

Influence of Polypropylene Fiber on the Strength Characteristics of Soil

Venkata Rathnam Ukkurthi

Managing Partner, Vensure Technos and Services
Corresponding Author Email: [ratnam108\[at\]gmail.com](mailto:ratnam108[at]gmail.com)

Abstract: *Enhancing the geotechnical characteristics of soil has become a standard procedure in the field of construction engineering since, in the end, it produces a sufficiently sturdy and long-lasting foundation- the most crucial component of any building project—and is known as soil stabilization. This study intends to investigate the use of polypropylene fiber as a stabilizer for soil and assess its impact on several soil qualities, including Atterberg Limits, Unconfined Compressive Strength, Maximum Dry Density, and Specific Gravity by combining different amounts of polypropylene fiber with a sample of soil.*

Keywords: soil stabilization, clayey soil, polypropylene

1. Introduction

The foundation is a critical component of any civil engineering construction project. The foundation eventually bears the load of any construction; hence, it is critical to build a suitable, solid foundation for every project. It is required to prepare the soil with a suitable bearing capacity in order to successfully transmit the weight of the structure onto the soil. Soil stabilization is the act of altering the physical properties of soil in order to increase its strength, durability, or other aspects. Soil stabilization is critical for road construction and other infrastructure development and maintenance problems. Soil stabilization is accomplished by adding lime, coconut coir, fly ash, plastic fiber, and other materials to the soil.

Polypropylene

Polypropylene (PP), commonly known as polypropene, is a thermoplastic polymer that is used in many different applications, including packaging. It is frequently utilized and generally accessible in ready-mix concrete. Polypropylene is the world's second most prevalent synthetic fiber after polyethylene. Polypropylene is represented chemically as C₃H₆.

Polypropylene Fiber Advantages:

- Polypropylene (PP) is a lightweight material.
- It is not absorbent. It has a high resistance to water absorption.
- Polypropylene has good chemical resistance. Most acids and alkalis have little effect on PP fibers.
- This fiber has a lower heat conductivity than other fibers

2. Materials used

1) Soil

Clayey soil was employed in the study. It was retrieved at Tirupati in Andhra Pradesh. It is a very plastic soil.

2) Reinforcement

Polypropylene fiber, a synthetic material, is used in this project. It results in a substantial rebound loss of 50-70%, demonstrating that it is a cost-effective strategy. The polymer utilized in the following studies has a length of 12 mm.

Table 1: Properties of Fiber

Fiber Properties	Values
Specific Gravity	0.91
Density(gm/cc)	0.91
Average length(mm)	6
Average diameter(mm)	0.034

3. Sample Preparation

The soil sample is cleaned of all organic matter and debris before being oven dried at about 105 °C and crushed. The varying percentages of fiber reinforcement used are 0%, 0.50%, 1.0%, 1.50% and 2.0%. The fiber content was initially hand-mixed into the air-dried soil sample in tiny increments, making sure that all of the fibers were well combined such that a reasonably homogeneous mixture was created, before adding the requisite water.

Table 2: Properties of Soil

S. No.	Properties	Value
1.	Specific Gravity(G)	2.72
2.	Density(ρ)	1.45 g/cc
3.	Liquid Limit(W _L)	76 %
4.	Optimum Moisture Content	18.5
5.	Shrinkage Limit	18.98%
6.	Maximum Dry Density	1.69 g/cc
7.	Unconfined Compressive Strength(q_u)	15.19 N/cm ²

4. Results & Discussion

1) Variation of Specific gravity

In both fine- and coarse-grained soils, the specific gravity of soil particle can be measured using a pycnometer. The following relationship is used to determine the specific gravity of soil.

$$G_T = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

M₁ = Weight of Empty Pycnometer

M₂ = Weight of Pycnometer and dry soil

M₃ = Weight of Pycnometer, soil and distilled water

M₄ = Weight of Pycnometer and distilled water

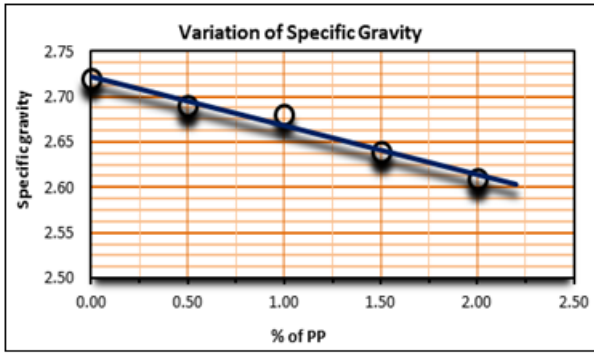


Figure 1: Variation of Specific Gravity

2) Variation of Atterberg limits

The water content at which soil behaves almost like a liquid yet has little shear strength is known as the soil's liquid limit. In just 25 blows, Casagrande's liquid limit mechanism closes the groove. Since it's challenging to obtain precisely 25 blows in a test, three to four tests are carried out, and the number of blows (N) needed in each test is ascertained. After that, a semi-log plot is created by connecting log N and water content (w). The water content that corresponds to N=25, as shown by the plot, is the liquid limit.

The soil's water content at which it is just enough saturated and the water just enough to fill all of the pores in the soil is known as the shrinkage limit. When the water content is lowered below the shrinkage limit, the volume of the soil does not diminish.

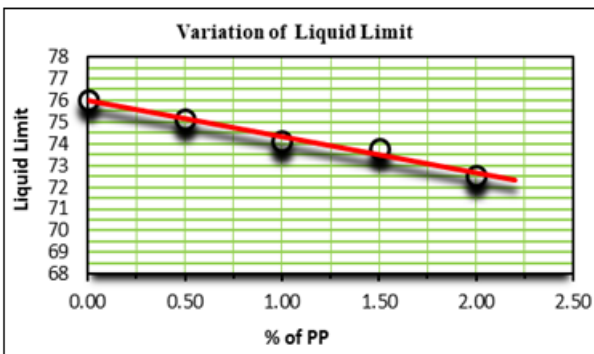
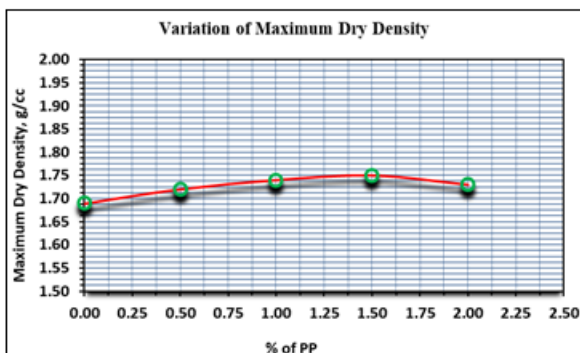


Figure 2: Variation of Specific Liquid limit

3) Variation of Maximum Dry Density

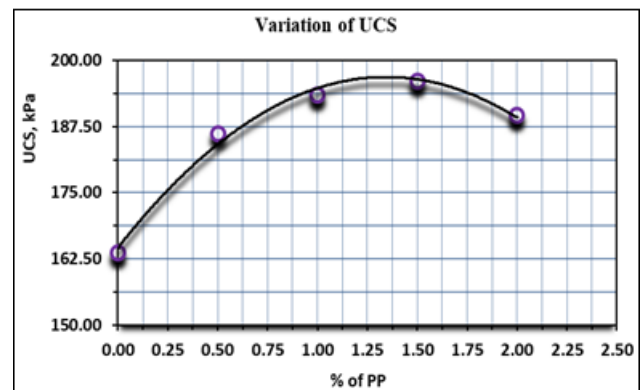
In a laboratory compaction test, various percentages of Polypropylene (PP) Fiber were mixed with the Soil. The percentages included 0%, 0.5%, 1%, 1.5%, and 2%. The resulting maximum dry density values at these respective percentages were recorded as follows: 1.69, 1.72, 1.74, 1.75, and 1.73.



This data reflects the influence of PP Fiber on the compaction characteristics of the material. The maximum dry density generally increases with the addition of PP Fiber, reaching its highest value at 1.5% (1.75). However, a slight decrease is observed at 2% (1.73), indicating a potential optimal percentage for enhancing compaction. The trend suggests that PP Fiber addition improves the packing of particles, resulting in higher dry density values. This can have implications for the engineering properties of the material, such as its strength, permeability, and durability. Further analysis of the data can help determine the most effective percentage of PP Fiber to achieve desired compaction characteristics for specific applications, balancing cost and performance factors.

4) Variation of Unconfined Compression Strength

In scenarios where field bearing capacity tests are impractical or costly, laboratory testing on undisturbed soil samples becomes a viable alternative. This method offers a more economical means to evaluate soil strength and select optimal materials for embankment construction. To this end, an experimental program was devised to determine the Unconfined Compressive Strength (UCS) values of soil samples with varying percentages of Polypropylene (PP) Fiber. The percentages tested included 0%, 0.5%, 1.0%, 1.5%, and 2.0%, with corresponding UCS values of 163.7, 186.2, 193.4, 196.1, and 189.6.



The data illustrates a notable trend: the UCS values generally increase as the percentage of PP Fiber in the soil mix rises. This suggests that the inclusion of PP Fiber enhances the soil's compressive strength. Such findings are crucial for engineers and designers when selecting the most suitable materials for embankment projects. By conducting these unconfined compression tests on undisturbed and remolded soil samples, a clearer understanding of the soil's strength characteristics is achieved, aiding in informed and cost-effective engineering decisions.

5. Concluding Remarks

1) Specific Gravity:

- The addition of PP Fiber did not significantly alter specific gravity values.
- Stability in specific gravity indicates consistent soil density.
- PP Fiber, within the tested range, showed no notable effect on overall soil mass per unit volume.

2) Atterberg Limits:

- PP Fiber reduced the liquid limit, indicating improved soil plasticity.
- An increase in shrinkage limit with PP Fiber suggests enhanced stability in soil volume changes.
- These changes demonstrate the positive influence of PP Fiber on soil plasticity and stability.

3) Maximum Dry Density:

- Maximum dry density increased with PP Fiber content.
- Optimal compaction was observed at 1.5% PP Fiber.
- A slight decrease at 2.0% PP Fiber suggests a limit to compaction enhancement.

4) Unconfined Compression Strength (UCS):

- UCS values consistently increased with higher PP Fiber content.
- The peak strength was observed at 1.5% PP Fiber.
- PP Fiber significantly enhanced the soil's compressive strength within the tested range.

These findings highlight the potential of Polypropylene (PP) Fiber as an effective soil stabilizer, improving soil properties such as plasticity, stability, compaction, and compressive strength. Engineers can utilize this data to make informed decisions regarding the use of PP Fiber in geotechnical projects, especially for soil stabilization applications.

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