Soil Strengthening Using Waste Materials

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Abstract: India has been coming into view as one of the world's fastest growing economies, which has brought it with a significant jump in construction activities. Hence, Structural Concrete Waste is increasing with the rapid growth in construction activities during construction process at construction sites and in plants, for the production of construction materials.

In addition to this, with the rapid increase in generation of waste from plastics industry all around the world due to Changing Consumption, Production Patterns and Economic Growth. 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. After food waste and paper waste, plastic waste is the third major constitute at municipal and industrial waste in cities. 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 the large quantities of structural concrete waste and extremely long periods required for natural decomposition of waste plastic, they are often the most visible component in waste dumps and open landfills resulting in serious environmental problems. So depending on this, the object of this thesis was chosen as "Soil Strengthening Using Waste Materials (Structural Concrete Waste and Polypropylene)".

In this research work, an extensive laboratory work have been carried out for utilization of fines obtained from structural concrete waste and waste fibres of polypropylene in the improvement of the various properties of the Clayey (CI) type of soil obtained from Chandigarh College of Engineering and Technology (CCET), Sector – 26, Chandigarh.

KEYWORDS: Soil Stabilisation, Structural Concrete Waste (Fines), Fibres of Waste Plastics, Plain Soil, Mixed Soil, Reinforcement, Reinforced soil, Polypropylene, Maximum Dry Density, Optimum Moisture Content, Direct Shear Strength Parameters, Unconfined Compressive Strength.

I. INTRODUCTION

For any structure, the foundation is most crucial and has to be strong to prop the entire structure. Soil near by the foundation plays very crucial part in foundation's strength. We need to have proper view about their properties and factors act on their behavior. The process of soil stabilization or improvement of properties helps us to achieve the required properties in a soil needed for the construction work. In recent life span, with the increase in the need for infrastructure, ungraded materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement to improve soil other than replacing the poor soil at the building site.

Here, in this project, soil stabilization has been done with the help of using the fines obtained from demolished concrete structures and randomly distributed polypropylene fibers obtained from waste materials. To upgrade soil in the shear strength parameters has been lay emphasis on and number of comparative studies has been carried out by using different methods of shear resistance measurements.

In this research work, the laboratory work is to carried out for the utilization of fines obtained from structural concrete waste of structures demolished in NITTTR, Sector – 26, Chandigarh and waste fibres of polypropylene (randomly distributed) obtained from the Supreme Industries, Village – Serseni (Lalru), Ambala – Chandigarh Highway, Distt.-S.A.S.Nagar, Punjab; producing a number of plastic items which are globally used for the different works, in the improvement of the various properties of the Clayey (CI) type of soil obtained from Chandigarh College of Engineering and Technology (CCET), Sector – 26, Chandigarh.

II. MATERIALS USED

2.1 SOIL

In the present study the soil procured from Chandigarh College of Engineering and Technology (CCET), Sector – 26, Chandigarh, (India) had been investigated and depending on the properties given below in Table-1 the soil had been classified as CI (Clayey Soil with Intermediate Compressibility).

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

Properties of the Soil Sample	Values of the Different Properties
Colour	Brown
Liquid Limit	36.23%
Plastic Limit	21.30%
Plasticity Index (IP)	14.93%
Type of Soil as per IS: 1498	CI
Specific Gravity (G)	2.60

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

Properties of the Soil Sample	Values of the Different Properties
Compressibility (MDD) Maximum Dry Density, (Ɣd(max)) Optimum Water Content, (*w*)	 1.99 10.95
Direct Shear Strength (DSS) Angle of Internal Friction (Φ) Cohesion (C)	24.22º 0.30 kg/cm^2

2.2 STABILISING MATERIAL

In this research work, improvements of soil properties have been carried out with help of the following waste materials.

a) Structural concrete Waste (Fines)
b) Polypropylene (Waste Fibres of Plastic)

2.2.1 Structural concrete Waste (Fines)

The fines obtained from the demolished concrete structure from NITTTR, Chandigarh.

2.2.2 Polypropylene (Waste Fibres of Plastic)

The waste fibre material –polypropylene obtained from the Supreme Industries, Village – Serseni (Lalru), Ambala – Chandigarh Highway, Distt.- S.A.S.Nagar, Punjab; producing a number of plastic items which are globally used for the different works, have been used.

III. METHODOLOGY ADOPTED

Laboratory investigations were conducted on the "Plain Soil", "Mixed soil" (Mixed Soil means the plain soil admixed with the optimum percentage of fines (10%)) and "Reinforced Soil" (Polypropylene is added in the mixed soil 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) sample for the improvement of the following engineering properties of the soil:

i) Maximum Dry Density at Optimum Moisture Content, and

ii) Direct Shear Strength Parameters

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 (γ_d(max)) of the Plain Soil (Table-3), Mixed Soil (Table-4) and Reinforced Soil (Table-5) by compacting the soil samples manually.

4.1.1 Determination of OMC-MDD of Plain Soil Samples

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

Sample No.	Dry Density (g/cc)	Water Content (%)
1	1.90	7.20
2	1.96	9.18
3	1.99	10.95
4	1.87	13.91
5	1.69	17.24

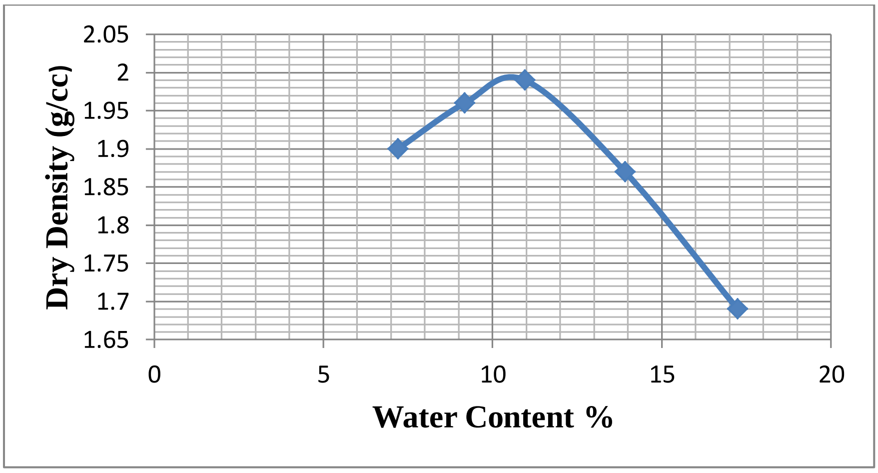

Fig. 1: OMC – MDD Curve for Plain Soil Sample

The maximum dry density of the plain soil has been found as 1.99 g/cc at 10.95% of optimum moisture content from the curve drawn in fig.1

4.1.2 Determination of the Optimum Quantity of the Fines to be added to the Plain Soil:

The fines have been added to the plain soil with the various percentages as detailed in the table-4, for the Optimization of the fines to be added.

Table 4: Various Percentages of the Fines added to the Plain Soil for OMC – MDD

Sample No.	Percentage of Fines									
	4%		7%		10%		12%		14%	
	Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)	Dry Density (g/cc)	Water Content (%)
1.	1.93	7.54	1.95	6.54	1.96	6.57	1.87	7.16	1.96	6.69
2.	1.99	9.16	2.03	7.94	2.05	7.96	2.02	8.83	1.99	10.36
3.	2.04	10.65	2.06	9.23	2.07	9.21	2.07	10.88	2.02	13.31

4.	1.95	11.66	2.08	10.50	2.09	10.37	2.01	12.92	1.99	14.58
5.	1.92	13.98	2.02	11.24	2.03	12.78	1.98	14.79	1.95	16.21

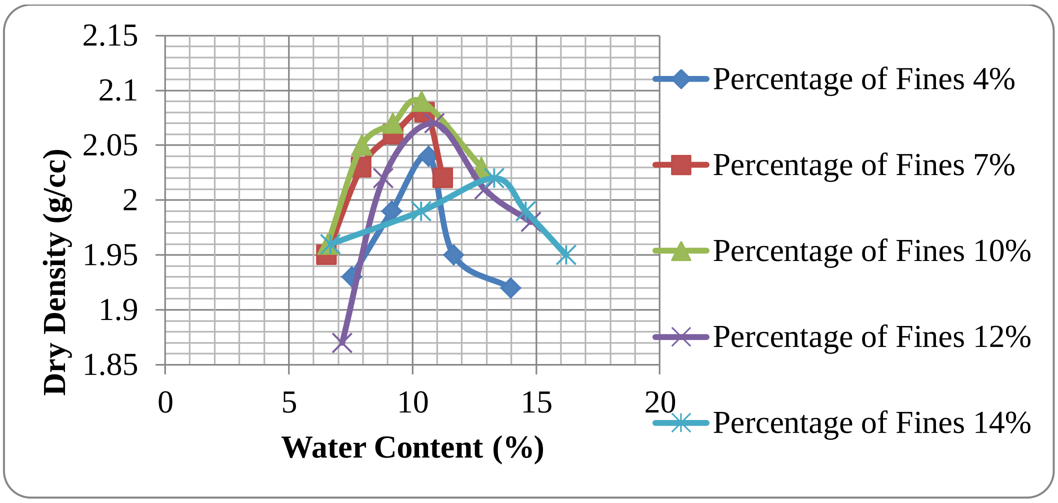

Fig. 2: Graphical Representation of OMC – MDD at Various Percentages of the Fines added to the Plain Soil

Table 5: Consolidated Result of OMC-MDD of Plain Soil admixed with varying Percentage of Fines.

Percentage of Fines	OMC (g/cc)	MDD (%)
0	10.95	1.99
4	10.65	2.04
7	10.50	2.08
10	10.37	2.09
12	10.88	2.07
14	13.31	2.02

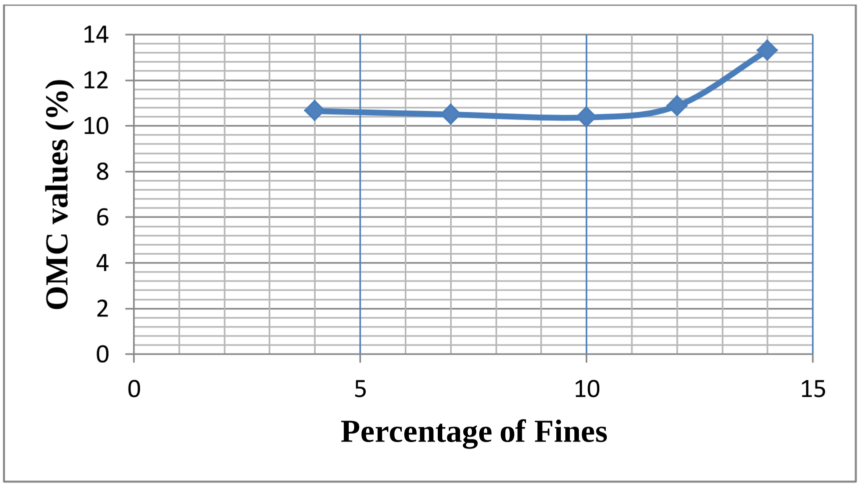

Fig. 3 Graphical Representation of OMC Values Corresponding to Different Percentages of Fines

The optimum quantity of the fines has been obtained from the fig. 3, as 10% by weight of the dry soil sample, to be called as "Mixed Soil" in this research work.

4.1.3 Determination of the OMC-MDD of the Reinforced Soil:

Polypropylene (waste fibres of plastics) has been added to the mixed soil by 10mm, 20mm and 30mm in length at 0.15%, 0.25% and 0.35% by weight of dry soil sample, to be called as Reinforced Soil" in this research work.

Table 6: Observations of OMC-MDD for the Soil Samples Mixed with 10% fines and Reinforced with 0.15%, 0.25% and 0.35% of Polypropylene by Weight of Dry Soil Sample.

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 (%)
10 mm	1.99	7.33	1.99	8.23	1.94	9.27
	2.02	9.09	2.03	10.12	1.97	10.46
	2.07	10.51	2.04	11.05	1.99	11.16
	2.06	12.75	2.02	13.09	1.96	13.39
	2.01	14.79	2.00	14.87	1.93	15.02
20 mm	2.01	7.37	2.01	7.33	1.98	7.45
	2.06	10.58	2.04	9.27	2.02	9.41
	2.05	11.77	2.05	11.13	2.04	11.54
	2.01	13.04	2.03	11.72	1.99	12.03
	1.97	14.63	1.99	13.24	1.93	13.61
30 mm	2.01	7.81	1.97	7.42	1.96	7.95
	2.05	10.63	1.99	9.36	1.97	9.53
	2.07	11.18	2.03	12.30	2.01	12.77
	2.03	13.04	1.98	13.94	1.97	13.51
	1.97	14.39	1.94	14.23	1.88	15.66

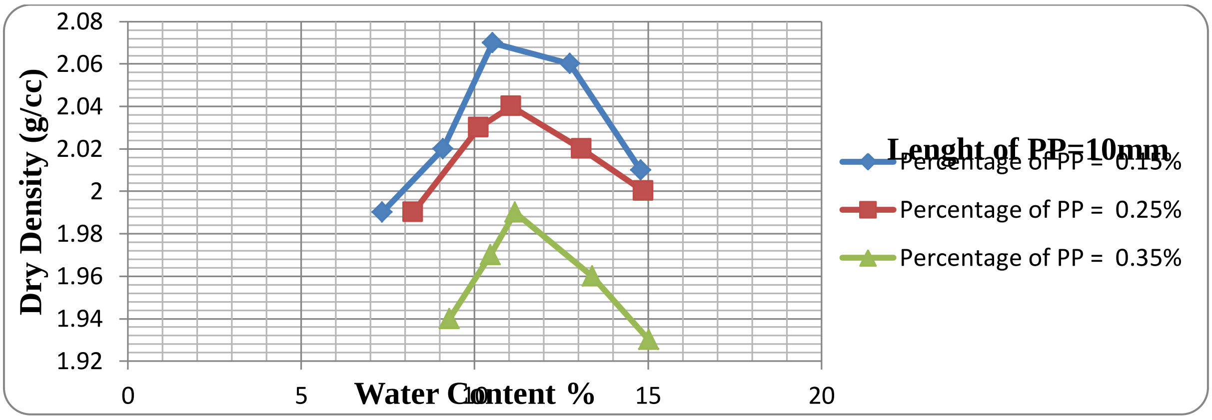

Fig. 4(a): Graphical Representation of OMC-MDD of Reinforced Soil (Length of PP=10mm)

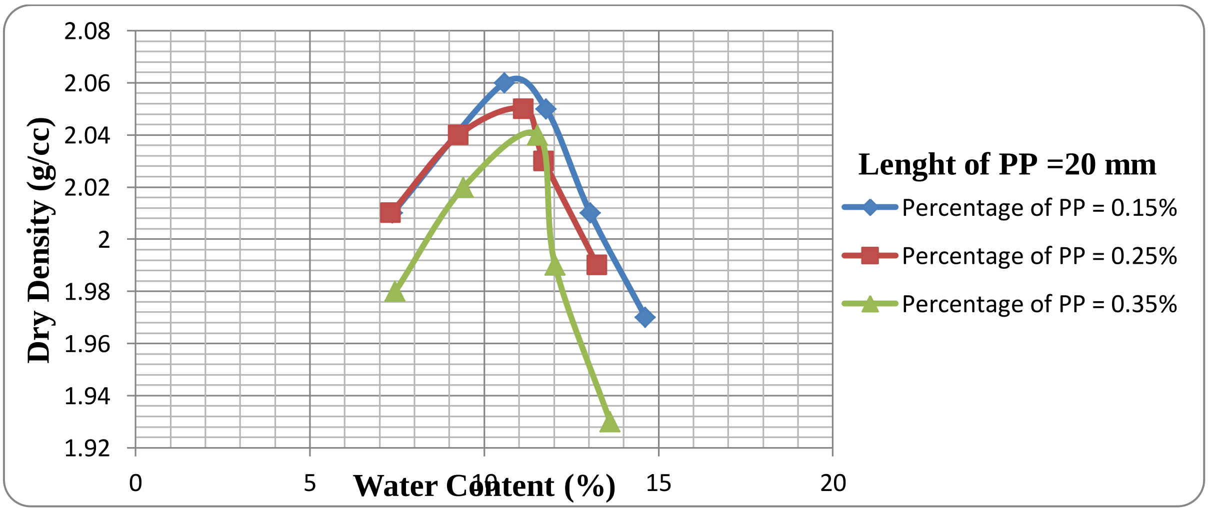

Fig. 4(b): Graphical Representation of OMC-MDD of Reinforced Soil (Length of PP=20mm)

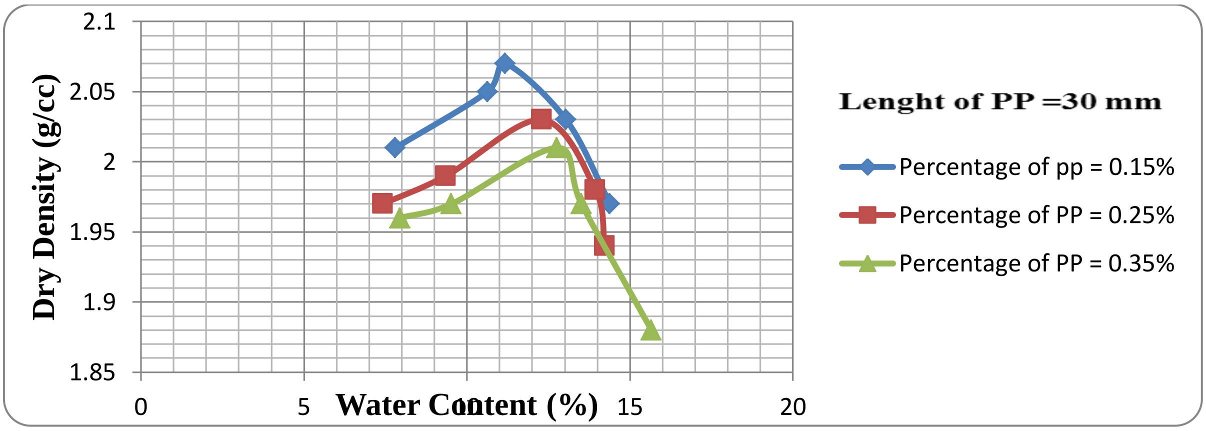

Fig. 4(c): Graphical Representation of OMC-MDD of Reinforced Soil (Length of PP=30mm)

Table 7: Consolidated Result of OMC-MDD Reinforced Soil

Length of PP	Percentage of PP 0%		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 (%)	Dry Density (g/cc)	Water Content (%)
10 mm	1.99	10.95	2.07	10.51	2.04	11.05	1.99	11.16
20 mm			2.06	10.58	2.05	11.13	2.04	11.54
30 mm			2.07	11.18	2.03	12.30	2.01	12.77

4.2 Direct Shear Strength (DSS) Parameters of the Soil

The mixed soil samples reinforced with the fibres of waste polypropylene had been tested by using the direct shear test apparatus at the maximum dry density (Υ_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-8.

Table 8: Values of DSS Parameters for Mixed Soil

Percentage of PP	Length of PP					
	10mm	20mm	30mm	10mm	20mm	30mm
	Angle of Internal Friction, Φ			Cohesion, c (kg/cm²)		
0%	24.77º			0.32		
0.15%	25.32º	26.55º	28.20º	0.36	0.39	0.41
0.25%	26.86º	28.79º	29.79º	0.47	0.43	0.45
0.35%	29.09º	30.66º	29.78º	0.47	0.49	0.45

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

Table 9: Comparisons of Increase in DSS of Mixed Soil with Reinforced Soil

Percentage of PP	Length of PP					
	10mm	20mm	30mm	10mm	20mm	30mm
	Increase in Angle of Internal Friction (Φ)			Increase in Cohesion (c)		
0%	24.77º			0.32 kg/cm²		
0.15%	2.22%	7.18%	13.84%	12.50%	21.87%	28.12%
0.25%	8.43%	16.22%	20.26%	46.87%	34.37%	40.62%
0.35%	17.44%	23.77%	20.22%	46.87%	53.12%	40.62%

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

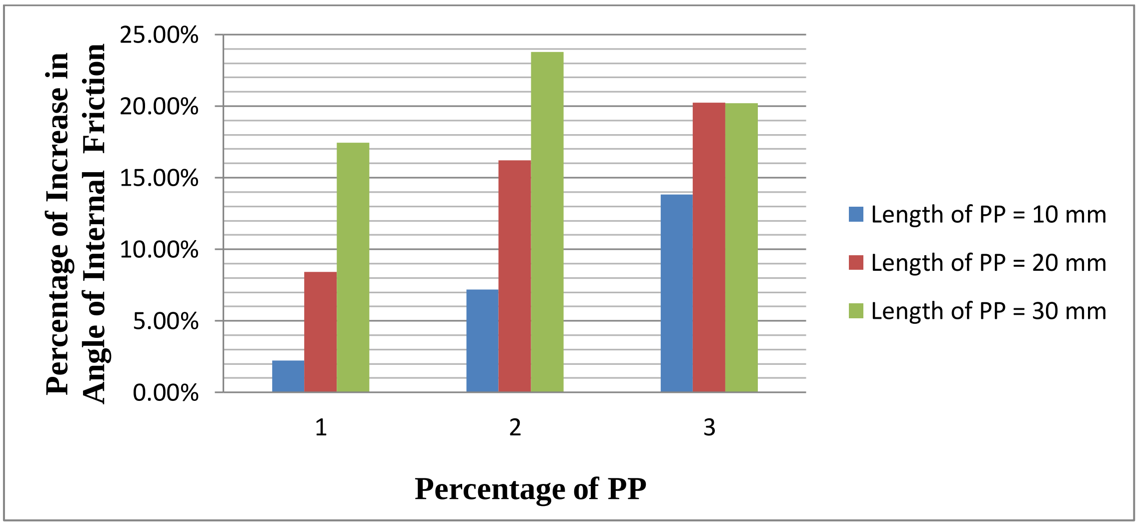

Fig. 5: Increase in Angle of Internal Friction with the Increase in Waste Fibres of PP

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

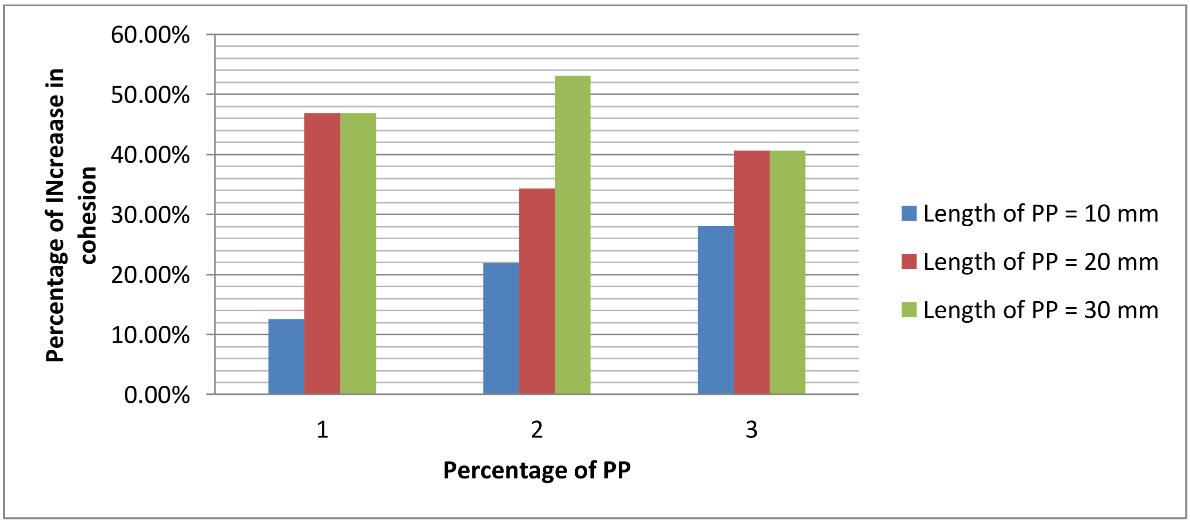

Fig. 6: Increase in Cohesion with the Increase in Waste Fibres of PP

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-10.

Table 10: Incremental Increase in DSS of Reinforced Soil

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		
0%	24.77º			0.32 kg/cm²		
0.15%	2.22%	7.18%	13.84%	12.5%	21.87%	28.12%
0.25%	6.08%	8.43%	5.63%	30.55%	10.25%	9.75%
0.35%	8.30%	6.49%	(-) 0.03%	0.00%	13.95%	0.00%

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

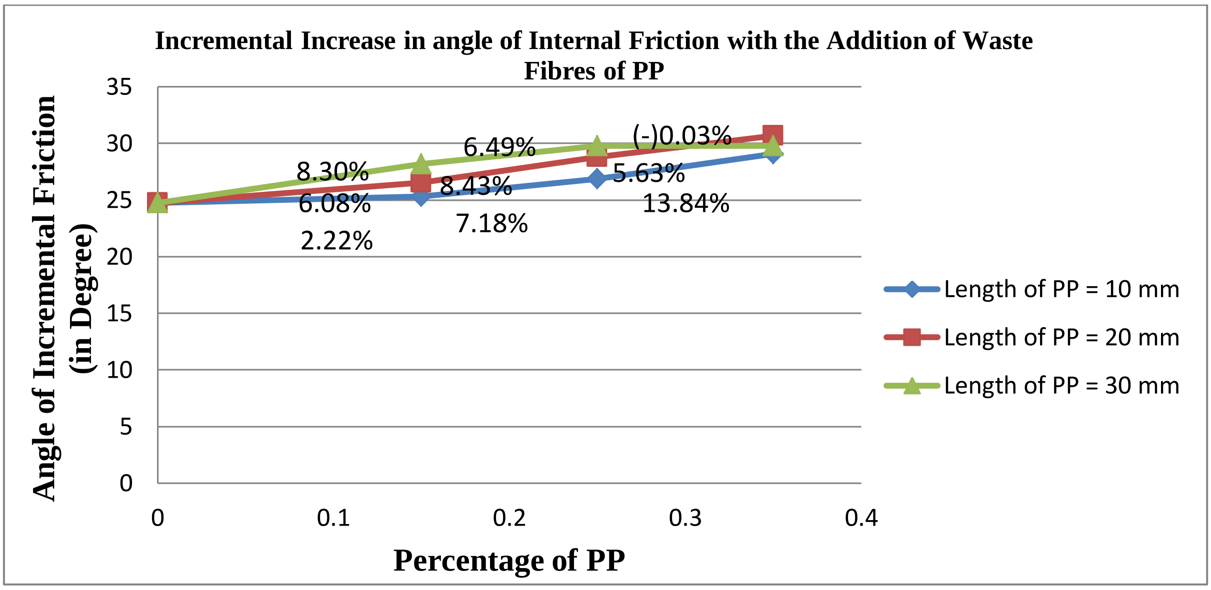

Fig. 7: Incremental Increase in Angle of Internal Friction with the Increase in Waste Fibres of PP

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

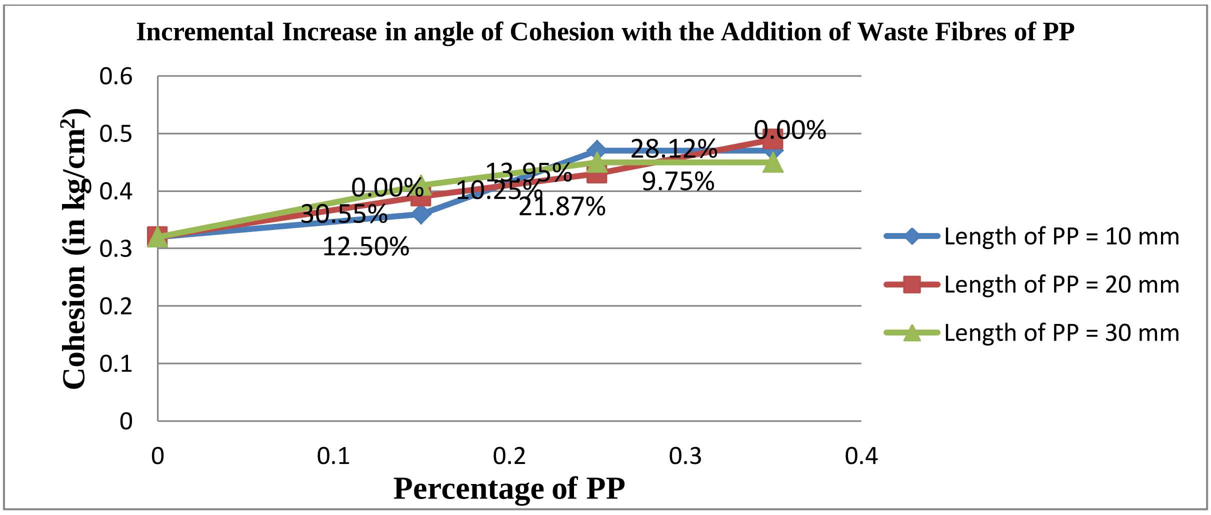

Fig. 8: Incremental Increase in Cohesion with the Increase in Waste Fibres of PP

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 5.03% increase in the Maximum Dry Density of plain soil when the fines added at 10% by weight of soil at 10.37% moisture content and marginal decrease in the Maximum Dry Density of the mixed soil with the increase in the fibre contents i.e. 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 23.77% increase in the angle of internal friction (Φ) and 53.12% increase in cohesion (c).

VI.RECOMMENDATIONS

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

i) The engineering properties of the soil collected from C.C.E.T. Chandigarh. (India) can be improved by using the fines and fibres of waste polypropylene as reinforcement.

ii) The optimum quantity of fibres of waste polypropylene as reinforcement that can be used to improve the engineering properties of clayey soil (CI) is found to be 20mm in length at 0.35% of polypropylene by weight of dry soil sample for DST.

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