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Comparative Study on Soil Stabilization using Coir Fibre and Polypropylene Fibre

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***Abstract*— Civil engineers have been using soil for decades since it is a cheap and readily available building material despite its poor physical properties. There are several methods to improve the engineering properties of the soil. But all those methods are not cost-effective and can cause environmental hazards. In this study, we used natural fibre like coconut coir fibre and synthetic fibre like polypropylene fibre. This project mainly focused on the compaction characteristics (MDD, OMC & UCS) and strength properties of expansive soils such as clayey soil. Compaction characteristics and bearing capacity can be improved by the stabilization process of soil. It is achieved by mechanically compacting the soil using heavy equipment or adding an admixture or reinforcing it. The reinforcement of soil with coir fibre is a low-cost technique, while the addition of polypropylene fibre has the advantage of being lightweight, durable, and effective in improving soil properties. This study compares the effects of coir fibre and polypropylene fibres on clayey soil through Standard Proctor tests, Unconfined Compressive Strength tests, and Liquid Limit tests.**

***Keywords*— Soil Stabilization, Coir Fibre, Polypropylene Fibre, OMC, Liquid limit, UCC**

I. INTRODUCTION

Foundations are very important in the construction sector to support and bear the load of the entire structure. Therefore, the foundation should be strong enough to extend the life of the structure. The strength of a foundation is highly dependent on the surrounding soil. Soils with low bearing capacity and low shear strength must be stabilized if they are to be used for construction purposes. In order to work with soil, one needs to be familiar with soil properties and factors that affect their behaviour. Soil stabilization means changing soil properties to improve soil stability or bearing capacity through controlled compaction, dosage or addition of admixtures. Clay is a variable and complex material that is often used for construction purposes due to its availability and low cost. However, in certain locations, clay soils may not be completely suitable for the intended purpose. In this case, adding a small amount of stabilizer can change the properties. Soil stabilization is obsolete due to outdated methods and a lack of engineering. In the modern era, soil stabilization is taking new forms as the demand for infrastructure and resources increases. Sustainable development cannot be achieved without introducing new technologies to make structures last longer. A variety of studies have been conducted on soil stabilization techniques and many methods have emerged that have proven to be effective in improving soil properties at an affordable price.

Fibre-reinforced soil acts as a composite material where the fibres add strength to the soil. The shear stress in the soil increases fibre tensile strength and increases the strength of the soil. The use of fibres in soil mimics the behaviour of plant roots and contributes to soil stability by adding strength to soils close to the surface where the effective stress is low. A growing body of research is being conducted in the field of geotechnical engineering on soil composites, made up of natural and synthetic fibres. Lump reinforcement is primarily used to increase the strength of a structure against deformation and shear failure by improving its stability. As mentioned earlier, soil enrichment is a method of improving soil properties using natural or artificial additives. Several reinforcement techniques are currently available to stabilize problematic soils. In this research, randomly distributed coir fibres and polypropylene fibres were used for soil stabilization. The purpose of this study is to focus on the improvement of shear strength parameters that affect its behaviour. Depending on the substrate, it stabilizes ground that is not suitable for foundations and exhibits the necessary performance for construction.

SCOPE AND OBJECTIVE

In this study, clay was stabilized with coir and polypropylene fibres. For varying fibre percentages, various geotechnical properties were calculated, including shear strength, optimum moisture content (OMC),

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Vol. 12 Issue 05, May-2023

maximum dry density (MDD), and unconfined compressive strength (UCS). Finally, the results were analyzed to find the maximum soil improvement.

The purpose of this research was to:

- Study the effects of coir fibres on the strength and compressibility based on shear parameters and compaction results.
- Compare MDD and OMC values of unreinforced soil and reinforced soil.
- Investigate the use of polypropylene fibres in geotechnical applications.
- Emphasize the economic efficiency of the construction industry.

II. LITERATURE REVIEW

Jyotesh Kumar Choudhary (2022)[3]: Presented a paper on "Study on Stabilization of Soil Using Polypropylene Fibre Waste" and in this study, waste polypropylene fibre was used as reinforcement. Compaction characteristics, unconfined compressive strength, direct shear test, and California bearing capacity ratio were evaluated for soil with randomly distributed small percentages (0%, 0.10%. 0.20%, 0 .30%, 0.40% and 0.50%) fibre. It was proven that fibre reinforcement is an effective method for improving soil properties. This study concluded that polypropylene fibre waste reinforcement was very efficient in improving different soil characteristics and bearing capacity of soil in an economical manner, as well as helping in sustainable development.

Yash Mishra (2022)[10]: A paper was presented on "Stabilization of Clay Soil Using Polypropylene Fibre" which aims to check the improvement of properties of clayey soil by adding polypropylene fibre. The soil parameters such as UCS and dry density were studied using different percentages of reinforcement (i.e. 0%, 0. 5%, 1%, and 1. 5%). The results of a series of tests were used to study the effect of reinforcement on clayey soil. It was concluded from the study that the fibre-reinforced soil was proven to be an effective soil development approach, especially for engineering projects on weak soils, where it can act as a substitute for deep/raft foundations, reducing both cost and energy.

Ujala Kumar (2022)[9]: The research paper was entitled as "Stabilization of Soil Using Coir Fibre". It focused on the compaction characteristics (MDD, OMC & UCS) and strength properties of expansive soils such as clayey soil. Coir-soil reinforcement is a low-cost approach to enhance soil properties. It studies the effects of coir on clay soil based on the results of standard Proctor tests, unconfined compressive strength tests, Atterberg limit test and California Bearing Ratio (CBR) tests. Coir fibre was added in varied proportions of 0.25%, 0.50%, 0.75%, and 1%. It was found that with the addition of coir at 0.5%, with clayey soil, the M.D.D changes from 1.87 g/cm3 to 1.96 g/cm3. C.B.R ratio from 2.12% to 6.71% and U.C.S value from 0.2058kg/cm2 to 0.3753 kg/cm2 at O.M.C 12.25%.

Anju Manoj (2022)[1]: The investigative paper entitled "Expansive Soil Stabilization using Glass Fibre and Epoxy Resin" aims to check the improvements in the properties of expansive soil by adding glass fibre and epoxy resin. The soil parameters such as liquid limit, plastic limit and maximum dry density were studied by varying the percentage of fibre and resin. It was found that, in the clayey soil, the value of M.D.D changes from 1.45g/cc to 1.67 g/cc and the C.B.R ratio changes from 2.01% to 5.9% with the inclusion of resin and glass. In this research, epoxy resin and glass fibre at 0.6% provide maximum soil strength.

P. Guruswamy Goud (2021)[5]: Published a paper on "Soil Stabilization Using Waste Fibre Materials". The purpose of the study was to investigate the use of waste fibrous materials in geotechnical applications. Direct shear tests and unconfined compression tests were done on two different soil samples to evaluate the shear strength of the unsaturated soil which was reinforced with waste polypropylene fibres. The applicability and effectiveness of fibre reinforcement as a substitute for deep foundations or raft foundations is the conclusion drawn from the obtained results.

J. Jagadeeshwar (2019)[2]: Published a paper on "Soil Stabilization by Using Coir Fibre". The experimental study was carried out in locally available soil reinforced with coir fibre. In this investigation, the soil sample was prepared at the maximum dry density corresponding to its optimum moisture content (OMC). The percentages of coir fibres were 0.25%, 0.5%, and 0.75%, based on the dry weight of the soil. Various Index properties were determined for the soil, and their shear strength was compared before and after coir addition.

III. METHODOLOGY

MATERIALS REQUIRED

1. CLAYEY SOIL:

Locally available clay soil collected from Chenkal, Neyyattinkara. A high percentage of fine particles are present in the soil, and when it is moist, it becomes sticky.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 12 Issue 05, May-2023

The water content of clay makes it plastic, but when it is dried or fired, it becomes hard, brittle, and non-plastic.

Fig.1: Clayey Soil

Table 1: Properties of Clayey Soil

PARAMETER	VALUES
Water Content	46..01%
Percentage of silt	44%
Percentage of clay	56%
Liquid Limit	58%
Specific Gravity	2.24
UCS	0.44 kg/cm^2
OMC	18%
MDD	1.31 g/cc

2. COIR FIBRE:

Locally available fibre was collected from the Neyyattinkara coir cluster. Coconut coir is a natural fibre extracted from coconut husks. This fibrous material is located between a coconut's hard internal shell and its outer coating. Unlike synthetic fibres, these fibres are biodegradable and environmentally friendly. It is the strongest natural fibre in terms of tearing strength and it retains this strength in wet conditions. As a result, coconut fibre has been chosen for this study as a reinforcement material.

Fig.2: Coir Fibre

Table 2: Physical Properties of Coir Fibre

PARAMETER	VALUES
Average Length	60mm
Average Diameter	0.22mm
Aspect Ratio	272.72

Advantages of coir fibre

- Coir fibre is a cost-effective and readily available material.
- It is rich in fibre and inherently non-toxic.
- Coir fibres are biodegradable and have low density.
- It has a high water retention value and is rich in micronutrients.
- It explores new uses without wasting fibre.
- It helps to create profitable employment to improve the living standards of individuals. .
- It is a renewable source and carbon dioxide-neutral material.

3. POLYPROPYLENE FIBRE:

Polypropylene fibre (PPF) is a linear polymer synthetic fibre derived from the polymerization of propylene. Besides being lightweight, this fibre is also resistant to absorbing moisture. Polypropylene fibres are resistant to alkalis.

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Fig.3: Polypropylene Fibre

Table 3: Physical Properties of Polypropylene Fibre

PARAMETER	VALUES
Average Length	12mm
Average Diameter	0.048mm
Aspect Ratio	250

Advantages of polypropylene fibre

- Polypropylene fibre is a light synthetic fibre.
- It has a low coefficient of friction.
- It has excellent moisture resistance.
- It shows good chemical resistance against a wide range of bases and acids.
- It minimizes volumetric shrinkage and expansion of soil.
- It helps to improve the shear strength of the soil.

IV. RESULTS AND DISCUSSION

Several tests have been performed to determine the properties such as liquid limit, UCC and maximum dry density with varying percentages of coir fibre and polypropylene fibre.

EFFECT OF COIR FIBRE

EFFECT OF COIR FIBRE ON MDD & OMC

The variation in the OMC and MDD on an increasing percentage of coir fibre is as follows:

Table.4: Effect Of Coir Fibre On OMC & MDD values

Percentage of Coir Fibre	Maximum Dry Density	Optimum Moisture Content
0.25%	1.37g/cc	17.6%
0.5%	1.41g/cc	15.2%
0.75%	1.42g/cc	14.1%
1%	1.4g/cc	16.6%
1.25%	1.39g/cc	17%
1.5%	1.38g/cc	17.4%

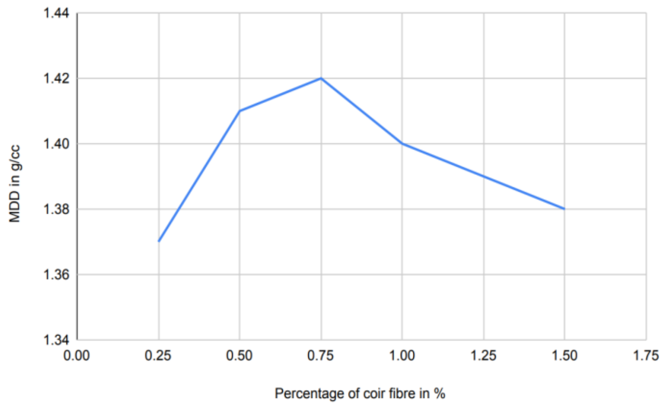

Fig.4: Effect of coir fibre on MDD

From the graph, it was observed that MDD value increased from 1.37 g/cc to 1.42 g/cc when the proportion of coir fibre increased from 0.25% to 0.75%. Further increment in coir fibre from 0.75% to 1.5% led to a decrease in MDD value from 1.42 g/cc to 1.38 g/cc respectively.

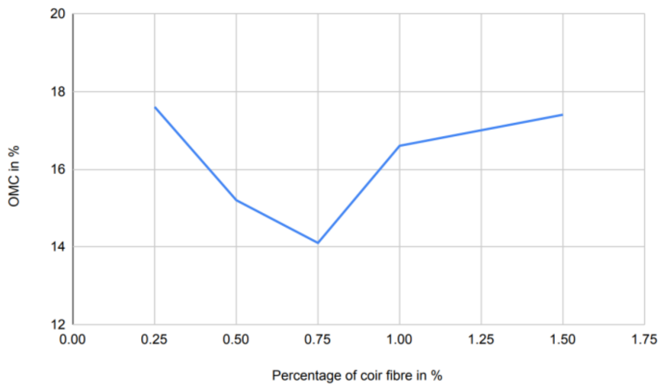

Fig.5: Effect of coir fibre on OMC

From the graph, it was observed that the OMC value decreased from 17.6% to 14.1% when the proportion of coir fibre increased from 0.25% to 0.75%. Further

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increment in coir fibre from 0.75% to 1.5% led to an increase in OMC value from 14.1% to 17.4% respectively.

EFFECT OF COIR FIBRE ON UCS

The variation in the UCS value on an increasing percentage of coir fibre is as follows:

Table.5: Effect of coir fibre on UCS values

Percentage of coir fibre	UCS (kg/cm^2)
0.25%	0.728
0.5%	1.01
0.75%	1.37
1%	1.193
1.25%	0.891
1.5%	0.784

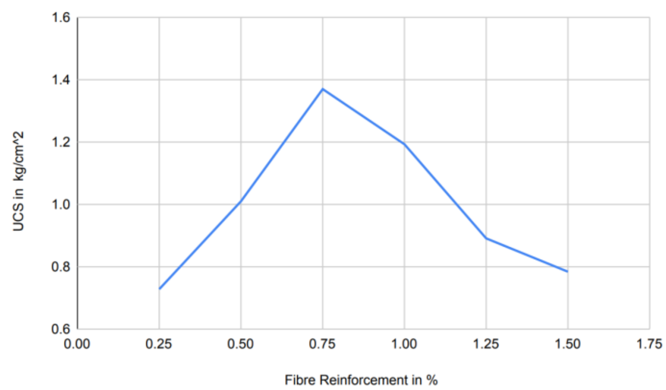

Fig.6: Effect of coir fibre on UCS

From the graph, it was observed that UCS value increased from 0.728kg/cm^2 to 1.37kg/cm^2 when the proportion of coir fibre increased from 0.25% to 0.75%. Further increment in coir fibre from 0.75% to 1.5% led to a decrease in UCS value from 1.37kg/cm^2 to 0.784kg/cm^2 respectively.

EFFECT OF COIR FIBRE ON LIQUID LIMIT

The variation in the liquid limit value on an increasing percentage of coir fibre is as follows:

Table.6: Effect of coir fibre on liquid limit values

Percentage of coir fibre	Liquid Limit
0.25%	51%
0.5%	48.4%
0.75%	46.8%
1%	47.5%
1.25%	49%
1.5%	49.8%

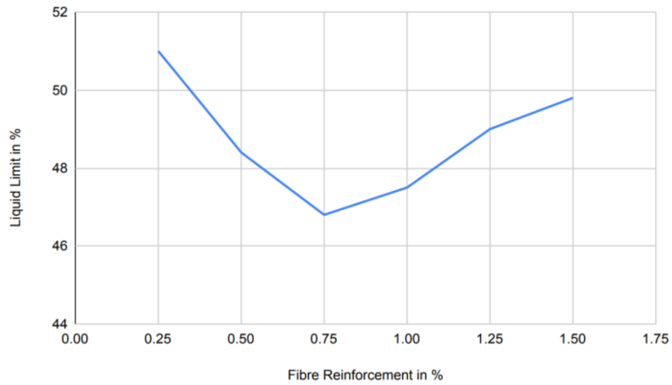

Fig.7: Effect of coir fibre on liquid limit

From the graph, it was observed that liquid limit value decreased from 51% to 46.8% when the proportion of coir fibre increased from 0.25% to 0.75%. Further increment in coir fibre from 0.75% to 1.5% led to an increase in liquid limit value from 46.8% to 49.8% respectively.

EFFECT OF POLYPROPYLENE FIBRE

EFFECT OF PPF ON MDD & OMC

The variation in the OMC and MDD on an increasing percentage of polypropylene fibre is as follows:

Table.7: Effect of PPF on MDD & OMC values

Percentage of PPF	MDD	OMC
0.25%	1.38g/cc	17.4%
0.5%	1.4g/cc	16.8%
0.75%	1.43g/cc	15.2%
1%	1.45g/cc	13.4%
1.25%	1.42g/cc	15.6%
1.5%	1.4 g/cc	16.4%

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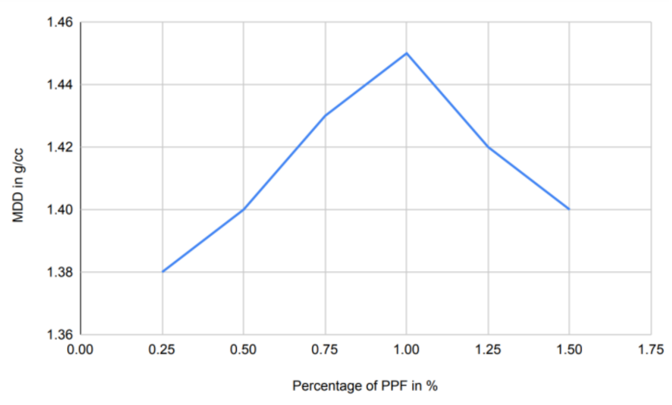

Fig.8: Effect of PPF on MDD

From the graph, it was observed that MDD value increased from 1.38g/cc to 1.45g/cc when the proportion of polypropylene fibre increased from 0.25% to 1%. Further increment in polypropylene fibre from 1% to 1.5% led to a decrease in MDD value from 1.45 g/cc to 1.4 g/cc respectively.

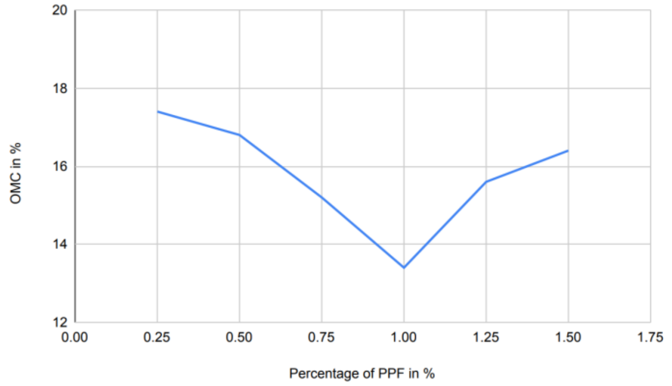

Fig.9: Effect of PPF on OMC

From the graph, it was observed that OMC value decreased from 17.4% to 13.4% when the proportion of polypropylene fibre increased from 0.25% to 1%. Further increment in polypropylene fibre from 1% to 1.5% led to an increase in OMC value from 13.4% to 16.4% respectively.

EFFECT OF PPF ON UCS

The variation in the UCS value on an increasing percentage of polypropylene fibre is as follows:

Table.8: Effect of PPF on UCS values

Percentage of PPF	UCS (kg/cm^2)
0.25%	0.894
0.5%	1.173
0.75%	1.322
1%	1.434
1.25%	1.266
1.5%	0.931

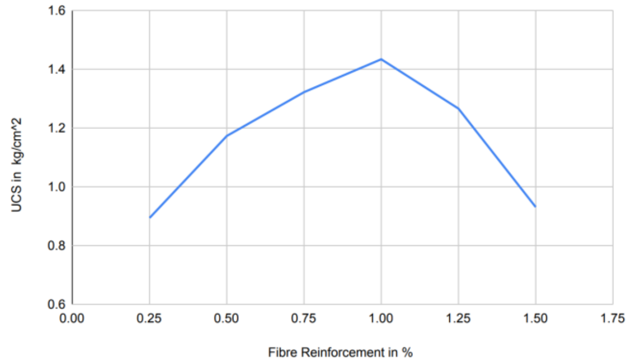

Fig.10: Effect of PPF on UCS

From the graph, it was observed that the UCS value increased from 0.894kg/cm^2 to 1.434kg/cm^2 when the proportion of polypropylene fibre increased from 0.25% to 1%. Further increment in polypropylene fibre from 1% to 1.5% led to a decrease in UCS value from 1.434kg/cm^2 to 0.931kg/cm^2 respectively.

EFFECT OF PPF ON LIQUID LIMIT

The variation in the liquid limit value on an increasing percentage of polypropylene fibre is as follows:

Table.9: Effect of PPF on liquid limit values

Percentage of PPF	Liquid Limit
0.25%	50.6%
0.5%	48%
0.75%	46.1%
1%	46.5%
1.25%	47.8%
1.5%	48.6%

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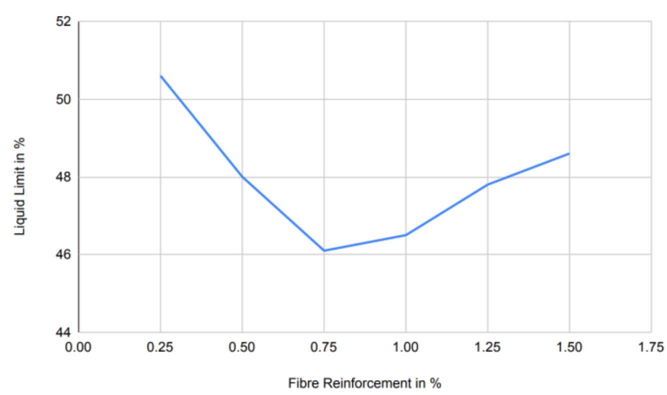

Fig.11: Effect of PPF on liquid limit

From the graph, it was observed that liquid limit value decreased from 50.6% to 46.1% when the proportion of polypropylene fibre increased from 0.25% to 0.75%. Further increment in polypropylene fibre from 0.75% to 1.5% led to an increase in liquid limit value from 46.1% to 48.6% respectively.

V. CONCLUSIONS

Based on the results of the experimental work on the soil stability investigation on clayey soil with different proportions of coir fibre and polypropylene fibre as reinforcement (0.25%, 0.50%, 0.75%, 1% and 1.25%), the following conclusions can be drawn:

- The soil used in the study contains more than 50% clay.
- The greatest improvement in dry density values (MDD) was observed when 0.75% of coir fibres were mixed with soil.
- The optimum MDD value for polypropylene fibre was found to be 1%.
- When compared to unstabilized soil, soil stabilized with coir fibre increased its MDD value by 8.4%, while soil stabilized with PPF increased its MDD value by 10.7%.
- The optimum UCS value for soil stabilized with coir fibre was 0.75% and PPF was 1%.
- The optimum value for liquid limit for soil stabilized with coir fibre and PPF was 0.75%.
- In light of the above data, it can be concluded that PPF is a durable and non-biodegradable synthetic fibre that provides greater strength to soil than coir fibre.

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