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Soil Stabilisation Using Polypropylene as Waste Fibre Material

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ABSTRACTS: There is a rapid increase in generation of waste plastics all around the world due to Economic Growth, Changing Consumption and Production Patterns. The world's annual consumption of plastic materials has increased from around 5 million tonnes in the 1950s to nearly 100 million tonnes. Thus, presently 20 times more plastic is produced as compared to 50 years ago. In Asia and the Pacific, as well as many other developing regions, plastic consumption has increased much more than the world's average due to rapid urbanization and economic development. So, with this, more and more resources are being used to meet the increased demand of plastics, which results in higher generation of plastic waste. After food waste and paper waste, plastic waste is the third major constituent at municipal and industrial waste in cities. Even the cities with low economic growth have started producing more plastic waste due to increased use of plastic packaging, plastic shopping bags, PET bottles and other goods/appliances using plastic as the major component. This situation gets worsened due to the fact that they are not even aware of the ill-effects of plastic waste to environment. Due to extremely long periods required for natural decomposition, waste plastic is often the most visible component in waste dumps and open landfills. Plastic waste recycling can provide an opportunity to collect and dispose off, plastic waste in the most environmental friendly way and conversely, it can be converted into a resource. Due to growing concern about the disposal of plastic waste, and the panic in the current environmentalist, the object of this thesis was chosen as "Soil Stabilisation Using Polypropylene as Waste Fibre Material" which is one of the types of the plastic waste. In this research work, an extensive laboratory work has been done to investigate the use of the waste fibres of the polypropylene for the improvement of the various properties of the Clayey (CL) type of soil obtained from Ambala City, Haryana (India). The physical properties of the "Plain Soil" as well as "Reinforced Soil" such as Maximum Dry Density at Optimum Moisture Content, Direct Shear Strength Parameters and Unconfined Compressive Strength have been determined with the use of waste fibres polypropylene in variation of length of 10mm, 20mm & 30mm at different percentage 0 %, 0.15%, 0.25% & 0.35% of waste fibre material by weight of the dry soil sample.

KEYWORDS: Soil Stabilisation, Fibres of Waste Plastics, Reinforcement, Polypropylene, Maximum Dry Density, Optimum Moisture Content, Direct Shear Strength Parameters, Unconfined Compressive Strength.

I. INTRODUCTION

Soil is highly Complex, Heterogeneous and Unpredictable material which has been subjected to vagaries of nature, without any control. The properties of soil change not only from one place to other but also at the place with depth and with a change in the environmental, loading and type, drainage and the conditions under which it exists. In comparison to other construction materials such as concrete or steel, it is not economically feasible to transport the soils from one place to other, because a huge quantity of soil is involved and it is not opened to inspect at greater depth for foundations of different structures. Sometimes, Civil Engineers are forced to construct structure at site selected for reasons other than soil conditions. Thus, it is increasingly important for the engineer to know the degree to which the engineering properties of the soil may improve or other alternatives that can be thought off for the construction of intended structure at the stipulated site. If unsuitable soil conditions are encountered at the site of a proposed structure, unsuitable soil can be bypassed by means of deep foundation extended to a suitable bearing

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material, poor material can be removed and replaced by a suitable material, or soil in-place can be treated by using any suitable ground improvement methods (soil stabilisation) to improve its engineering properties.

Therefore, to work at the selected site, we need to have proper knowledge about their properties and factors which affect their behaviour. Hence, from the beginning of construction work, the necessity of enhancing the soil properties has come to the light and the process of soil stabilisation helps us to achieve the required properties in a soil needed for the construction work. Site feasibility study for geotechnical projects is of far most beneficial before a project can take off. Site survey usually takes place before the design process begins in order to understand the characteristics of subsoil upon which the decision on location of the project can be made. The following geotechnical design criteria have to be considered during site selection:

- i) Design load and function of the structure.
- ii) Type of foundation to be used.
- iii) Bearing capacity of subsoil.

In the past, the third criteria played a major role in decision making on site selection and once the bearing capacity of the soil was poor, the following were options:

- i) Change the design to suit site condition.
- ii) Remove and Replace the in-situ soil.
- iii) Abandon the site.

Abandoned sites due to undesirable soil bearing capacities dramatically increased, and the outcome of this was the scarcity of land and increased demand for natural resources. Affected areas include those which were susceptible to liquefaction and those covered with soft clay and organic soils. Other areas were those in a landslide and contaminated land. However, in most geotechnical projects, it is not possible to obtain a construction site that will meet the design requirements without ground modification. The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications. Nowadays, soils such as, soft clays and organic soils can be improved to the civil engineering requirements. This state of the art review focuses on soil stabilisation method which is one of the several methods of soil improvement.

II. MATERIALS USED

2.1 SOIL

In the present study the soil procured from Ambala City, Haryana (India) had been investigated and depending on the properties given below in Table-1 the soil had been classified as CL (Clayey Soil with Low Compressibility).

Table 1: Determination of Classification of Soil Depending on the Index Properties

Sr. No.	Properties of the Soil Sample	Values of the Different Properties
1.	Liquid Limit	28.10%
2.	Plastic Limit	16.26%
3.	Plasticity Index (IP)	11.84
4.	Type of Soil as per IS: 1498	CL
5.	Specific Gravity (G)	2.62

The various engineering properties of the plain soil have been determined and are tabulated as given below:

Table 2: Values of Engineering Properties of the Plain Soil

Sr. No.	Engineering Property of the Plain Soil Sample	Observed Value
1.	Compressibility (MDD) Maximum Dry Density, ($\gamma_{d(max)}$) Optimum Water Content, (w)	2.06 g/cc 10.90 %
2.	Direct Shear Strength (DSS) Angle of Internal Friction (Φ) Cohesion (c)	23.59° 0.32 kg/cm ²
3.	Unconfined Compressive Strength, (UCS)	2.14 kg/cm ²

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2.2 STABILISING MATERIAL

In this research work, soil stabilisation have been carried out with waste fibre material –polypropylene (randomly distributed)obtained from the Supreme Industries, Village – Sersen (Lalru), Ambala – Chandigarh Highway, Distt.- S.A.S.Nagar, Punjab; producing a number of plastic items which are globally used for the different works.

III.METHODOLOGY ADOPTED

Laboratory investigations were conducted on the plain soil and soil reinforced with the fibres of the waste polypropylene in variation of length of 10mm, 20mm & 30mm at different percentage 0.15%, 0.25% and 0.35% of waste fibre material by weight of the dry soil sample for the improvement of Compressibility (MDD), Direct Shear Strength (DSS) and Unconfined Compressive Strength (UCS) of the soil.

IV.EXPERIMENTAL INVESTIGATIONS AND RESULTS

4.1 Compaction Test

The Modified Proctor’s Test have been conducted for the determination of the Optimum Moisture Content (w) and Maximum Dry Density ($\gamma_{d(max)}$) of the plain (Table-3) as well as reinforced soil (Table-4) by compacting the soil samples manually.

Table 3: Data for OMC-MDD of Plain Soil Samples

Sr. No.	Sample No.	Dry Density (g/cc)	Water Content (%)
1.	1	2.03	8.39
2.	2	2.06	10.90
3.	3	1.99	13.50
4.	4	1.84	18.80

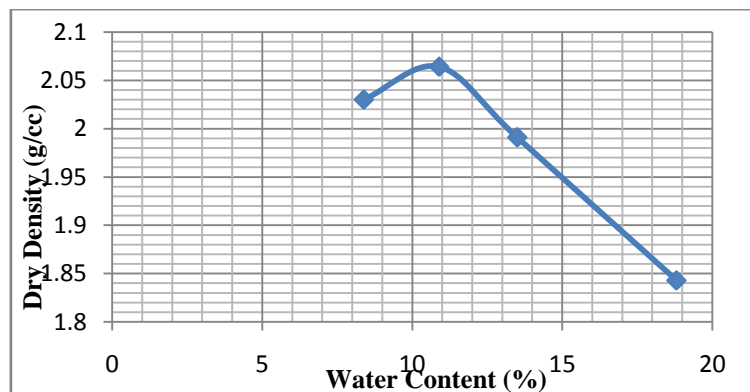


Fig. 1: OMC – MDD Curve for Plain Soil Sample

The maximum dry density of the plain soil has been found as 2.06g/cc at 10.90% of optimum moisture content from the curve drawn in fig.1 and tabulated given below in Table-5.

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Table 4: Data of OMC – MDD for the Soil Reinforced with Polypropylene

Sr. No.	Length of PP	Percentage of PP 0.15%		Percentage of PP 0.25%		Percentage of PP 0.35%	
		Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)
1.	10 mm	1.89	8.15	1.94	8.47	1.78	8.09
		1.97	10.09	2.05	11.51	1.97	9.87
		2.05	11.56	2.03	12.63	2.02	11.47
		1.93	13.75	1.89	13.82	1.88	12.95
		1.86	15.91	1.78	15.87	1.75	14.23
2.	20 mm	1.96	8.03	1.96	7.93	1.92	8.02
		2.04	11.83	1.99	9.90	1.99	9.93
		1.98	12.98	2.02	11.80	2.02	11.85
		1.89	14.27	1.97	12.41	1.94	13.97
		1.82	15.91	1.92	13.97	1.79	14.89
3.	30 mm	1.92	7.73	1.96	8.10	1.92	7.95
		2.00	9.92	2.01	10.15	1.97	8.87
		2.04	12.13	2.04	11.97	2.02	11.86
		1.92	13.94	1.94	14.09	1.96	13.68
		1.79	14.89	1.81	15.93	1.87	15.79

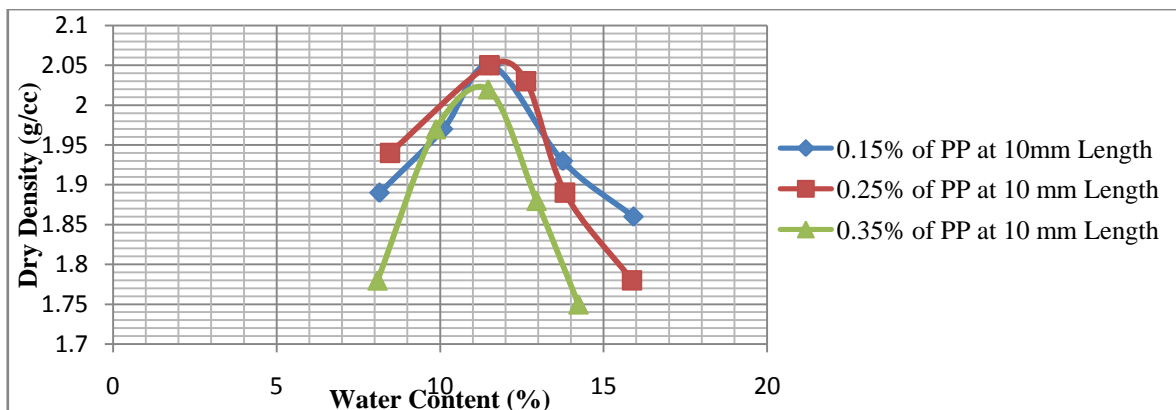


Fig. 2: OMC–MDD Curve for the Soil Reinforced with PP at 10mm Length

The maximum dry density of the soil reinforced with different percentages of PP at 10 mm length has been found from the curve drawn in fig.2 and are tabulated given below in Table-5.

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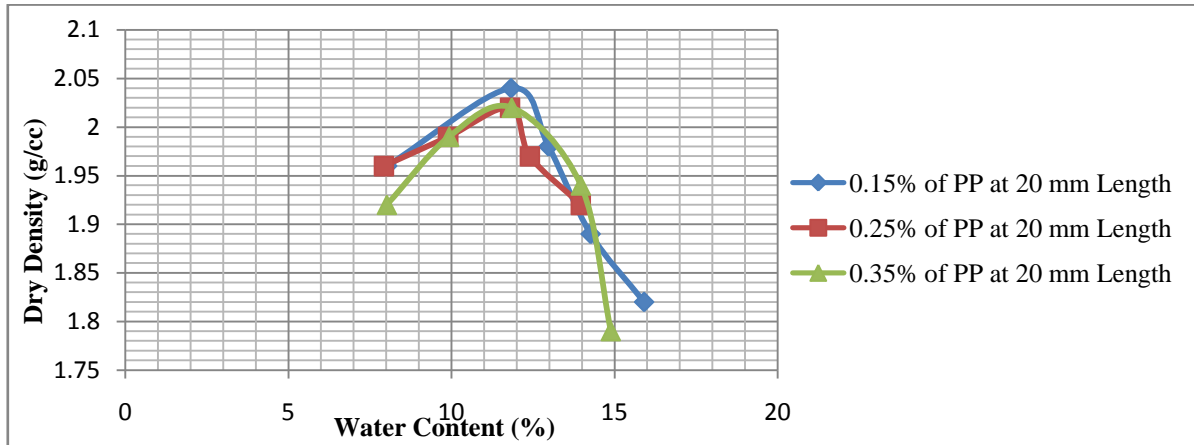


Fig. 3: OMC-MDD Curve for the Soil Reinforced with PP at 20mm Length

The maximum dry density of the soil reinforced with different percentages of PP at 20 mm length has been found from the curve drawn in fig.3 and are tabulated given below in Table-5.

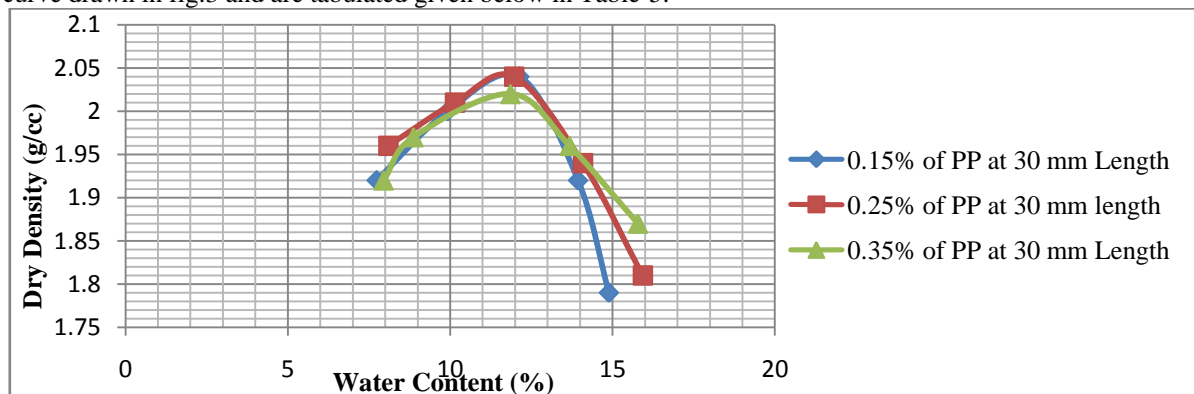


Fig. 4: OMC-MDD Curve for the Soil Reinforced with PP at 30mm Length

The maximum dry density of the soil reinforced with different percentages of PP at 30 mm length has been found from the curve drawn in fig.4 and are tabulated given below in Table-5.

Table 5: The values of OMC-MDD

Length of PP	Percentage of PP 0%		Percentage of PP 0.15%		Percentage of PP 0.25%		Percentage of PP 0.35%	
	Max. Dry Density (g/cc)	Optimum Moisture Content (%)	Max. Dry Density (g/cc)	Optimum Moisture Content (%)	Max. Dry Density (g/cc)	Optimum Moisture Content (%)	Max. Dry Density (g/cc)	Optimum Moisture Content (%)
10 mm	2.06	10.90	2.05	11.56	2.05	11.51	2.02	11.47
20 mm			2.04	11.83	2.02	11.80	2.02	11.85
30 mm			2.04	12.13	2.04	11.97	2.02	11.86

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4.2 Direct Shear Strength (DSS) Parameters of the Soil

The clayey soil samples of plain and reinforced with the fibres of waste polypropylene had been tested by using the direct shear test apparatus at the maximum dry density ($\gamma_{d(max)}$), and optimum moisture content (w), for the analysis of the direct shear strength parameters and the results for the same has been tabulated as given below in Table-6.

Table 6: Values of DSS Parameters of the Soil

Sr. No.	Percentage of PP	Length of PP					
		10mm	20mm	30mm	10mm	20mm	30mm
		Angle of Internal Friction, Φ			Cohesion, c (kg/cm ²)		
1.	0%	23.59°			0.32		
2.	0.15%	24.08°	25.64°	26.86°	0.35	0.37	0.38
3.	0.25%	25.79°	27.46°	28.64°	0.37	0.41	0.43
4.	0.35%	28.28°	29.53°	28.48°	0.44	0.47	0.42

The comparisons of the direct shear strength parameters of the plain soil with the direct shear strength parameters of the reinforced soil are as follows:

Table 7: Comparisons of Increase in DSS of Reinforced Soil with Plain Soil

Sr. No.	Percentage of PP	Length of PP					
		10mm	20mm	30mm	10mm	20mm	30mm
		Increase in Angle of Internal Friction (Φ)			Increase in Cohesion (c)		
1.	0%	23.59°			0.32 kg/cm ²		
2.	0.15%	2.08%	8.69%	13.86%	9.38%	15.63%	18.75%
3.	0.25%	9.33%	16.41%	21.41%	15.63%	28.13%	34.38%
4.	0.35%	19.88%	25.18%	20.73%	37.50%	46.88%	31.25%

The increase in angle of internal friction with the addition of waste fibres of PP has been graphically shown in fig.5

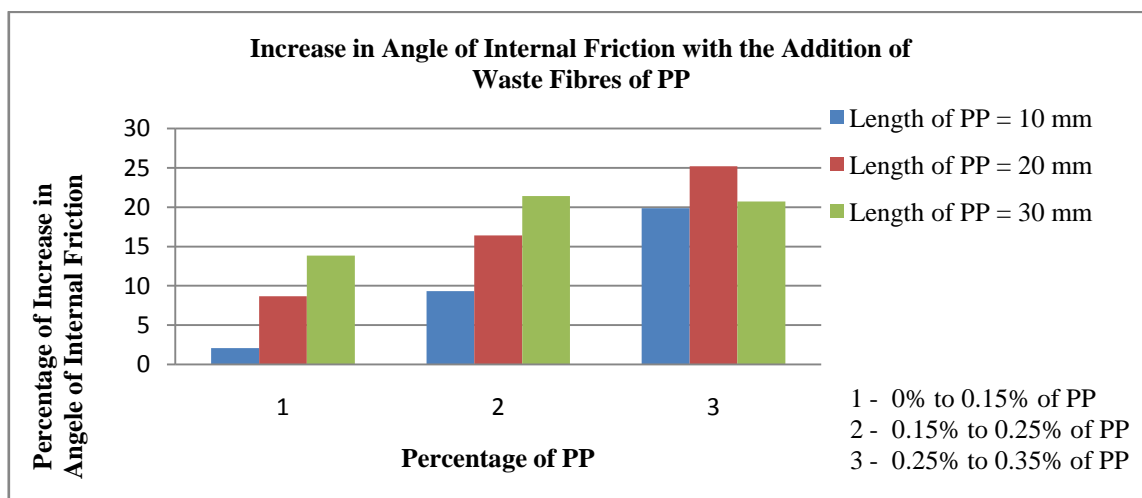


Fig. 5: Increase in Angle of Internal Friction with the Increase in Waste Fibres of PP

The increase in cohesion with the addition of waste fibres of PP has been graphically shown in fig.6

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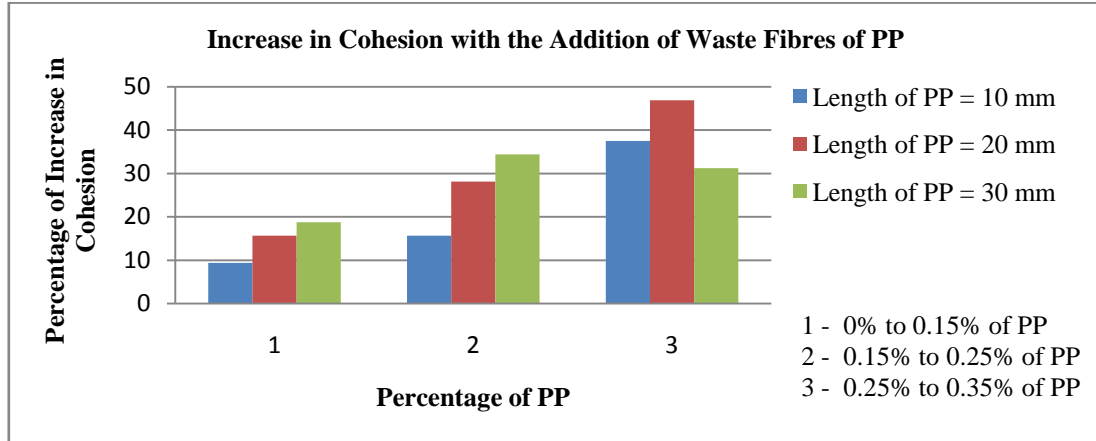


Fig. 6: Increase in Cohesion with the Increase in Waste Fibres of PP

It has been observed from the experimental investigations that the direct shear strength parameters has been increased with the addition of the waste fibres of PP, depending on which the incremental increase in DSS parameters has been tabulated as given below in Table-8.

Table 8: Incremental Increase in DSS of Reinforced Soil

Sr. No.	Percentage of PP	Length of PP					
		10mm	20mm	30mm	10mm	20mm	30mm
		Incremental Increase in Angle of Internal Friction, Φ			Incremental Increase in Cohesion, c		
1.	0%	23.59°			0.32 kg/cm ²		
2.	0.15%	2.08%	8.69%	13.86%	9.38%	15.63%	18.75%
3.	0.25%	7.10%	7.09%	6.63%	5.71%	10.81%	13.16%
4.	0.35%	9.65%	7.54%	(-) 0.56%	18.92%	14.63%	(-) 2.38%

The incremental increase in angle of internal friction with the addition of waste fibres of PP has been graphically shown in fig.7

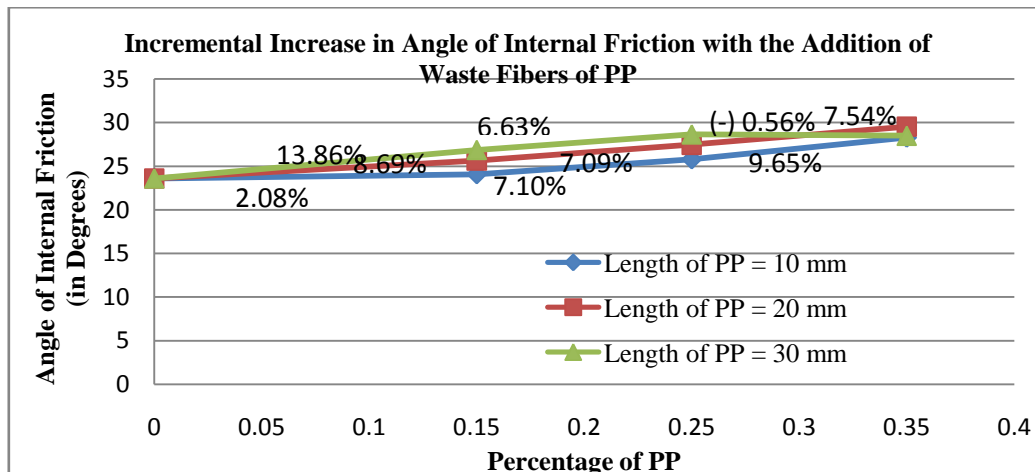


Fig. 7: Incremental Increase in Angle of Internal Friction with the Increase in Waste Fibres of PP

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The incremental increase in cohesion with the addition of waste fibres of PP has been graphically shown in fig.8

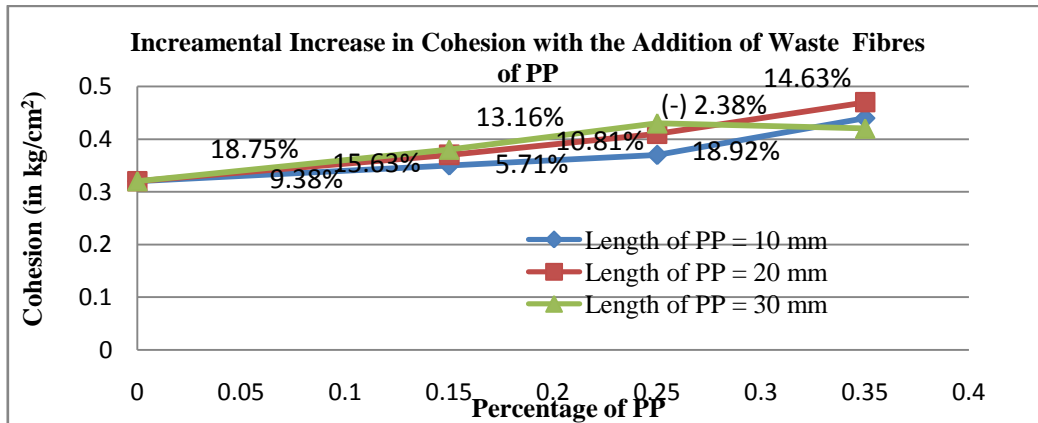


Fig. 8: Incremental Increase in Cohesion with the Increase in Waste Fibres of PP

4.3 Unconfined Compressive Strength (UCS) of the Soil

The clayey soil samples of plain soil and reinforced with the fibres of waste polypropylene had been tested by using the unconfined compressive strength test apparatus at the maximum dry density ($Y_{d(max)}$), and optimum moisture content (w), for the analysis of the unconfined compressive strength and the results for the same has been tabulated as follows:

Table 9: Values of UCS of the Soil

Sr. No.	Percentage of PP	Length of PP		
		10mm	20mm	30mm
		UCS of Reinforced Soil, (kg/cm ²)		
1.	0%	2.14		
2.	0.15%	2.87	3.15	2.92
3.	0.25%	3.19	3.27	3.15
4.	0.35%	2.94	2.99	2.80

The comparisons of unconfined compressive strength of the plain soil with the unconfined compressive strength of the reinforced soil are as follows:

Table 10: Comparisons of Increase in UCS of Reinforced Soil with Plain Soil

Sr. No.	Percentage of PP	Length of PP		
		10mm	20mm	30mm
		Increase in UCS of Soil		
1.	0%	2.14 kg/cm ²		
2.	0.15%	34.11%	47.20%	36.45%
3.	0.25%	49.07%	52.80%	47.20%
4.	0.35%	37.38%	39.72%	30.84%

The increase in UCS of soil with the addition of waste fibres of PP has been graphically shown in fig.9

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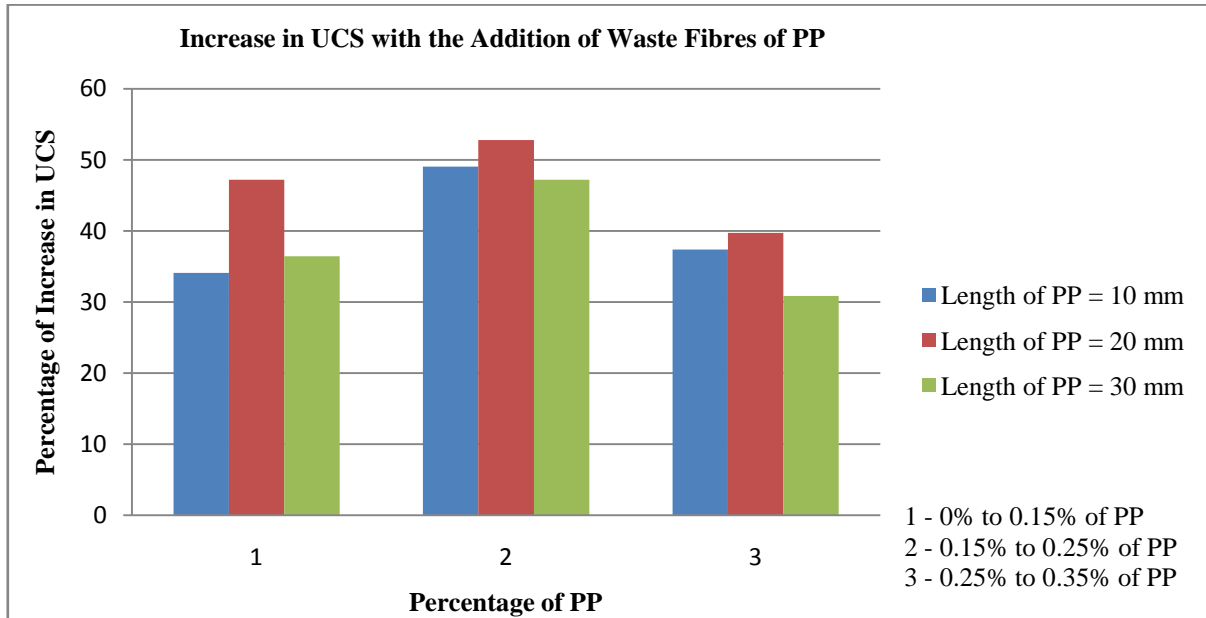


Fig. 9: Increase in UCS with the Increase in Waste Fibres of PP

It has been observed from the experimental investigations that the unconfined compressive strength of the soil varied with the addition of the waste fibres of PP, depending on which the incremental increase in UCS of the reinforced soil has been tabulated as given below in Table-11.

Table 11: Incremental Increase in UCS of Reinforced Soil

Sr. No.	Percentage of PP	Length of Polypropylene		
		10mm	20mm	30mm
		Incremental Increase in UCS of Reinforced Soil		
1.	0%	2.14 kg/cm ²		
2.	0.15%	34.11%	47.20%	36.45%
3.	0.25%	11.15%	3.81%	7.88%
4.	0.35%	(-) 8.50%	(-) 9.36%	(-) 12.5%

The incremental increase in UCS of soil with the addition of waste fibres of PP has been graphically shown in fig.10

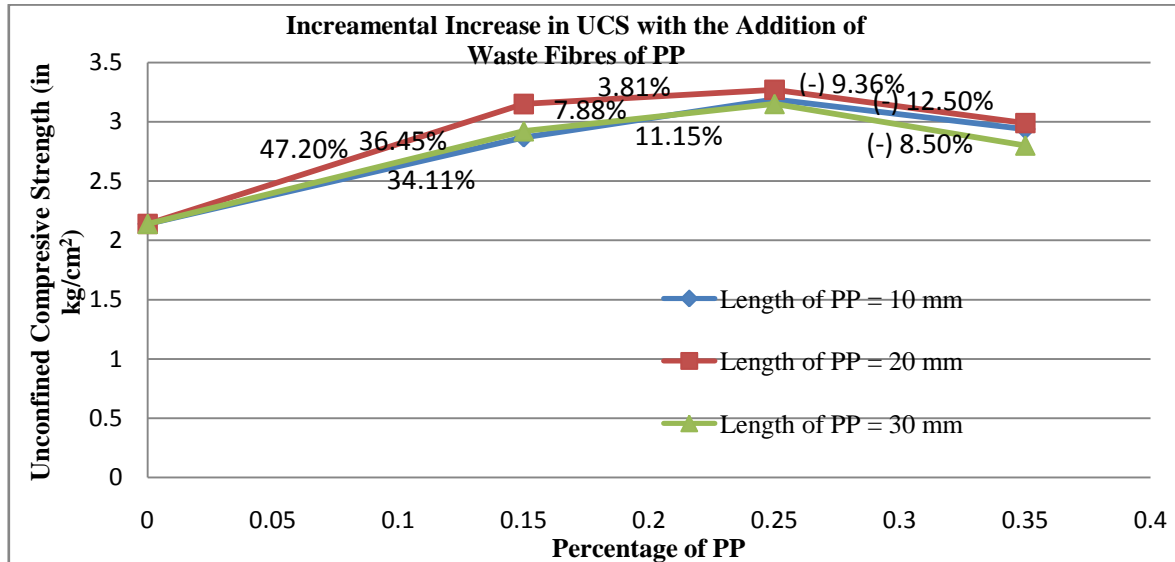


Fig. 10: Incremental Increase in UCS with the Increase in Waste Fibres of PP

V. CONCLUSIONS OF THE STUDY

On the basis of the analysis and interpretations of the results obtained from the experimental investigations carried out in the present research work, the following conclusions are drawn:

5.1 Compressibility of the Soil

In case of the compressibility, it is concluded that there is marginal decrease in the maximum dry density ($\gamma_{d(max)}$), with the addition of waste fibres of the polypropylene.

5.2 Direct Shear Strength Parameters of the Soil

The direct shear strength parameters of the soil reinforced with waste fibres of polypropylene used for the improvement of the engineering properties of the soil with 20 mm length and 0.35% weight of polypropylene by weight of dry soil sample, is found as 25.18% increase in the angle of internal friction (Φ) and 46.88% increase in cohesion (c).

5.3 Unconfined Compressive Strength (UCS) of the Soil

The unconfined compressive strength (UCS) of the soil reinforced with waste fibres of polypropylene used for the improvement of the engineering properties of the soil with 20mm length and 0.25% weight of polypropylene by weight of dry soil sample, is found as 52.80% increase in UCS.

VI. RECOMMENDATIONS

On the basis of the experimental investigations in this study, it is recommended that:

- The engineering properties of the soil collected from Ambala, Haryana (India) can be improved by using the fibres of waste polypropylene as reinforcement.
- The optimum quantity of fibres of waste polypropylene as reinforcement that can be used to improve the engineering properties of clayey soil (CL) is found to be 20mm in length at 0.25% of polypropylene by weight of dry soil sample for UCS, and 0.35% of polypropylene by weight of dry soil sample for DST.

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