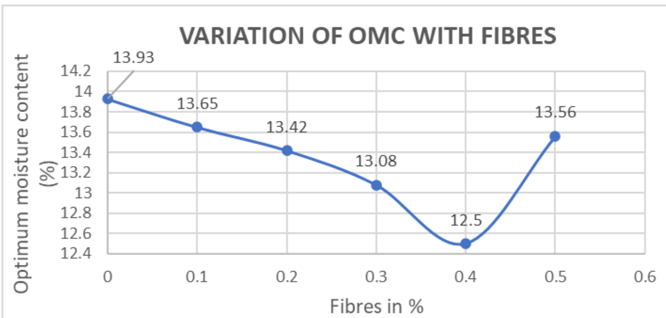


Fig. 3. Variation of OMC with fibers

➢ The variation of optimum moisture content with addition of different percentages of fibers by weight of soil shows it becomes minimum at 0.4% fiber then increases.

2) Unconfined compressive strength

Description	Unconfined Compressive strength UCS (Kg/cm²)
100% Soil	0.21809
99.90% Soil + 0.10% fiber	0.310
99.80% Soil + 0.20% fiber	0.3523
99.70% Soil + 0.30% fiber	0.37271
99.60% Soil + 0.40% fiber	0.38376
99.50% Soil + 0.50% fiber	0.36409

Table 4: UCS variation for different percentage of fiber

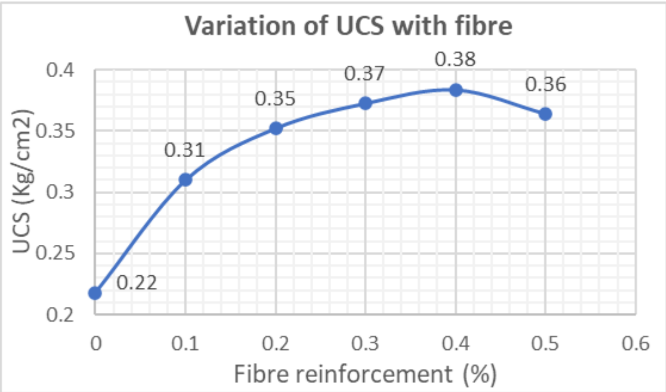


Fig. 4. Variation of UCS of soil with fiber

- The variation of UCS shows that the UCS increases up to 0.4% fiber then decreases. It increases from 0.22 Kg/cm² to 0.38 Kg/cm² for 0.4% fiber.

- The combined unconfined compressive strength graph for different percentages of fibers is shown below

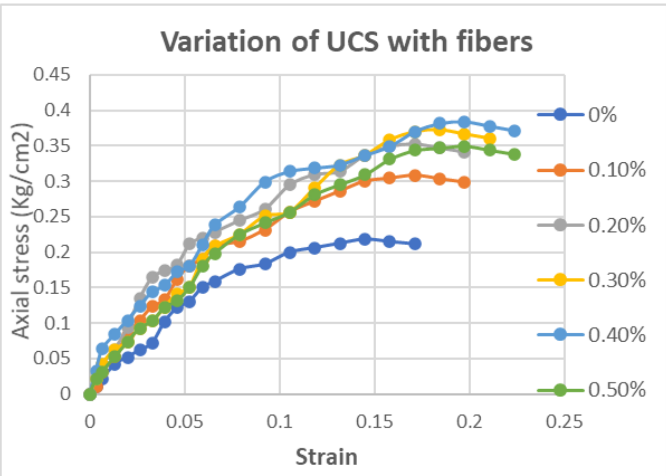


Fig. 5. Axial stress vs. strain graph for different percentage fiber

- The graph shows with increase in fiber percentage the failure occurs at increased strain.

3) Direct Shear test

Description	Cohesion C, (kg/cm²)	Angle of internal friction ϕ (degrees)
100% Soil	0.113	18.78
99.90% Soil + 0.10% fiber	0.159	18.21
99.80% Soil + 0.20% fiber	0.169	17.90
99.70% Soil + 0.30% fiber	0.184	17.679
99.60% Soil + 0.40% fiber	0.196	17.599
99.50% Soil + 0.50% fiber	0.199	17.097

Table 5: C and ϕ values for different percentage of fiber

- The variation of cohesion and angle of internal friction with fibers are shown below

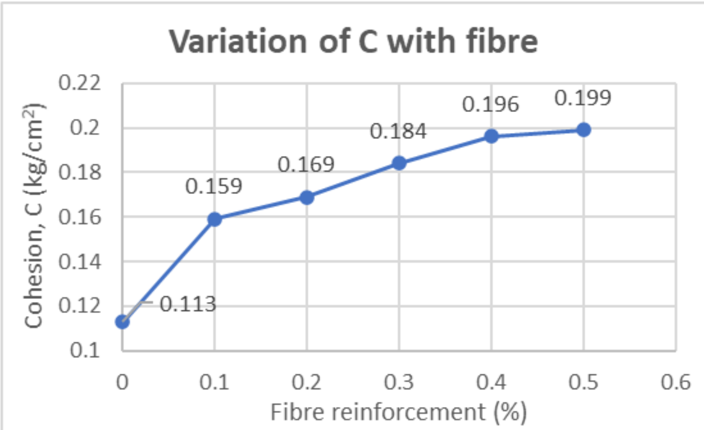


Fig. 6. Variation of cohesion of soil with different percentage of fiber

- The cohesion value increases with increase in fiber percentage up to 0.4% fiber then it becomes nearly constant.

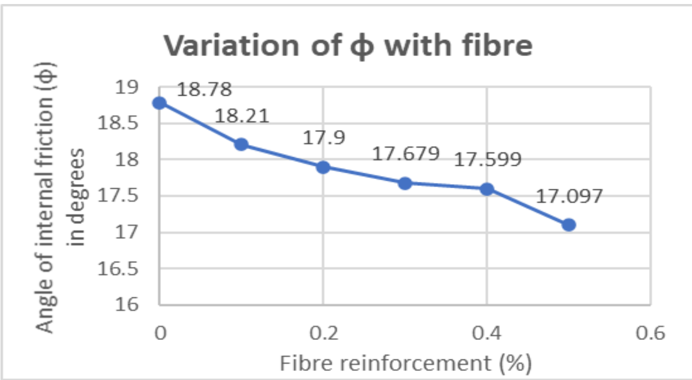


Fig. 7. Variation of angle of internal friction with fiber

- ϕ values shows a slight decrease with increase in fiber percentage and becomes nearly constant upto 0.4%

fiber and then abrupt decreases with further increase in fibers.

4) California Bearing Ratio test

Sl. No.	Sample Type	Unsoaked CBR (%)		CBR Value (%)
		2.5 mm	5 mm	
1	100% Soil	1.87	1.76	1.87
2	99.90% Soil + 0.10% fiber	2.129	2.1	2.129
3	99.80% Soil + 0.20% fiber	2.555	2.44	2.555
4	99.70% Soil + 0.30% fiber	3.066	2.896	3.066
5	99.60% Soil + 0.40% fiber	3.236	3.07	3.236
6	99.50% Soil + 0.50% fiber	2.981	2.896	2.981

Table 6: CBR value of soil for different percentage of fiber

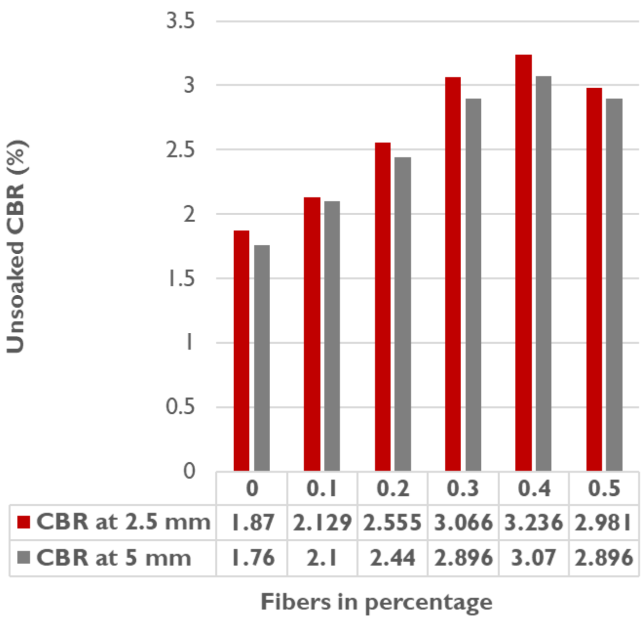


Fig. 8. Bar chart variation for unsoaked CBR for 2.5 mm and 5 mm penetration

- Maximum unsoaked CBR value obtained was 3.236% for 0.4% fiber. CBR value increases up to 0.4% fiber and decreases.

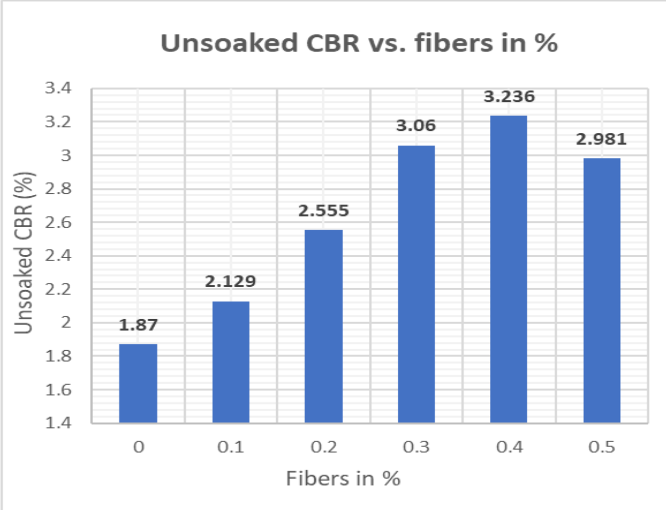


Fig. 9. Bar chart variation for Unsoaked CBR for different percentage of fiber

- Load verses penetration graph for different percentage reinforcement is shown below

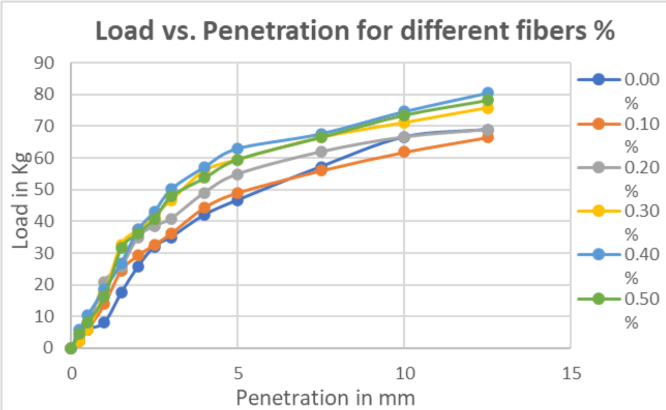


Fig. 10. Load vs. Penetration for different % fiber

4. CONCLUSIONS

According to the results of various experiments performed for the unreinforced and reinforced soil following interferences can be drawn for the engineering properties of soil.

- Results of Standard proctor test shows that there is increase in maximum dry density (MDD) of the soil from 1.87 to 1.94 for 0.40% fiber and then decreases for further increase in fiber percentage due to low specific gravity of the polypropylene fiber.
- Optimum moisture content (OMC) values shows that it decreases with increase in fiber percentage and then increases after 0.40% fiber reinforcement.
- The Unconfined compressive strength increases with increase in fiber percentage. It increases from 0.21809 Kg/cm^2 to 0.38376 Kg/cm^2, shows maximum for 0.4% fiber then decreases.

- From the axial stress vs. strain graph, it shows with increase in fiber percentage failure occurs at increased strains i.e., more deformation hence, ductility of the specimen increases.
- The cohesion increases to 0.199 kg/cm² from 0.113 kg/cm² for 0.5% fiber and angle of internal friction decreases to 17.599˚ from 18.78˚ for 0.4% fiber. This shows direct shear strength parameter cohesion increases and angle of internal friction decreases with addition of fibers. So, 0.4% fiber gives optimum results.
- On the basis of CBR test results, maximum CBR value is obtained for 0.40% fiber reinforcement shows a significant increase of 73.05%. This helps in decreasing the thickness of the subgrade.
- The increase in UCS and CBR is due to shear effect produced by randomly distributed fibers and then decreases may be due to increased fiber content causes slippage between fibers.
- Various experiments shows that 0.4% fiber reinforcement gives optimum results for strength enhancement.

From the above conclusion waste fiber reinforcement is very effective in enhancing various properties and bearing capacity of soil in cost-effective way and also helps in sustainable development.

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