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Stabilisation of soil using sodium hydroxide treated polypropylene fiber

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Abstract-Soil stabilisation is the process by which strength properties of soil can be improved with the use of adding some materials like Lime, NaOH, polypropylene etc. There is a rapid increase in waste quantity of plastic fiber materials, these waste plastic fiber materials are generally dumped or thrown, which may deteriorate the ecology and environment, because these are non-biodegradable fiber materials. Among these, one of the waste fiber materials are polypropylene fiber materials. In this present work polypropylene fiber has been used as ingredients for soil stabilisation. The soil has been replaced by the polypropylene fiber in certain percentages and tests have been performed. The soil was replaced with varying proportions of polypropylene fiber to find out the optimum quantity of polypropylene fiber. From the experimental results, it has been found that various properties of the soil replaced with 1.0% of polypropylene fiber by weight of soil gives optimum results. The value of Unconfined Compressive Strength has increased from 3.24 kg/cm^2 to 7.41 kg/cm^2 which make it clear that it can be used to bear higher loads. The value of MDD has also been increased but percentage of increment is low.

Keywords —Polypropylene fiber, Soil, Sodium hydroxide, Maximum dry density, Optimum moisture content,, unconfined compressive strength.

I. INTRODUCTION

Soil is extremely complex, heterogeneous substance which has been subjected to varieties of nature. Properties of soil do not change only with location to location but also with respect to depth, climate and drainage condition of soil [1]. Foundation is very important part of any civil engineering construction work. Load of any structure is ultimately taken by foundation; hence it is very necessary to prepare a sufficient strong base for any structure. In India, a major portion of total land area is covered by clayey soil. Of this, a large proportion is expansive soil. These soils contain minerals such as montmorillonite that are capable of absorbing water. When they absorb water their volume increases. Structures such as spread footings, highways, railways, airport runways and earth dams etc. constructed over this expansive soil may be severely damaged due to its high swell-shrinkage behaviour. So such soils need to be stabilised to increase its strength, durability and to prevent erosion. Various studies have been carried out on expansive soils to improve its properties [2]. In the ancient time, some natural materials including wood, bamboo, reeds, wheat straw, and rice straw were used to improve the strength of soil. With the advent of synthetic fibers and its rapid development, plenty of synthetic fibers have been employed in many fields as innovative engineering materials, as well as main reinforcement agents for ground improvement, When some fibers geotextile of high tensile strength is laid in soil, the engineering properties of soil are improved, There is a rapid increase in waste quantity of plastic fibres, These waste plastic fibers are generally dumped or thrown, which may deteriorate the ecology and environment because these are non-biodegradable fiber materials. Among these, one of the waste fiber materials is Polypropylene fiber material which has been used as ingredients for soil stabilisation. From previous research work it is found that PP fiber does not influence the OMC but decreases the MDD [1],[3],[6],and according to [4],[5] MDD first increases slightly with PP fiber and then decreases. because the reduction of average unit weight of PP fiber in the soil-fiber mixture. and polypropylene fiber increases the unconfined compressive strength indicates that Polypropylene fibre reinforcement is more effective in improving tensile strength than the compressive Strength. Thus PP fibre enhances the ductile behaviour of soils, reducing shrinkage settlements [6] and the reinforced soil is known as fibers-reinforced soil. The soil can be treated and stabilised well at a relatively low cost by using this

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stabilizer [4],[7].In this experimental investigation, the aim was to study the effect of polypropylene fiber reinforcement on the improvement of physical and mechanical properties of a soil sample obtained from BIT Sindri college campus. The experimental program was carried out on compacted soil specimens with 0%, 0.25%, 0.5%, 0.75% , 1% and 1.25% polypropylene fiber additives, and the results of compaction test and unconfined compressive strength test are found. Despite the difficulties encountered in representative specimen preparation due to random distribution of fiber [6] ,the fiber has been treated with sodium hydroxide solution for their complete dispersion and thus difficulties in specimen preparation is minimised.

II. MATERIALS USED

For stabilisation of soil using polypropylene fiber, materials are described in table1.

Table: 1 Materials used

S.N.	Name of materials	Source of material/supplier
1.	Soil	B.I.T Sindri campus
2.	Polypropylene (PP)	Waltar enterprises, Navimumbai
3.	Sodium hydroxide (NaOH)	E-Merck Worli Mumbai
4.	Distilled water	
5.	Sodium carbonate	Pallav Chemicals &Solvents Pvt. Ltd. Tarapur, Boisar
6.	Sodium hexametaphosphate	E-Merck Worli Mumbai

A. SOIL

The soil sample used in this study has been collected from B.I.T. Sindri campus from a depth of 1m to 1.5 m below the ground surface by open excavation, the soil was dried and pulverized to perform the various experimental studies.

Table: 2 Properties of the natural soil [9], [10],[11],[12],[13],[14].

S. No.	Parameters	Values
1.	Specific gravity	2.47
2.	OMC	15.53 %
3.	MDD	1.74 g/cc
4.	Liquid limit	39.21%
5.	Plastic limit	21.96%
6.	Plasticity index	17.25%
7.	UCS	3.24kg/cm^2
8.	Soaked CBR	1.92%
9.	Unsoaked CBR	4.09%
10.	Percentage finer(clay + silt)	63.5%
11.	Classification of soil	CI

From the standard proctor test, the compaction curve was obtained as shown in figure:1.

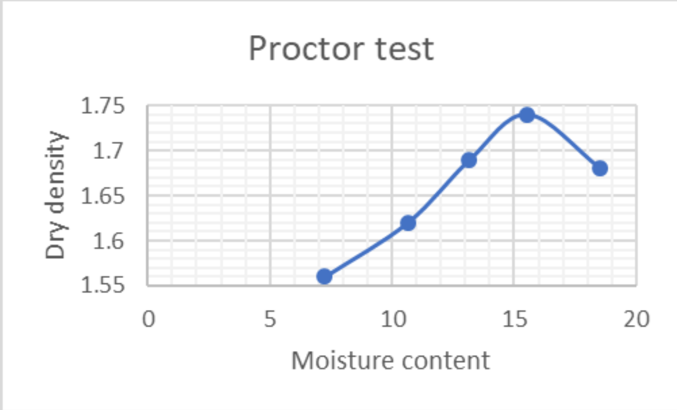

Figure:1 Moisture content-Dry density curve

From above curve

Maximum dry density= **1.74 g/cc**

Optimum moisture content= **15.53 %**

From wet sieve analysis and hydrometer test, Grain size distribution curve is plotted in figure: 2.

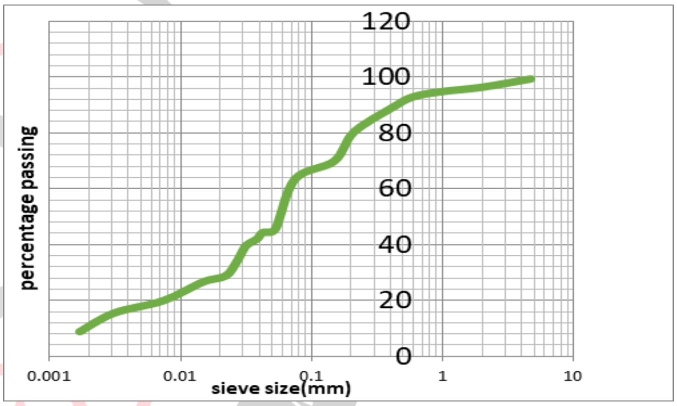

Figure:2 Grain size distribution curve of natural soil

From above graph and calculations, it is found:

Percentage of clay = 15.25%

Thus, the classification of soil is **CI (Clay with intermediate compressibility)**

B. Polypropylene fiber

Polypropylene is a thermoplastic polymer. It has high melting point of 160°c, high ignition point of 590°c, low thermal and electrical conductivity and hydrophobic and chemically inert nature which does not absorb or react with soil moisture or leachate, and its cost is low. And when mixed with soil it acts as reinforcement in the soil and increases the soil property and also increases the ductility of the soil and due to its hydrophobic and chemically inert nature it does not absorb the water and does not react with the water and soil particles. These fibers remain as it is after many more years it does not leach out .and from previous literatures it was observed that Polypropylene fiber is a good stabilising material. These polypropylene (PP) fibers are of 12 mm length. These micro fibers prevent crack formation and provide reinforcement. They are mainly used in mortar where thickness of plaster is 10 mm or more.

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They are suitable for waterproofing or repair of structures. Hence this fibre is suitable for the stabilisation of soil.

Figure:3 Polypropylene fibre

Figure:4 Polypropylene fibre showing 12 mm average size

SPECIFICATION OF POLYPROPYLENE FIBER

Table: 3: specification of PP fibre

Material	100% virgin polypropylene (pp)
Length	12.0+/- 0.25mm
Diameter	24 micron (approx.)
Aspect ratio	500 (approx.)
Melt point	162 degree centigrade
Specific gravity	0.91
Thermal and electric conductivity	Low
Alkali resistance	100% alkali proof
Acid and salt resistance	High

III. SAMPLE PREPARATION

TREATMENT OF PP FIBRE

PP Fiber is hydrophobic in nature they do not absorb any moisture content, these fibers are not dispersed properly in water. Thus NaOH is used for complete dispersion of PP

.

Following steps to be carried out for the treatment of fibre

- Solution of 2% NaoH was made
- PP fibres were weighed and dispersed for 10-20 hours
- PP fibers were taken out and washed in distilled water
- Oven dried for 20-24 hour at temperature of 65^{0}C-70^{0}C
- And again fibres were weighed to ensure that there is no weight gain in fibres and the fibres so obtained is treated and is ready for use as reinforcement in soil.

Figure:5 Dispersion of PP fibre in NaOH solution

Dosing:
Different %ge of PP fiber i.e. 0.25%,0.5%,0.75%,1.0% and 1.25% of PP fiber by weight of soil are used.

Mixing:
Treated PP fibers are then mixed with soil by hand properly to get uniform mix and added water as per requirement.

Figure:6 mixing of PP fiber with soil

Sample preparation for Testing of soil

For experimental study different samples have been prepared with different proportions of polypropylene fiber, which have been given in the table:4.

Table:4 Sample preparation

S.N.	Percentage of soil (by weight)	Percentage of PP (by weight)
1.	100 %	0%
2.	99.75%	0.25%
3.	99.5%	0.50%
4.	99.25%	0.75%
5.	99.0%	1.0%
6.	98.75%	1.25%

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IV. EXPERIMENTAL INVESTIGATION

A. PROCTOR COMPACTION TEST

The Proctor compaction test is a laboratory **geotechnical** testing method used to determine the soil compaction properties, specifically, to determine the **optimum** moisture content at which soil can reach its **maximum** dry density. The optimum moisture content (OMC) and maximum dry density (MDD) can be determined in the laboratory by performing a standard test which was designed by Proctor. As per Proctor, a definite relationship exists between the soil moisture content and the degree of dry density to which a soil may be compacted. For a specific amount of compaction energy applied on the soil there is one moisture content at which a particular soil attains maximum dry density, this moisture content is called optimum moisture content (OMC). Maximum dry unit weight obtained is a function of Compactive effort and method of compaction for a particular type of soil. Compactive effort is a measure of mechanical energy applied to the soil mass.

B. UNCONFINED COMPRESSIVE STRENGTH (UCS) TEST

The main objective of this test is to determine the unconfined compressive strength of a cohesive soil. It is defined as the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test. Since there is no confining pressure (i.e. cell pressure), so it is called unconfined compression test.

V. RESULTS AND DISCUSSION

Test Results of the Modified Soil

The results obtained from the Standard proctor test and unconfined compression test have been analysed to study the effect of polypropylene fibers on the behaviour of soils. During the investigation ,it was observed that the strength of fiber reinforced soil at optimum moisture content increased with increasing amount of fiber and the water content-density relationship shows that increase in the fiber content up to 1 % by dry weight of soil has significant effect on the magnitude of maximum dry density and optimum moisture content . The variation of maximum dry density and optimum moisture contents with PP fiber are shown in figure 7 & 8.

Proctor test data: Table 5 shows the Variation of maximum dry density with the variation of polypropylene fibres

Table5: Values of OMC & MDD Test results [14]

S.N.	Soil (%)	PP (%)	MDD (g/cc)	OMC (%)
1.	100.00	0	1.74	15.53
2.	99.75	0.25	1.69	16.92
3.	99.50	0.50	1.71	15.93
4.	99.25	0.75	1.75	15.48
5.	**99.00**	**1.00**	**1.78**	**14.51**
6.	98.75	1.25	1.71	17.82

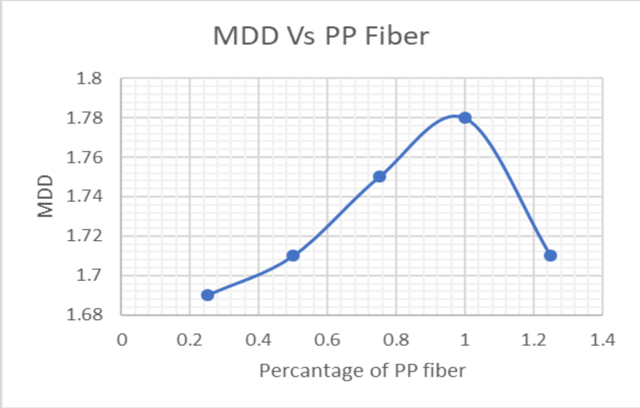

Figure:-7 Variation of MDD with % of PPF

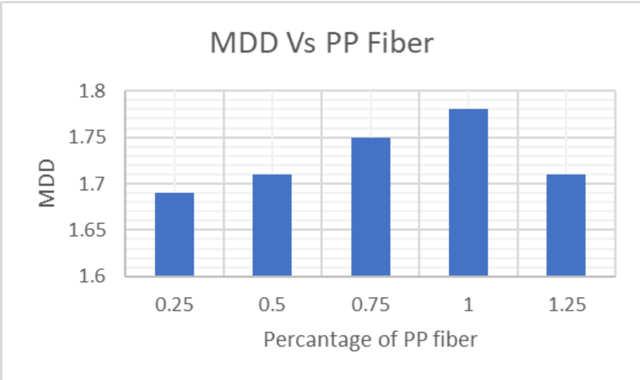

Figure:8 Bar chart Variation of MDD with % of PPF

From the proctor test data it was observed that the strength of fiber reinforced soil at optimum moisture content increased with increasing amount of fiber and the water content-density relationship shows that increase in the fiber content up to 1 % by dry weight of soil has significant effect on the magnitude of maximum dry density and optimum moisture content . The variation of maximum dry density and optimum moisture contents with PP fibers are shown in above figure. The above graph shows that maximum dry density of soil increases with the increase in polypropylene fiber upto 1 % of PP fiber and then decreases, but the increment in MDD is not much more due to low density of PP fiber.

Unconfined Compressive Strength Test Data

Values of UCS of the soil sample mixed with different percentages of PP fiber and its variation with natural soil have been given in table 6

Table 6: Values of UCS Test results [9]

S.N.	Soil (%)	PP (%)	UCS (kg/cm^2)
1.	100.00	0	3.24
2.	99.75	0.25	3.58
3.	99.50	0.50	5.13
4.	99.25	0.75	6.21
5.	**99.00**	**1.00**	**7.41**
6.	98.75	1.25	5.27

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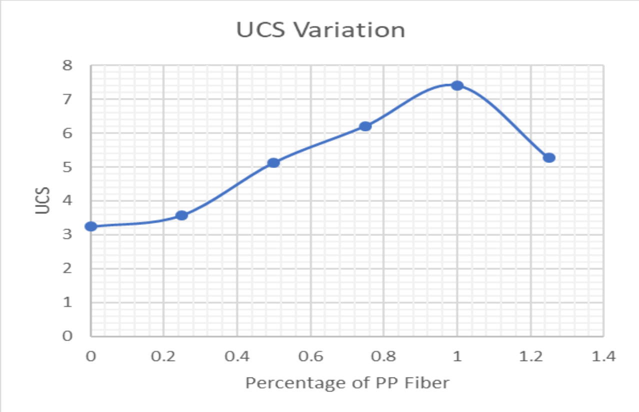

Figure: 9 Variation of unconfined compressive strength with % of PPF

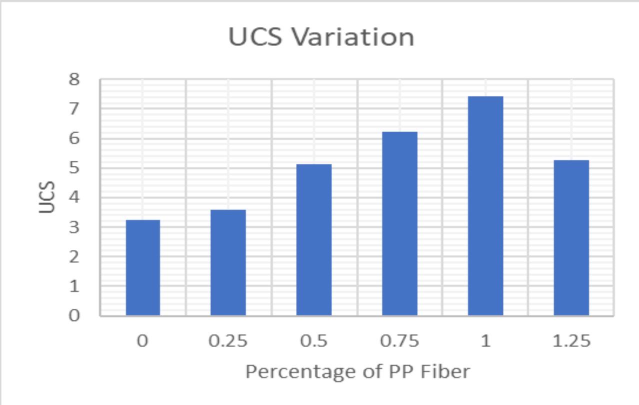

Figure:-10 Bar chart Variation of UCS with % of PPF

From unconfined compression test, it was observed that the unconfined compressive strength of natural soil is 3.24 $kg/cm^2$and the strength value increases to 7.41 kg/cm^2 at polypropylene of 1% and then decreases. There is an increase in strength of about 128.70% at 1% fiber content The variation of maximum value of unconfined compressive strength with respect to polypropylene fiber is shown in table 6 and graph is shown in figure 9 and 10.

VI. CONCLUSION

This study investigated the effect of polypropylene fiber reinforcement on the improvement of physical and mechanical properties of soil sample. From the experimental results, it has been found that various properties of the soil replaced with 1.0% of PP fibre by weight of soil gives optimum results. The value of Unconfined Compressive Strength has increased from 3.24 kg/cm^2 to 7.41 kg/cm^2 which make clear that it can be used to bear higher loads. The value of MDD has also been increased but percentage of increment is low.

APPENDIX

LIST OF ABBREVIATION USED

CBR-California bearing ratio
CI-Clay with intermediate compressibility
MDD-Maximum dry density
NaOH-Sodium hydroxide
OMC-Optimum moisture content
PP-Polypropylene
UCS-Unconfined compressive strength

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