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The Effect of Polypropylene Wastes on Engineering Properties of Local Soil of Pantnagar, India (29.0222° N, 79.4908° E)

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Abstract: ***In Terai region of India soft soils are found in abundance, these soft soils are not suitable for civil engineering projects as the stability and strength of these soils vanishes. Thus, these soils will be either replaced by soils suitable for construction, or will be improved by stabilization. The long-term performance of any construction project depends on the soundness of the underlying soils. Soil stabilization process can be applied either mechanically or chemically. This paper presents an analysis of local soil of Pantnagar, India (29.0222° N, 79.4908° E) and an experimental investigation of stabilization of this location's clayey soil using polypropylene waste fiber (PPWF). The effect of PPWF on the physical and engineering properties of the local soil has been studied by conducting Atterberg limits, compaction parameters, California bearing ratio and unconfined compressive strength testing after 7 days curing. Different percentages of PPWF were added (0.25, 0.50, 0.75 and 1%), by the dry weight of the soft soil. The results indicated that the PPWF has a positive impact on the engineering and physical properties of soft soil. Additionally, it can be recommended that addition of PPWF in an optimum amount reduced the plasticity index(PI), increased the maximum dry density (MDD) and decreased the optimum moisture content (OMC), thus improving the compressive strength within 7 days curing.***

Keywords: Terai region; Soil stabilization; Polypropylene waste; Soft soil; Optimum moisture content

1. Introduction

India is a developing nation and the growing population of India is demanding new construction activities. Projects like dams, piling, embankment and highways construction has become a popular practice (Basu and Maertens, 2007). These projects are sign of development and they are taking place all over the nation, whereas in many parts of the nation the soil types are unsuitable for these construction activities. For any civil structure, foundation plays a vital role. For the laying an efficient foundation, the soil around it must be suitable for construction purposes else the structure may collapse or get damaged. The long-term performance of any construction project depends on the soundness of the underlying soils (Arya and Ameta, 2017). So the soil stabilization process is popularly adopted to deal with this problem, it changes the physical and engineering properties of soil in order to augment its strength, stability, durability and other properties and prevent formation of dusts and erosion of soil (Sen and Kashyap, 2012).

Conventionally, soil stabilization was carried out by adding small amounts of lime, fly ash, coconut coir, and other fibers as they form a bond with soil particles (Cristelo et al., 20.13). In the research paper polypropylene waste fiber (PPWF) is used for soil stabilization. The results obtained were more satisfactory than the conventional method as (-C3H6-)n polymer forms much more stronger bonds with the soil particles hence improving its physical and engineering properties as corroborated by many research projects and publications (Upreti et al., 2018; Firoozi et al., 2014; Cai et al., 2006).

The local soil of Pantnagar, India (29.0222° N, 79.4908° E) was used as a soil sample. The sample was collected in a jute bag and was cured for 7 days, after this, different tests were performed on soil sample to obtain the results for analyzing the local soil. For soil stabilization process, PPWF was added in different percentages as (0.25, 0.50, 0.75 and 1.00%) to prepare different specimen. These specimens were then tested to note the results.

In India, around 70% of total plastic consumption is discarded as waste. Around 5.6 million tonnes per annum of plastic waste is generated, which is about 15,342 tonnes per day. The addition of PPWF serve two purposes, firstly it is stabilizing the soil to improve its properties so that effective construction activities takes place, and the disposal of waste polymers which has its own deleterious effects on environment.

2. Material and Method

2.1 Materials

2.1 Polypropylene Waste Fiber (PPWF)

PPWF polymer (-C3H6-)n are the rigid, thermoplastic polymer. They are cheap and easily available as it is widely used in packaging of various products. It provides high rebound loss. Fiber strips which passes through 10mm sieve is used in this study. Different samples were prepared by adding PPWF percentage 0.25%, 0.50%, 0.75%, 1% by dry weight of soil.

Properties of PPWF_

a) Melting Point of Polypropylene - 135 - 159°C
b) Density of Polypropylene - 0.905 – 0.915 g/cm^3
c) Excellent resistance to diluted and concentrated acids, alcohols and bases
d) Flammability: Polypropylene is a high flammable material
e) Specific Gravity – 0.92

f) Average Length – 60mm, Average Diameter – 0.034 mm.
g) PPWF retains mechanical & electrical properties at elevated temperatures, in humid conditions and when submersed in water. It is a water-repellent plastic.
h) PPWF has good resistance to environmental stress cracking.

2.2 Local Soil

In this study, sample soil was collected from the campus of Pantnagar, India (29.0222° N, 79.4908° E). The soft soil was extracted from a depth around 1.5 – 2m below the ground level and was collected in jute bags. The bag was transported to laboratory, as soon as the samples arrived to the laboratory; the natural moisture content was calculated. Sample soil was cured for 7 days, and then dried in an oven at 110^0C. Thereafter tests were performed on sample soil to determine its characteristics. The sample collected was found to be clayey soil. Firstly sieve analysis was performed to determine the distribution of aggregate particles by size within a given sample.

Table 1: Properties of local soil

Properties	Values
Specific Gravity(G)	2.40
Density(ρ)	1.50
Liquid Limit	43.56%
Plastic Limit	24.32%
Shrinkage Limit	18.98%
Maximum Dry Density	1.64gm/cc
Unconfined Compressive Strength	15.14N/cm^2

Figure 1: Google map of Pantnagar from where soil sample was collected

Method of preparation

The soil sample that was brought to the laboratory is cleared of all organic matters then it is dried in oven at 110^0C. After drying, it is crushed to break down any large pieces agglomerated and then prepare sample to carry tests on it. Different percentage (0.25, 0.50, 0.75, and 1.00%) of PPMF is added by the dry weight of the treated soil in this soft soil to prepare samples manually. The treated soil specimens were cured for 7 days before they were subjected to test.

3. Laboratory Experiments

3.1 Atterberg Limits

Atterberg limits include Liquid Limit (LL), Plastic Limit (PL), Shrinkage Limit (SL), and Plasticity Index (PI). The Liquid Limit of the soil is the water content at which it behaves like a liquid with small amount of shear strength. Casagrande’s Liquid Limit device is used in which it flows to close the groove in just 25 blows. Practically it is difficult to get exactly 25 blows to close the groove, so number of tests is conducted to record the number of blows (N). Semi-log plot is drafted log (N) versus water content. From the graph the water content corresponding to N=25 is obtained as it is the Liquid Limit. In Plastic Limit test, the soft soil is rolled till its diameter becomes around 3mm, in this case the soil crumbles, and a sample is taken for measuring the moisture content which represent Plastic Limit. The Shrinkage Limit (SL) is the water content where further loss of moisture will not result in any more volume reduction as soil is saturated. The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.

3.1.1 Proctor Compaction Test

The Proctor compaction test determines the optimal moisture content at which soil sample will become most dense and achieve its maximum dry density. Compaction reduces the air voids and results in densification. Degree of compaction is measured in terms of dry density. Suitable amount of water was added to 2000g of dry powdered soil. The sample soil was mixed thoroughly and compacted in a standard mould using 2.5kg hammer in three layers; each layer was exposed to 25 blows. A sample for moisture content measurements was taken with stabilizer in it and was tested.

3.1.2 California Bearing Ratio Test

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of soil sample. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

C.B.R. = (Test Load/Standard Load) ×100

Table 2: Penetration-standard load

Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055

CBR test was conducted on soil sample. Test consists of causing a cylindrical plunger of 50mm diameter to penetrate a pavement component material at 1.25mm/minute. The loads for 2.5mm and 5mm are recorded. In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value.

3.1.3 Unconfined Compressive Strength Test

The unconfined compressive test determines the shearing resistance of soil sample. An axial load is applied using either strain-control or stress-control condition. The unconfined compressive strength is defined as the maximum unit stress obtained within the first 20% strain. For this test, soil sample was prepared of length 7.6cm, diameter 3.8cm and its cross section area (A_0) = 11.34 cm^2. Frictionless end plates of 7.6cm diameter with silicon grease coating on it hold the sample. The apparatus loading frame capacity was 2t with constant rate of movement. Sample was tested with different percentage of PPWF and results were recorded.

4. Result and Discussions

1) Atterberg Limit

The influence of adding PPWF (0.25%, 0.50%, 0.75%, and 1%) by dry weight of the sample soil on the Atterberg limits is shown in the figure no.2 below. It is noted that LL, SL, PL all decreased with increase in concentration of PPWF, which ultimately results in decreasing the value of PI (PI= LL-PL). The LL of sample soil 43.56 gets reduced to 38.08 as the PPWF concentration increased. The SL of sample soil 18.98 reaches to 16.89 as the experiment proceeded. Also the PL of the sample soil 24.32 gets reduced to 21.59 as PPWF percentage increased. The value of PI reduced from 19.24 for sample soil to 16.49 as the PPWF was added in increasing concentration. The decrease in value of PI corroborates the improvement in soil properties. In addition, a similar behavior was noticed in previous research studies on clayey soils stabilized with polypropylene (Kinjal et al., 2012; Khodary et al., 2017). PPWF form bonds with soil sample particles due to exchange of ions, formation of bond could be attributed as a reason to change the consistency limits.

Table 3: Atterberg limits of soil sample and soil sample with PPWF %.

Soils	*LL*	*SL*	*PL*	*PI*
Soil Sample	43.56	18.98	24.32	19.24
Soil Sample with 0.25% PPWF	42.85	18.30	24.06	18.79
Soil Sample with 0.50% PPWF	41.54	17.31	23.50	18.04
Soil Sample with 0.75% PPWF	39.98	17.16	22.71	17.27
Soil Sample with 1.00% PPWF	38.08	16.89	21.59	16.49

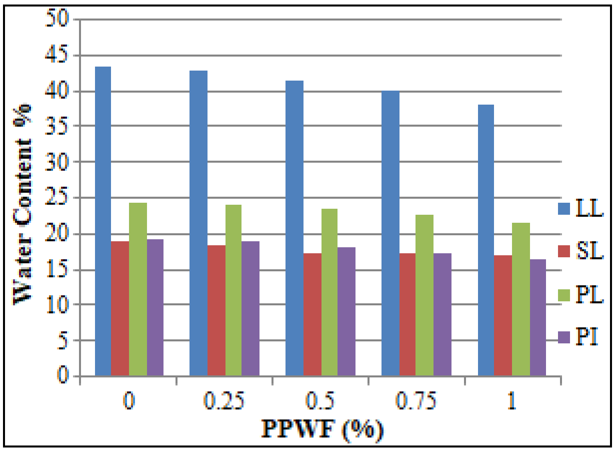

Figure 2: Atterberg limits

2) Proctor Compaction Test

Proctor compaction test is carried out to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for sample soil (SS) and for the soil stabilized with PPWF content (0.25%, 0.50%, 0.75%, and 1.00%). Determining OMC and MDD helps to prepare specimens for experiments like Unconfined Compressive Strength, California Bearing Ratio, and Tri-axial test. The effect of adding different percentages of PPWF in sample soil is shown in the figure no.3 below. The result shows that with addition of PPWF in sample soil there is an increase in MDD and decrease in OMC. The MDD increased from 1.64 gm/cm^3 to 1.69 gm/cm^3 when stabilized with different percentages of PPWF whereas OMC decreased from 19.91% to 18.05% for the same percentage of PPWF. Similar behavior was also observed for soft clayey soil stabilized with polypropylene (Priya et al., 2017; Upreti et al., 2018; Prabhavathi et al., 2017). The characteristics of proctor test are based on specific gravities and grain size distribution of both the stabilizer and soil (Hossain and Mol, 2011). The decrease in OMC could be attributed to polypropylene polymer as it decreases the amount of water held by the flocculent of soil structure. Also it could be attributed to the elevated water repulsion by PPWF.

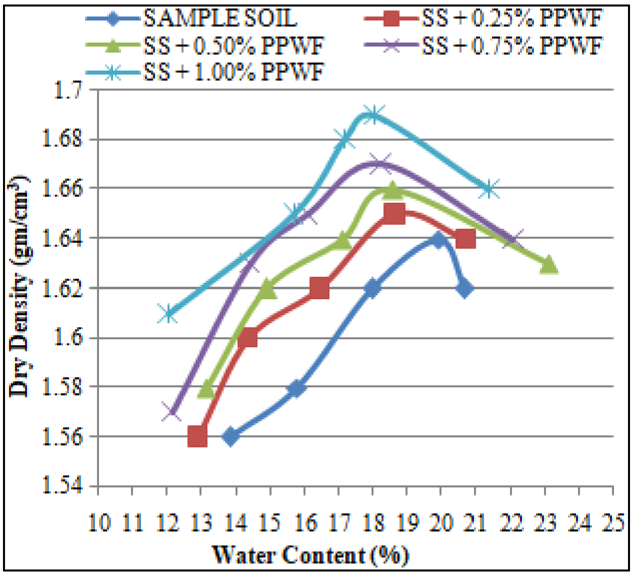

Figure 3: Compaction parameters of sample soil and soil with PPWF contents.

3) California Bearing Ratio Test

The effect of percentages (0.25%, 0.50%, 0.75%, and 1.00%) of PPWF on CBR values is shown in the table no.4. CBR value (%) for 5mm plunger penetration for all percentages is less than CBR value (%) for 2.5mm plunger penetration. This means that load carrying capacity is decreased with increasing penetration. This may be attributed to the fact that as the penetration of plunger increases, it starts rupturing the structure of the test material. So CBR value at 2.5mm is the CBR value of that sample. As the PPWF percentages increased, the CBR value (%) also increased for different sample as shown. PPWF as a stabilizer contributes more strength to the soil samples. Similar result was achieved in previous research also (Behbahani et al., 2016; Prabhavathi et al., 2017; Kalantari et al., 2010). In addition, stabilization and the curing technique of soil stabilized with PPWF also changed the CBR value as from poor (CBR from 0-4%) to fair and further experiments could be conducted with greater percentage of PPWF to make it good (CBR from 7 to above 20%).

Table 4: CBR value of soil samples with PPWF.

Specimen	Load(kg) (2.5mm)	Load(kg) (5.0mm)	CBR Value (2.5mm)	CBR Value (5.0mm)
SOIL SAMPLE(SS)	57.95	76.65	4.23%	3.73%
SS + 0.25% PPWF	59.86	80.55	4.37%	3.92%
SS + 0.50% PPWF	61.37	85.28	4.48%	4.15%
SS + 0.75% PPWF	63.15	88.98	4.61%	4.33%
SS + 1.00% PPWF	64.80	93.29	4.73%	4.54%

4) Unconfined Compressive Strength Test

The influence of PPWF (0.25%, 0.50%, 0.75%, and 1.00%) on compressive strength is shown in the figure no.4. As the percentage of PPWF increases, the UCS value also increases. For the sample soil, UCS value is 15.14 N/cm^2; this value reaches up to 18.86 N/cm^2 for 1.00% PPWF. Similar pattern of UCS increment due to stabilization was also seen in previous research (Naeini et al., 2012; Xing et al., 2018; Malekzadeh and Bilsel, 2012). This increment could be attributed to PPWF as it acts as reinforcement for soft soil. The PPWF reinforcement and sample soil have rough surfaces and high rigidity. This phenomena increase the connectivity and interlocking forces inside soil particles, as a result strength value of soil increases. This experiment only shows a general trend of UCS Value under influence of PPWF increment. For optimum value of UCS further experiments could be conducted on soil with greater percentage of PPWF.

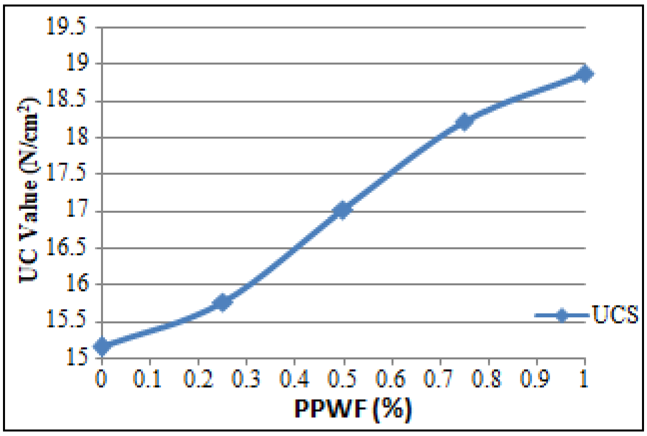

Figure 4: UCS Value for PPWF %.

Length of sample (L) = 7.6cm

Diameter of sample (D) = 3.8cm

Cross section area of sample (A_0) = 11.34 cm^2

Table 5: UCS relation with load and area

Fiber (%)	Failure Load, P (N)	Displacement ΔL (cm)	Strain €=ΔL/L	Corrected Area A= A_0/(1-€) (cm^2)	UCS Value= P/A (N/cm^2)
0.00	171.68	0.1188	0.0156	11.52	15.14
0.25	178.60	0.1164	0.0153	11.51	15.75
0.50	192.89	0.1159	0.0152	11.51	17.01
0.75	206.50	0.1134	0.0149	11.51	18.21
1.00	213.87	0.1120	0.0147	11.50	18.86

5. Conclusion

In this study, various percentages of PPWF have been mixed with sample soil to study their effect on different characteristics of the clayey soil such as Atterberg limits, compaction parameters, California bearing ratio and unconfined compressive strength .The conclusion of this investigation are:

1) The use of PPWF have a positive effect on the results of the Atterberg limits as ultimately it reduces the plasticity index (PI) .The results showed that with the use of PPWF ,the PI reduced from 19.24% for soft soil to 16.49% as the experiment proceeded. This result indicates that the soil of Pantnagar (29.0222° N, 79.4908° E) has the tendency to absorb water content and will lose water as climate changes. These phenomena could damage the superstructures above this soil. On the other hand PPWF has water resistance tendency, stabilizing soil with this could resolve this issue and has shown positive effect on Atterberg limits.
2) Additionally, MDD increased and OMC decreased with the increase of PPWF. MDD increased from 1.64 gm/cm^3 to 1.69 gm/cm^3 and OMC decreased from 19.91% to 18.05%. The degree of compaction is measured in terms of dry density, so with the result, it is suggested that it would reduce the further compaction cost of soil and make it economical because it reduces the required energy to obtain its MDD.
3) The PPWF content in the soft soil has increased the CBR value. The CBR value has increased from 4.23% to 4.73% due to increment of polymer content. The CBR test is used for the evaluation of sub grade strength of roads and pavements. The CBR value obtained by this

test is used with the empirical curves to determine the thickness of pavement and its component layers. According to the result, CBR lies below 5. Further PPWF content must be added and specimen should be tested to obtain its optimum value.

4) The PPWF has developed the unconfined compressive strength of the clayey soft soil as it increased from 15.14 N/cm^2 for sample soil to 18.86 N/cm^2 after curing of samples for 7 days. It could be stated that using PPWF in soil stabilization has the capability to develop its physical and engineering properties during short periods of curing. Also using PPWF is economical and environment friendly.

6. Scope for Further Study

The author could study the influence of PPWF content (greater than 1%) after curing soil sample for 7 days. Also different tests with varying PPWF content could be performed on soil with 28 days curing to see the influence of curing days.

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