SOIL STABILIZATION USING POLYPROPYLENE

Submitted in partial fulfilment of the requirements

for the degree of

Bachelor of Engineering

by

Mr. Ansari Kashif Ahmed (14CES04)

Mr. Khan Aqib (14CES13)

Mr. Khan Mohd Asif (14CES19)

Mr. Khan MohdShakir (14CES21)

Under the guidance of

Prof. Rohan Dasgupta

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

New Panvel, Navi Mumbai-410206

2017 – 2018

A Project Report on

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CERTIFICATE

This is to certify that the project entitled **"Soil Stabilization Using Polypropylene"** is a bonafide work of **Mr. Ansari Kashif Ahmed (14CES04), Mr. Khan Aqib Mehfooz (14CES13), Mr. Khan Mohd Asif (14CES19)** and **Mr. Khan MohdShakirMohd Sabir (14CES21)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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APPROVAL SHEET

This dissertation report entitled **"Soil Stabilization Using Polypropylene"** by **Mr. Ansari Kashif Ahmed (14CES04), Mr. Khan Aqib Mehfooz (14CES13), Mr. Khan Mohd Asif (14CES19)** and **Mr. Khan MohdShakirMohd Sabir (14CES21)** is approved for the degree of "Civil Engineering"

Examiners

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Supervisors:

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2. …………………………

Date: 04/05/2018

Place: New Panvel

DECLARATION

We declare that this written submission represents my ideas in our own words and where others ideas or words have been included; we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: 04/05/2018

ABSTRACT

Naturally found soil may or may not be strong enough to hold superstructures. For weak soil the method of soil stabilization is used to increase its strength. Consequently, randomly distributed fibre-reinforced soils have recently attracted increasing attention in geotechnical engineering. Among various methods of soil stabilization, one is to reinforce the soil with fibres. This study investigates and compares the differences between unreinforced and reinforced soil. Soil here is reinforced with polypropylene fibre of length 24mm with varying percentage by mass of soil as 0.6% 0.8% 1.0% and 1.2%. The soil was tested and basic properties were identified. Unconfined compression tests have been carried out to draw inferences about the effect of polypropelene fibres on strength of soil. This study also finds out the optimum dosage of polypropylene fibre by analysing the results and obtaining the best values possible.

Keywords—Soil stabilisation, Polypropylene fibre, Soil reinforcement,Optimum dosage

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ABBREVIATION NOTATION AND NOMENCLATURE

PP	Polypropylene
C	Cohesion
UCS	Unconfined Compressive Strength
W_L	Liquid Limit
W_p	Plastic Limit
I_p	Plasticity Index
ASTM	American Society of Testing Materials
IS	Indian Standard
C_u	Uniformity Coefficient
C_C	Coefficient of Curvature
SL	Shrinkage Limit
SW	Well Graded Sand
SM	Sand with Silt
OMC	Optimum Moisture Content
MDD	Maximum Dry Density
P	Load
A	Area
□	Strain

Chapter 1

Introduction

1.1 General

With the reduction of available land resources, moreand more construction of civil engineering structures iscarried out over weak or soft soil, which leads to theestablishment and development of various ground improvement techniques such as soil stabilization andreinforcement. Soil is highly complex, heterogeneous and unpredictable material which has been subjected to unexpected change of weather, without any control, The properties of a soil depend not only on its type but also on the conditions under which it exists and loading and drainage conditions. In order for the safe and strong structure, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behaviour. The process of soil stabilization helps to achieve the required strength in a soil needed for the construction work. From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans utilized various methods to improve soil strength some of these methods were so effective that their buildings and roads still exist. Improvement of certain desired properties of soil like compaction unconfined compression, shear strength, swelling characteristics can be undertaken by a variety of soil improvement techniques.

1.2 Problem Statement

The safety of any geotechnical structure is dependent on the strength of soil. If the soil fails, the structure founded on it can collapse. Understanding shear strength is the basic to analyze soil stability problems like: lateral pressure on earth retaining structure, slope stability, bearing capacity. While constructing any structure of any form, it directly depends upon the relation between soil, structure and its loading. There are various methods to improve the shear strength of the soil but most of them are very costly. therefore it is necessary to find low cost alternative for the same

1.3 Proposed Solution: Polypropylene Fibre

Polypropylene (PP), also known as polypropylene, is a thermoplastic polymer used in a wide variety of applications. An addition polymer made from the monomer propylene, it can be produced in a variety of structures giving rise to applications including packaging and labeling, textiles, plastic parts and reusable containers of various types, laboratory equipment, automotive components, and medical devices. It is a white, mechanically rugged material, and is resistant to many chemical solvents, bases and acids.

Figure 3.2.1.1 Polypropylene Fibres

1.4 Objectives of the study

The objectives of this study are:

1. To find the shear strength of natural soil (un-reinforced) using unconfined compression test
2. To find the shear strength of soil mixed with Polypropylene fibres using unconfined compressive test.
3. To compare the shear strength of natural soil(un-reinforced) with that of soil mixed with Polypropylene fibres
4. To suggest the optimum proportion of polypropylene fibres for soil improvement

Chapter 2

Literature Review

2.1 General

During the literature review for this work, we have referred quite a few text and reference books on geotechnical engineering; and technical and research papers from various national and international journals. This part focuses on the literature of improvement of soil using polypropylene.

2.2 Review of Literature

Dean R Frietag, (1986) has obtained some data on the effect of fibres on the strength of a compacted fine grained soil. The soil used was a residual limestone soil that classified as a lean sandy clay (CL). The liquid limit was 42 and the plasticity index was 22. Three different synthetic fibres were used: (1) A spun nylon string; (2) polypropylene rope fibre; and (3) a polypropylene olefin concrete reinforcement fibre trade-named Fibre-mesh. The approach used in the study was to compare the unconfined compression strength of plain and reinforced specimens compacted over a sufficiently wide range of water content to define the compaction curve.Randomly distributed fibres in a compacted fine-grained soil can result in greater strength and toughness. The amount of strength gain for samples wet of optimum was about 25%, which was comparable to the benefits found for other materials and other fibres.

Y. Yilmaz (2011) had undertaken an experimental program to investigate the effects of discrete polypropylene fibres and low dosage ordinary Portland cement (OPC) on the stress-strain and unconfined compressive strength behavior of clayey soil. Multifilament polypropylene fibre in three different lengths (6.0mm, 12.0mm, and 19.0mm) and two fibre dosages (i.e. 0.5% and 1.0% by dry weight of soil) were considered. Using compaction characteristics of untreated soil 9 different fibre-cement-soil mixtures (i.e. fibre/soil-cement ratio of 0.5% and 1.0% and cement/soil ratio of 0.0%, 3.0% and 6.0% by dry weight) were composed, and their unconfined compression test were carried out after 1, 7 and 28-days curing periods. Increasing cement content and curing period causes an increase in UCS of the fibre-cement-clay mixtures and reversely increase in fibre content seems to decrease UCS of the mixture. Among other fibre lengths 19 mm length multifilament polypropylene fibre (M19) with 1.0% inclusion gives the highest increase USC at all cement dosages. As a general tendency the increase in fibre length results an increase in USC. On the contrary, the effect of fibre length on the UCS is unclear for 0.5% fibre inclusion

Mona Malekzadeh (2012) has undertaken a study in which the initial part was to study effect of polypropylene fibre on maximum dry density and optimum moisture content of soil with different fibre inclusions. Different percentages of polypropylene fibre inclusion were done such as 0.5%, 0.75% and 1.0%. The second phase of this study comprises of UCS test tensile test and swelling test. After testing the standard unreinforced soil and reinforced soil it is seen that the time required for failure of the sample increases which means that the ductility of the soil increases after reinforcement. Under the Unconfined compressive test it is observed that as the reinforcement increases the better value is obtained so polypropylene can be regarded as a good material for reinforcement of soil. The split tensile test were also carried to observe the tensile strength of soil thought the method is for concrete testing soil moulds were tested and some correction factor was applied, while testing it was observed that the tensile strength of soil increases as the percentage of polypropylene to the soil increases. It is then concluded that optimum moisture content of soil is not influenced by inclusion of polypropylene fibre whereas MDD decreases . Maximum value of cohesion can be observed with 1% of fibre inclusion which is approximately 1.5 times the value of unreinforced soil. Similarly tensile strength increased 2.7 times the unreinforced soil sample. It implies that ductility increases, reduction in shrinkage settlements during desiccation and hence detrimental damages to structures such as roads and pavements may be prevented

Aykut Senol (2014) had found the effect of polypropylene fibre on the low plasticity clayey soil. He gave the experimental results of using polypropylene fibre to improve the plasticity of soil. He had taken 5 samples of different proportions of PP fibres as 0.25%, 0.5%, 0.75%, 1% and 1.25% by weight of soil. They had carried out unconfined compression test and interpreted the results. They found that the soil with polypropylene with 0.75% gives better strength.

Dilip Kumar and Ashish Gupta (2014) investigated the use of fibre in geotechnical engineering, for stabilization of soil by providing fibre reinforcement to it is advantage. Two advantages namely (a) increase in bearing capacity of soil and (b) reduction in the erosion of top soil by water. Mass scale utilization of fibre can be carried out especially in that area which are very much important or prone to heavy damage due to flood. The work is an attempt to check the feasibility of fibre in the soil stabilization by providing fibre reinforcement to the soil.Load carrying capacity of road soil increases with increasing the number of layer of fibre in sub-soil strata. The settlement of foundation decreases with increasing the thickness of fibre. The OMC of the soil increases from 15% to 15.8% and 16%, when the fibre is used at a depth of 40mm and 80mm. The CBR value of soil first increases from3.65 to 4.0 when the fibre is used at a depth of 40mm and this value decreases to 3.74 when we use it at a depth of 80mm.The value of coefficient of permeability reduces from 6.043 x $10^{-6}$to 4.012043 x 10^{-6} and 3.457043 x 10^{-6} when the fibre is used at a depth of 40mm and 80mm. Similarly, the value C (KN/m^2) changes from 3.57 to 3.87 and 4.02, when the fibre is used at a depth of 40mm and 80mm. And the value of Φ (in degree) changes from 29 to 30.8 and 31.2.

Behzad Amir-Faryar and M. Sherif Aggour (2014) researched that different approaches i.e. a concrete approach and metallurgical approach were described and sustainable soil approach was introduced. The synthetic soil used was Kaolinite and was reinforced with commercially available fibre state such as 12.7 mm and 19 mm.

Soğancı, A. S. (2015) has investigated effect of polypropylene fibre on expansive soil, expansive soil are swollen in nature if it is found in foundation it can be replaced by granular soil but instead of replacing the soil it can be achieved by reinforcing the polypropylene fibre with the soil. It decreases the swelling percentage of soilor by applying this method automatically cost will decrease. A series of test were conducted to study the effects of fibre on expansive soil on swelling characteristics. Reinforced stabilized soil specimen were prepared at four different percentages of fibre content (0.25%, 0.50% 0.75%, 1.0%) and three different fibre lengths (6mm, 12mm, 20mm),unconfined compression and one dimensional swell test were performed. The tensile strength value increased to a great extent by reinforcing the fibre with soil values were obtained with 0.5%-0.75% with 12mm fibre. The highest values were obtained with 0.56-0.75% content for the 12mm length fibre. Moisture content does not change whereas maximum dry density reduces as fibre content increased in compaction test.Increasing the fibre content had increased the peak axial stress, Swell percent was reduced as the fibre Increased. As a result of this investigation it is clearly found that the stabilization technique with polypropylene method is very useful for ground improvement.

Kiran S P (2016) has analysed the effect of reinforcing polypropylene and polyester to the soil The soil was reinforced with different percentage of polypropylene and polyesterfibres and found both material as good stabilizing material chemical binding occurs between minerals in the soil and chemicals in the polypropylene and polyester material which eventually results in increasing the angle of internal friction of sand and ductility of sandy soil. In case of polypropylene it can enhance up to 32% and polyester up to 17% of the strength compare with the normal soil mix. While comparing polypropylene and polyester fibre the polypropylene fibre gives better results of 0.4% mix with sandy soil and comparatively twice the strength value than the polyester mix.

Muske Srujan Teja (2016) has investigated the effects of polypropylene fibres on shear strength of unsaturated soil by carrying out shear strength and unconfined compressive tests on two different samples for the effective use of soil for replacement of deep foundation and made a cost effective approach to raft foundation. He varied the percentage of fibre inclusion as 0.05% 0.15% and 0.25%. Basic properties were examined and accordingly the comparative study was done and came to conclusion that 19.6% net increase in cohesion of unreinforced soil sample and 0.25% reinforced sample and also increase in angle of internal friction was observed to 1.59% on comparing soil that is unreinforced and other reinforced with 0.25%. depending upon these values he concluded that fibre reinforced soil can be considered as good ground improvement technique specially in weak soil where it can act as a substitute to deep and raft foundation reducing cost as well as energy.

C. M. Satya Priya, S. Archana et. al.(2017) studied soil stabilization by reinforcing polypropylene to the soil with different percentages such as one sample with no reinforcement and others with 0.5% 1% and 1.5% The samples were first tested for free swell index and it was found that with increase in polypropylenefibre content the swelling of soil decreased. At 1% of polypropylene no swelling was observed and further at 1.5% too no swelling was observed. Then the soil samples were tested by standard proctor test and found that up to 1% of soil content specific gravity increases and after that it decreased similarly UCS tests were performed and observed that up to 1% of polypropylene content the UCS value increased and after that it decreased. From the data obtained it was found that soil strength increases as the percentage of reinforcement of polypropylene increases and it was thereby inferred that pp fibre can be used effectively for stabilization of soil.

2.3 Gaps and Findings

Among the literatures studied it is clear that some has reinforced soil with polypropylene and polyester with binding material such as cement and fly-ash whereas some has used varying lengths of polypropylene and some has used varying water content and studied various soil properties and compared the data to get the optimum dosages of fibres. So here in this study we will analyse the soil with the gap observed like fixing the polypropylene length to 24mm and varying percentage of polypropylene content by weight such as 0.6% 0.8% 1.0% 1.2%

Chapter 3

Materials and Methodology

3.1 General

This study demonstrates the use of Polypropylene fibres as a reinforcement material in soil. In which, an experimental work will be carried out to find the compressive strength of soil before and after reinforcement. The results generated by testing of soil with different proportion of PP fibres will helps to find optimum dosage of PP fibres in soil with similar properties. The graph will helps to understand the effect of reinforcement of PP fibres by proportion of its weight.

3.2 Materials

3.2.1 Soil

The main material use for this study is soil. The soil has been from a field located near Bhiwandi. The soil properties is been tested with different experiments to find its characteristics properties which is later discussed in future chapter 4.

3.2.2 Polypropylene Fibre

Polypropylene fibre was used in this study is provided by the Sunil Chemical Industries Pvt. Ltd., Sewree-15. Colour of Polypropylenefibre is white with a density of $0.91 g/cm^3$.The melting point of fibre is 150°c-165°c as provided by the supplier. The properties of PP fibres as provided by the supplier are as follows.

i. Colour – White.

ii. Length – 24mm

iii. Density – 0.91g/cm^3

iv. Melting point – 150°c-165°c

v. Product code – Fibre-crete MF

3.3 Methodology

Procurement of the materials was the important phase of the study. Soil was collected from the vicinity of Bhiwandi. For PP fibres indiamart.com is used to find the supplier of the fibre and PP fibre is collected from the supplier. By studying various papers which was published earlier test to be performed and the proportion of inclusion of fibre is decided as 0.6%, 0.8%, 1.0%, and 1.2%.

3.3.1 Random fibre reinforcement

This arrangement has discrete fibres distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally waste from plastic industries named as polypropylene. Randomly distributed fibres have some advantages over the systematically distributed fibres. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur generally in other soils.

3.3.2 Tests

All tests that were performed were according to their respective Indian Standard code. The test was performed in laboratory.

The tests are as follows

I) Grain size analysis

In accordance with IS 2720 (Part 4):1985.

Apparatus:

Set of sieves, 4.75mm, 2.36mm, 1.18mm, 600micron, 425µ, 300µ, 150µ, and 75µ, weighing balance, Oven, Mechanical shaker

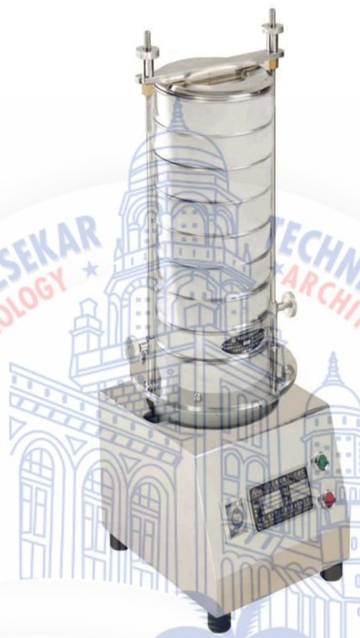


Figure 3.3.2.1 Mechanical Sieve Shaker

Procedure:

Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving.

Dry Sieving:

1. 1000gm of the soil sample was taken.

2. Sieve analysis test was conducted using sieves.

3. Sieving was done by mechanical sieve shaker for 10 minutes.

4. Soil retained on each sieve was weighed.

5. The percentage retained on each sieve was calculated on the basis of the total weight of the soil sample taken.

6. From these results the percentage passing through each of the sieves was calculated.

7. Grain size curve for the soil was drawn on semi-logarithmic graph.

II) Atterberg's limits

i) Liquid limit

Apparatus:

Casagrande's liquid limit device, Grooving tools of both standard and ASTM types, Oven Evaporating dish, Spatula, IS Sieve of size 425 µm, Weighing balance

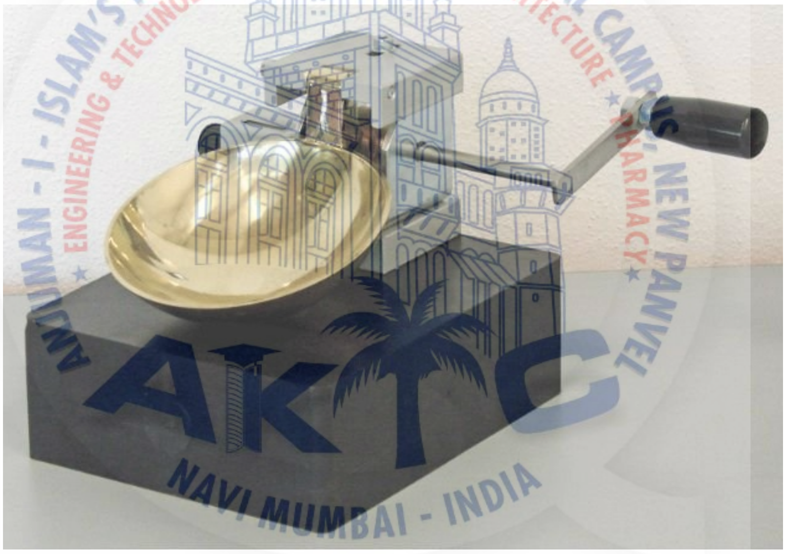


Figure 3.3.2.2 Casagrande's liquid limit device

Test Procedure

1. Portion of the soil paste was placed in the cup of the liquid limit device.

2.The mix was levelled so as to have a maximum depth of 1cm.

3.Grooving tool was drawn through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.

4. After the soil pat has been cut by grooving tool, the handle was rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.

5. About 10g of soil was taken near the closed groove and water content was determined.

6. The soil of the cup was transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. Test was repeated.

7. Liquid limit was determined by plotting a ‘flow curve’ on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points

ii) Plastic limit

Apparatus:

Porcelain evaporating dish about 120mm diameter, Spatula, Container to determine moisture content, Container to determine moisture content, Oven, Ground glass plate – 20cm x 15cm, Rod – 3mm dia. and about 10cm long

Test Procedure:

1. 8g of the soil was taken and rolled it with fingers on a glass plate. As instructed the rate of rolling should adopted was between 80 to 90 strokes per minute to form a 3mm dia.

2. The dia. of the threads was reduced to less than 3mm, with no cracks appearing, indicating that the water content is more than its plastic limit

3. The process was repeated to alternate rolling and kneading until the thread crumbled.

4. crumbled pieces were collected and from that moisture content was analysed.

5. The process was repeated twice more with fresh samples of plastic soil each time.

iii.)Shrinkage limit

In accordance with IS 2720-1972

Apparatus

Oven, Sieve 425-micron, Mercury, Desiccator, Weighing balance, with 0.01g accuracy

Figure 3.3.2.3 Shrinkage limit Apparatus

Test Procedure:

1. 100 gm. of soil sample was taken from a thoroughly mixed portion of the material passing through 425 microns IS sieve is taken.

2. About 30 gm. of above soil sample was placed in the evaporating dish and thoroughly mixed with distilled water and made a paste

3. The weight of the clean empty shrinkage dish was determined and recorded.

4. The dish was filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula.

5. Then the dish with wet soil was weighed and recorded immediately.

6. The wet soil cake is air dried until the color of the pat turns from dark to light. Then it is oven dried at a temperature of 1050 C to 1100 C for 12 to 16 hours. The weight of the dish with dry sample is determined and recorded. Then the weight of oven dry soil pat is calculated (W_0).

7. The shrinkage dish was placed in the evaporating dish and the dish was filled with mercury, till it overflowed slightly. Then it was pressed with plain glass plate firmly on its top to remove excess mercury. The mercury from the shrinkage dish was poured into a measuring jar and the volume of the shrinkage dish was calculated. This volume was then recorded as the volume of the wet soil pat (V).

8. A glass cup was placed in a suitable large container and the glass cup was removed by covering the cup with glass plate with prongs and pressed it. The outside of the glass cup was wiped to remove the adhering mercury. Then it was placed in the evaporating dish

9. Then the oven dried soil pat was placed on the surface of the mercury in the cup and pressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish.

10. The mercury so displaced by the dry soil pat was weighed and its volume (V_o) was calculated by dividing this weight by unit weight of mercury.

III.)Standard Proctor Compaction Test

In accordance with IS 2720 (Part 7):1980.

Apparatus

Cylindrical mould& accessories [volume = 1000cm3], Rammer [2.6 kg], Balance [1gaccuracy], Sieves [19mm], Mixing tray, Trowel, Graduated cylinder [500 ml capacity], Metal container.

Figure 3.3.2.4 Standard Proctor

Test Procedure:

1. 5 Kg. of soil was taken and the water is added to it to bring its moisture content to about 4 % in coarse grained soils and 8% in case of fine grained soils with the help of graduated cylinder

2. The mould with base plate attached was weighed to the nearest 1 gm. The extension collar was attached with the mould.

3. Then the moist soil in the mouldwas compacted in three equal layers, each layer being given 25 blows from the 2.6 Kg rammer dropped from a height of 310 mm. above the soil.

4. The extension is removed and the compacted soil is leveled off carefully to the top of the mould by means of a straight edge.

5. Then the mould and soil was weighed to the nearest 1 gm.

6. The soil was removed from the mould and a representative soil sample was obtainedfor water content determination.

7. Steps 3 to 6 are repeated after adding suitable amount of water to the soil in an increasing order.

IV.) Unconfined Compressive Strength Test:

In accordance with IS 2720 (Part10)-1991.

Apparatus:

Unconfined compressive test apparatus (proving ring type), Proving ring, capacity 1 KN, accuracy 1 N, Dial gauge, accuracy 0.01 mm, Weighing balance, Oven, Stopwatch, Sampling tube, Split mould, 38mm diameter, 76mm long, Sample extractor, Knife, Vernier calipers, Large mould.

Figure 3.3.2.5 UCS test Machine

Test Procedure

1. Soil which is to be tested was mixed with water. This sample was then filled in the mould which was oiled in advance. The mouldwas having the same internal diameter as that of specimen which is to be tested.

2. The mould was opened carefully and sample was taken out

3. Prepared two set of such samples for testing .

4. Measured the initial length and diameter of the specimen.

5. The specimen was kept on bottom of the loading device. Adjusted upper plate to make contact with the specimen.Dial gauge (compression) was set at zero. The dial gauge reading provided the deformation in the sample and in turn strain.

6. Compressed the specimen until crakes were developed or until a vertical deformation of 20% was reached. the dial reading was approximately taken at every 1 mm deformation of the specimen.

7. The proving ring reading provided the corresponding load in- turn axial stress on the sample.

8. Repeated the specimen with different dosage of pp fibre

9. Determined water content of each sample.

3.3.3 Calculations and Computation

For various calculation of tests readings MS Excel sheets has been used.MS Excel is also used to plot graphs of test's readings.

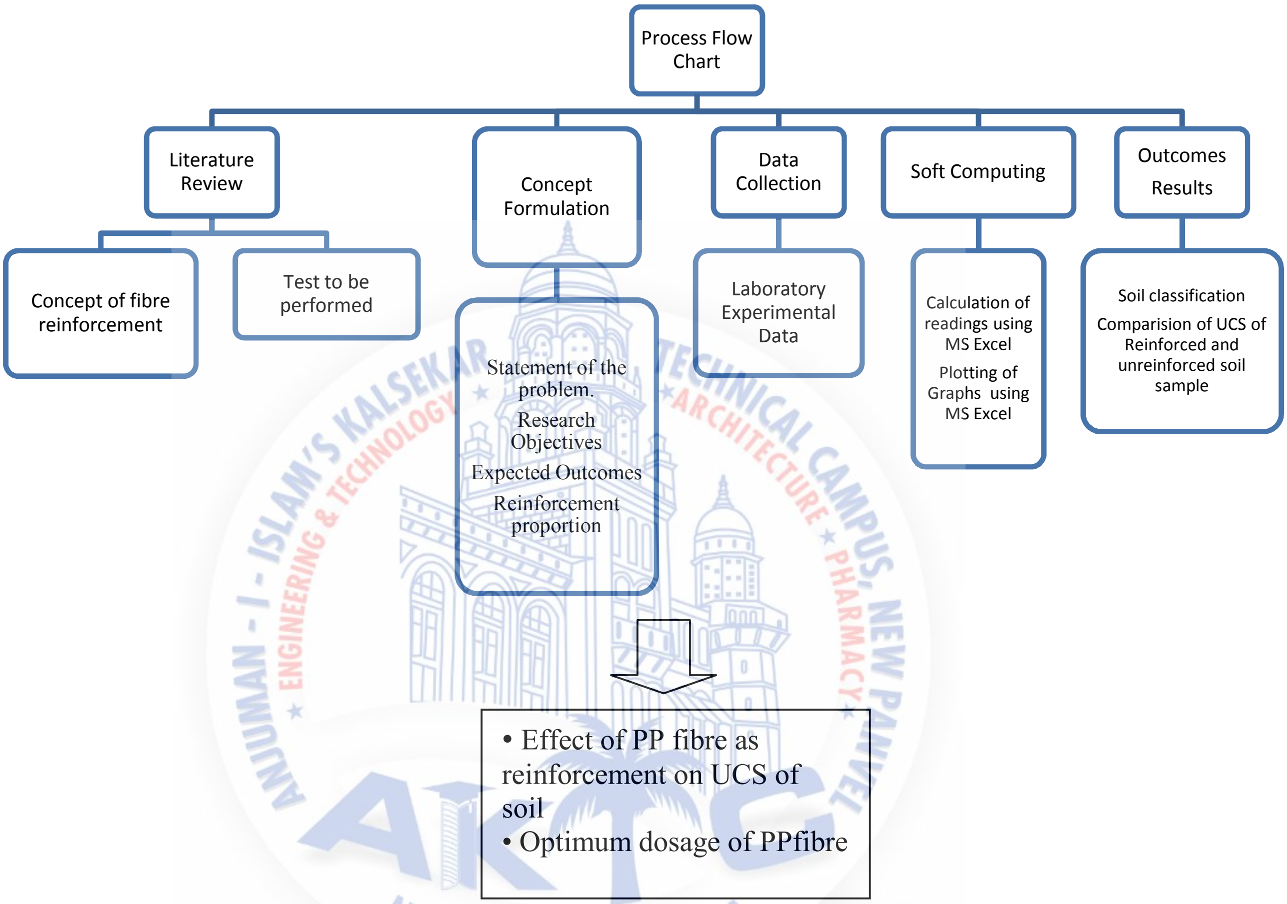


Figure 3.3.3.1 Process Flow Chart

Chapter 4

Results and Discussion

4.1 General

Experimental determination of various soil properties has been carried out in accordance with their respective Indian Standard code. For every experiment of soil properties determination no. of samples were tested and their average has been taken. For Unconfined Compressive Strength test the soil sample is prepared with different proportion of Polypropylene fibre such as 0.6%, 0.8%, 1.0%, 1.2% is prepared. Plain soil is also prepared for comparison of reinforced and plain sample. Two samples for each proportion is prepared and tested. Readings were noted and calculation is done and results are interpreted.

4.2 Experimental Data

4.2.1 Grain size Analysis

Figure 4.2.1.1 Sieve Analysis (Mechanical sieve shaker)

Table 4.2.1 Readings of Sieve Analysis

Sr. No.	Sieve Size (mm)	Mass retained in each sieve (g)	Cumulative Mass Passed (g)	Total % passed
1	4.75	0	1000	100
2	2.36	5	995	99.5
3	1.18	310	685	68.5
4	0.6	205	480	48
5	0.425	105	375	37.5
6	0.3	45	330	33
7	0.15	180	150	15
8	0.075	45	105	10.5
9	PAN	105	0	0
TOTAL		1000		

Percentage of fines (passing 75µ sieve) = 10.5%

Since the % of fines i.e. passing through 75µ is 10.5% which lies between 5% - 12%, According to Indian standard of soil classification Border line Cases requiring Dual symbol should be adopted.

More than 50% passes through 4.75mm sieve then the soil Sample is Sand. For further classification of soil the use of uniformity coefficient and coefficient of curvature is required.

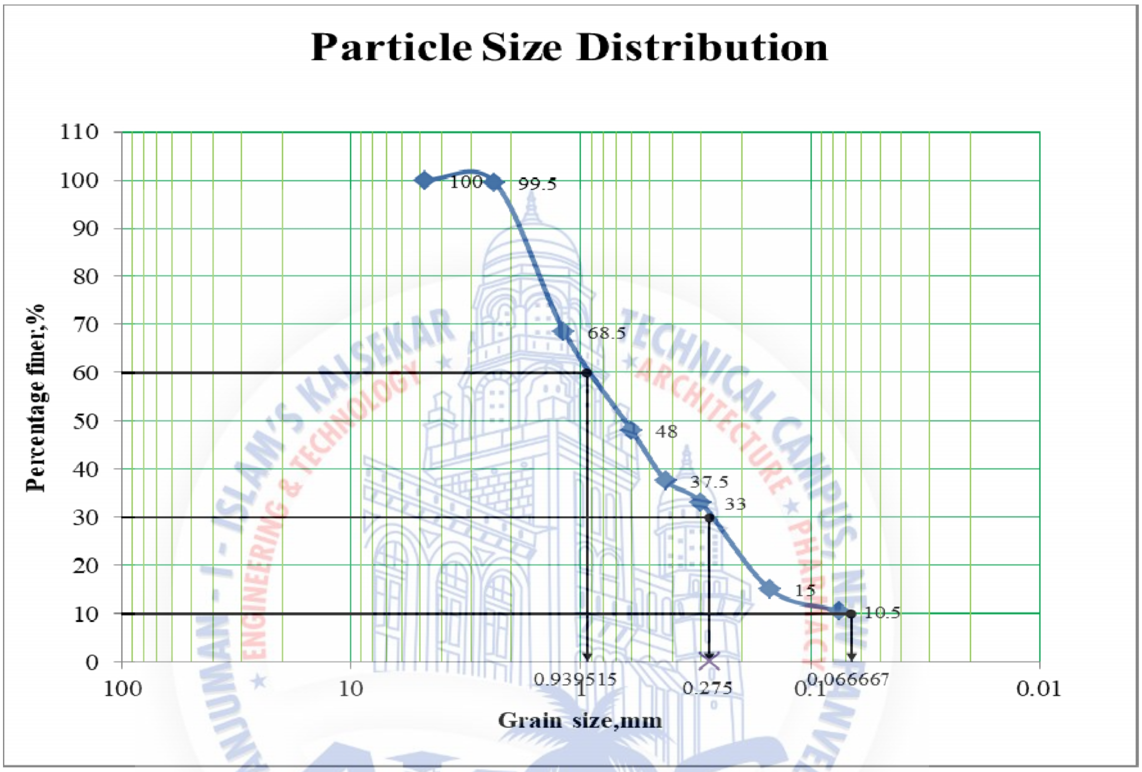


Figure 4.2.1.2 Particle size distribution

D_{10} = 0.066667
D_{30} = 0.275
D_{60} = 0.939515

Uniformity coefficient ,$C_u = \frac{D6}{D1} = \frac{0.9}{0.0} =$ **14.09** **$C_u > 6$**

Coefficient of curvature, $C_c = \frac{D_3{}^2}{D_1 \; X \, D_6} = \frac{0.2 \quad {}^2}{0.0 \quad X\, 0.9} =$ **1.2073** **$1 < C_c < 3$**

Therefore by value of C_u and C_c ,the soil can be classified as well graded sand (SW). Classification should be done by border line case (Dual Symbol) , further classification is done using Plasticity chart given in IS 1498:1970.

4.2.2 Atterberg's Limits

4.2.2.1 Plastic Limit

In accordance with IS 2720 (Part 5) – 1985

Three samples were tested for plastic limit. The soil sample were prepared and test procedure is followed in accordance with IS 2720 (Part 5) – 1985. Readings are noted down and results are interpreted.

Table 4.2.2 Readings for Plastic Limit

Determination no.	1	2	3
Weight of empty container (g) (W_0)	15	15	15
Weight of container + wet soil (g) (W_1)	21	22.4	20
Weight of container + oven dried soil (g) (W_2)	19.8	20.9	18.9
Weight of water (W_1-W_2)	1.2	1.5	1.1
Weight of Oven dried soil (W_2-W_0) (g)	4.8	5.9	3.9
Water content (%) (W_1-W_2)/(W_2-W_0)	25	25.42	28.20

Average water content of plastic limit test W_p= 26.20 %

4.2.2.2 Liquid Limit

In accordance with IS 2720 (Part 5) – 1985

Four samples are tested using Casagrande's liquid limit device in accordance with IS 2720 (Part 5) – 1985. The water content varies in each sample and number of blows given to soil sample using apparatus are noted down. Graph is plotted using water content and number of blows.

Figure 4.2.3 Casagrande's Apparatus and Soil Specimen in it

Table 4.2.3 Liquid limit

Determination no.	1	2	3	4
No. of blows	18	22	26	33
Weight of empty container (g) (W_0)	15	15	15	15
Weight of container + wet soil (g) (W_1)	30	35	32	31
Weight of container + oven dried soil (g) (W_2)	26	30	28	27.5
Weight of water (W_1-W_2)	4	5	4	3.5
Weight of Oven dried soil (W_2-W_0) (g)	11	15	13	12.5
Water content (%) (W_1-W_2)/(W_2-W_0)	36.36	33.33	30.76	28

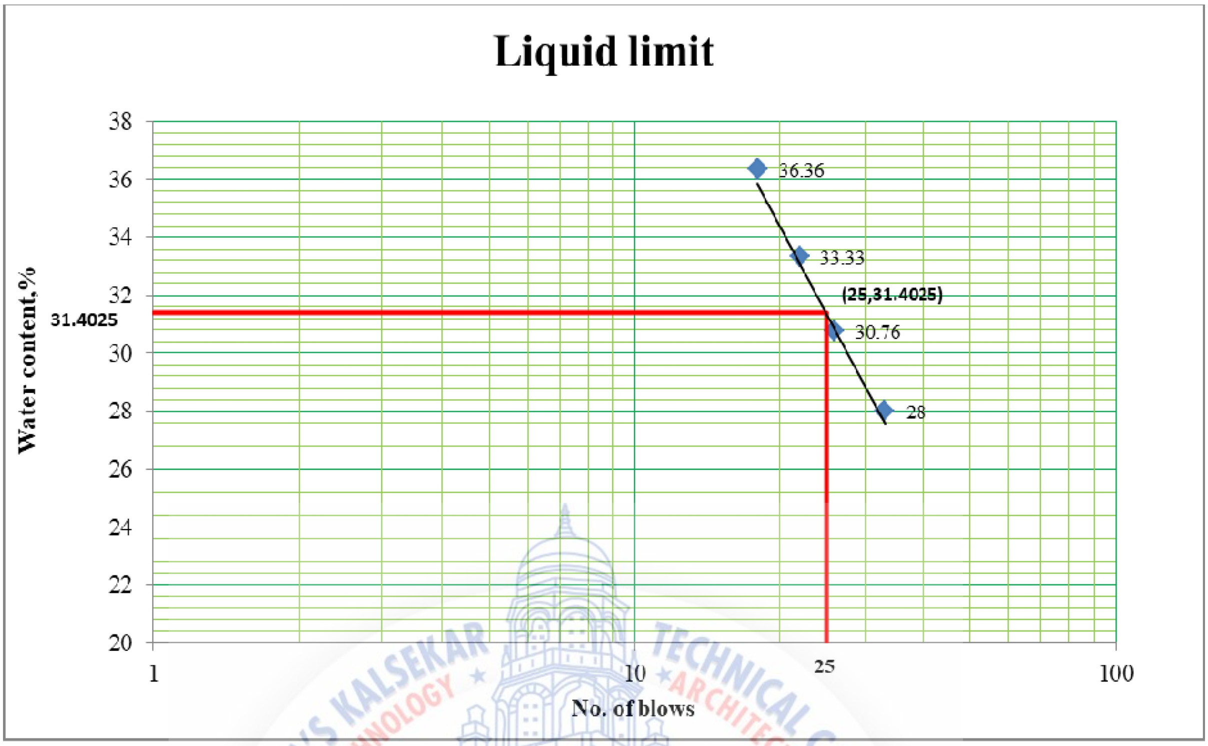


Figure 4.2.2.1 Liquid Limit Graph

Liquid limit of soil specimen corresponding to 25 no. of blows (W_L) = **31.4025%**

Plasticity index (I_p) = (W_L-W_P) = 31.4025 – 26.20 = 5.2025

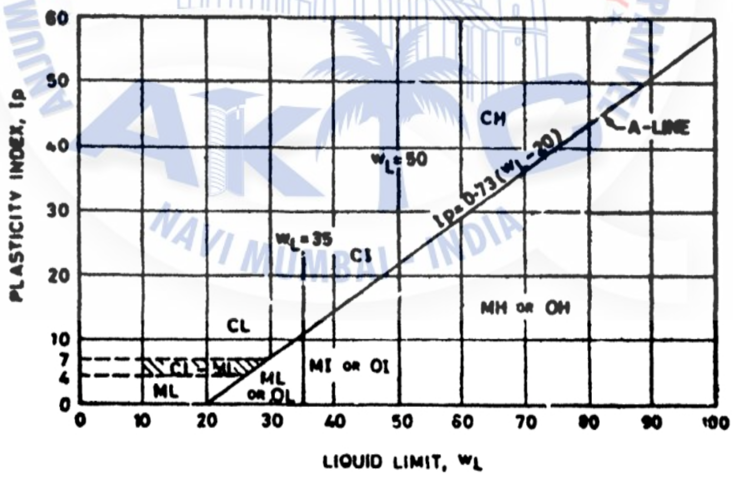


Figure 4.2.2.2 Plasticity Chart from IS 1498:1970

I_{pc} = 0.73 (W_L – 20) = 0.73 * (31.4025 – 20) = 8.3238

- $I_p < I_{pc}$

According to plasticity chart, the value corresponds to I_p and W_L grade the soil as silt. Therefore using Border line cases (dual symbols) the can be classified as well graded sand with silt (SW-SM).

4.2.2.3 Shrinkage Limit

In accordance with IS 2720-1972

Shrinkage limit test were performed on a given sample according to IS 2720-1972.

The soil pat was prepared in a shrinkage dish and oven dried for 24 hours. Readings were noted before and after oven drying. The volume of soil pat is calculated and shrinkage in volume of soil pat is determined by the displacement of volume of mercury by soil pat. Results are interpreted then.

Figure 4.2.2.3 Determination of Shrinkage Limit

Table 4.2.4 Shrinkage limit

Sr no.	Description	Readings
1	Mass of empty shrinkage dish (M_0) (g)	30
2	Mass of wet soil + shrinkage dish (M_1) (g)	70
3	Mass of wet soil (M_2) (g)	40
4	Mass of dry soil + dish (M_3) (g)	55
5	Mass of Dry soil (M_4) (g)	25
6	Volume of shrinkage dish = Volume of wet soil (V_1) (cm^3)	22.5

7	Volume of Dry soil (V_2) (cm^3)	16.5
8	Weight of Water (g)	15

ρ_w = 1 g/cc

Shrinkage Limit $=\left[\left(\frac{M_2-M_4}{M_4}\right)-\left(\frac{V_1-V_2}{M_4}\right)\rho_w\right]*100$

$$=\left[\left(\frac{4\ -2}{2}\right)-\left(\frac{2\ .5-1\ .5}{2}\right)*1\right]*100$$

SL =36%

4.2.3 Standard Proctor Compaction Test

Standard proctor compaction test is carried out using the procedure given in IS 2720 (Part 7):1980

5 kg of soil sample is taken and 12 % of water by weight of soil is added to the soil Soil mixed thoroughly and moulded in 3 layers in the standard proctor mould with 25 no. of blows by 2.6 kg rammer from a free fall of 300mm .

The weight of empty mould and mould with compacted soil is noted down.

Further water content increases in increasing order and same procedure is followed and readings are noted down

Graph is plotted using water content and Dry density and MDD is found out.

Table 4.2.5 Standard Proctor Test

Determination no.	1	3	5	6	7	8	9
Weight of mould, W_1 (g)	7705	7705	7705	7705	7705	7705	7705
Weight of mould + compacted soil, W_2 (g)	9185	9500	9740	9815	9875	9925	9365
Wt. of compacted soil $W=W_2-W_1$ (g)	1480	1795	2035	2110	2170	2220	1660
Bulk density $\gamma=\frac{W}{V}$ (g/cm^3)	1.345	1.63	1.85	1.918	1.97	2.01	1.51
Water content w (%)	12	17	21.71	23	27.88	31	37
Dry density $\gamma_d = \frac{\gamma_b}{(1+w)}$ (g/cm^3)	1.2	1.39	1.52	1.55	1.54	1.5	1.4

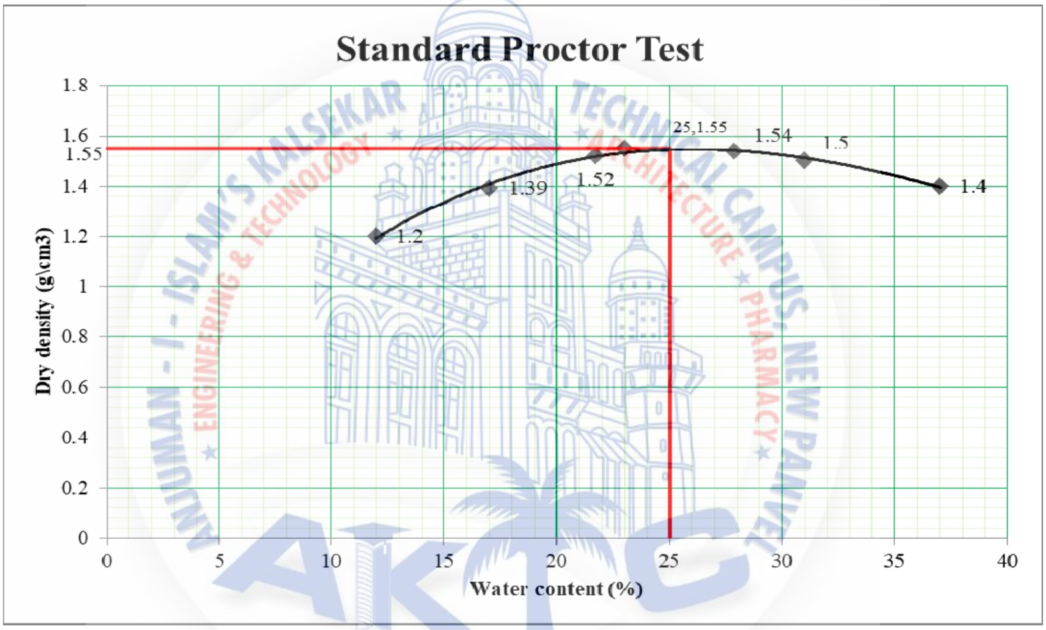


Figure 4.2.3.1 Graph of standard proctor test

OMC = 25%

MMD = 1.55 g/cm^3

4.2.4 Unconfined compressive test

In accordance with IS 2720 (Part10)-1991.

In UCS test total 5 different types of samples are prepared. The samples are plain and Reinforced with 4 different proportion of PP fibres. Two samples of each type are prepared and tested.Due to water reducing properties of PP fibres 5% additional water than OMC is adopted. Throughout the test water content of the sample kept constant at 30%. Readings are noted down in table and compressive strength is calculated with help of Ms Excel. Stress-strain Graph has also been plotted for getting clear idea of variation of strength. Lastly comparison of all 5 samples is done to find the proportion of PP fibres which gives maximum strength.

Followings are the data of samples tested:

4.2.4.1 Plain/Unreinforced soil Sample

Figure 4.2.4.1 Plain soil sample

This sample is plain with 30% water content by the weight of soil. Soil mould is prepared by following procedure of IS code. UCS test is performed and results are obtained (refer Appendix for detail readings). Graphs of results are shown below:

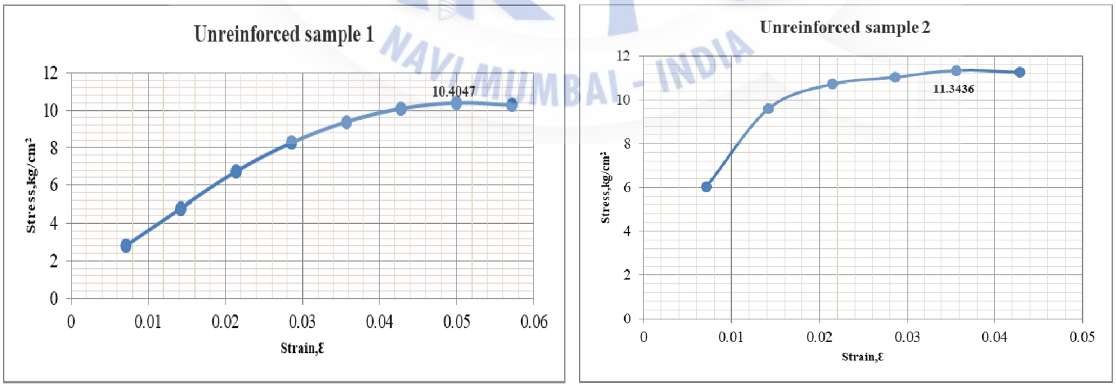


Figure 4.2.4.2 Graphs of plain soil samples

Average UCS of Plain soil Samples is (q_u) =**10.87415 kg/cm²**.

The value of cohesion of soil (c) = $\frac{q_u}{2} = \frac{1\ .8}{2}$ =5.437075 kg/cm²

4.2.4.2 Reinforced samples

Figure 4.2.4.3 Reinforced soil sample

Samples are reinforced with randomly distributed PP fibres. The proportion of mix of PP fibres is 0.6% , 0.8% , 1.0% , 1.2% of weight of soil sample .Water content is kept at 30% by the weight of soil. Soil mould is prepared by mixing soil and PP fibre together. Homogeneous mixture is prepared. UCS test is performed and results are obtained (refer Appendix for detail readings). Graphs of results are shown below:

4.2.4.2.1 Soil Reinforced with 0.6% PP

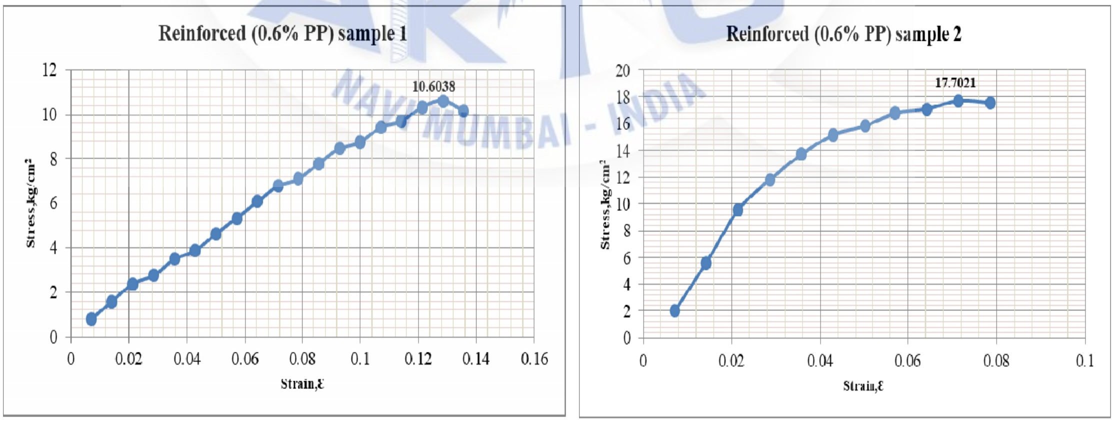


Figure 4.2.4.4 Graphs of samples with 0.6% of PP fibres

Average UCS of soil sample reinforced with 0.6 % of PP fibres (q_u) = 14.15295 kg/cm^2

Cohesion of soil sample reinforced with 0.6 % of PP fibres (c) $=\frac{q_u}{2} = \frac{1\ .1}{2}$ =7.0764 kg/cm^2

4.2.4.2.2 Soil sample reinforced with 0.8% PP fibres

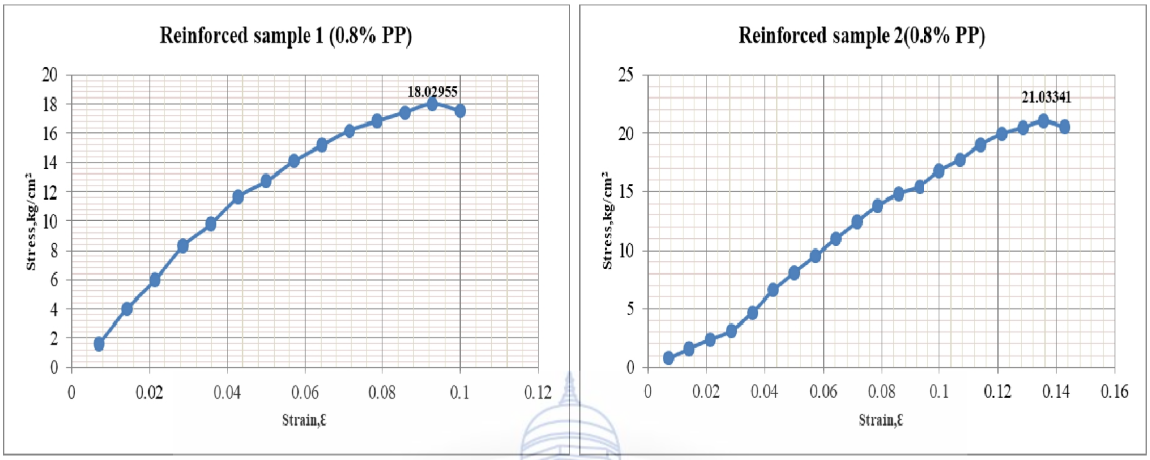


Figure 4.2.4.5 Graphs of sample reinforced with 0.8% PP fibres

Average UCS of soil sample reinforced with 0.8 % of PP fibres (q_u) = 19.53148kg/cm^2

Cohesion of soil sample reinforced with 0.8 % of PP fibres (c) $=\frac{q_u}{2} = \frac{1\ .5}{2}$ = 9.7657 kg/cm^2

4.2.4.2.3 Soil Reinforced with 1.0 % PP fibres

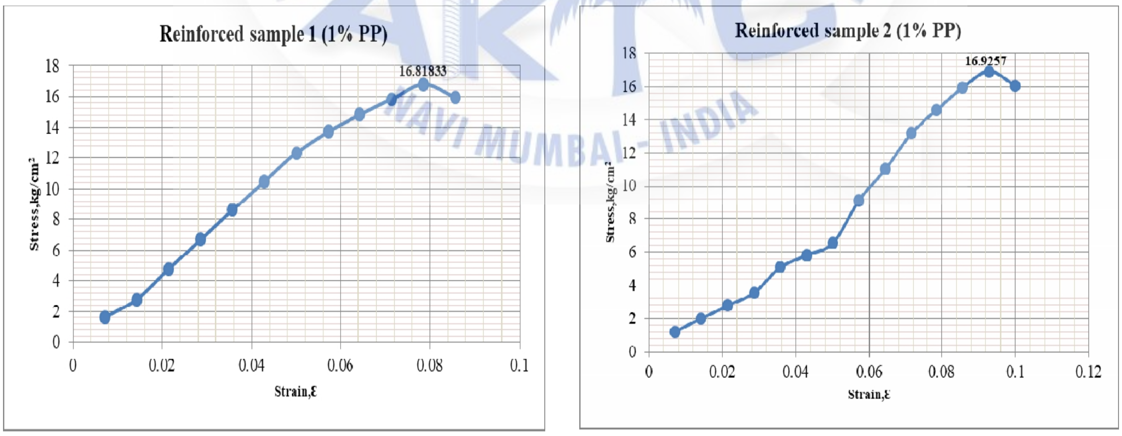
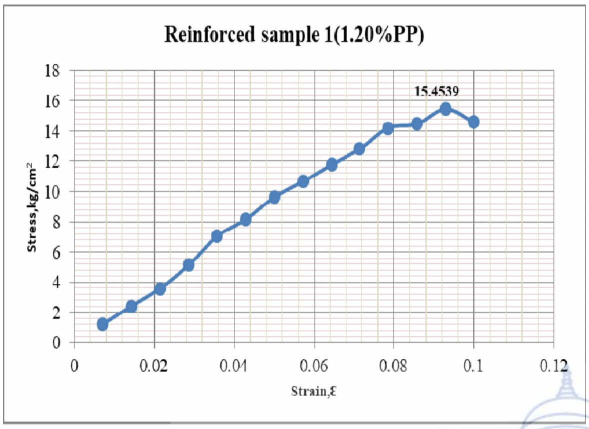


Figure 4.2.4.6 Graphs of soil sample Reinforced with 1.0 % of PP fibre

Average UCS of soil sample reinforced with 1.0 % of PP fibres (q_u) = 16.87201 kg/cm^2

Cohesion of soil sample reinforced with 1.0 % of PP fibres (c) $=\frac{q_u}{2} = \frac{1\ .8}{2}$ = 8.4360 kg/cm^2

4.2.4.2.4 Soil Reinforced with 1.2% of PP fibres



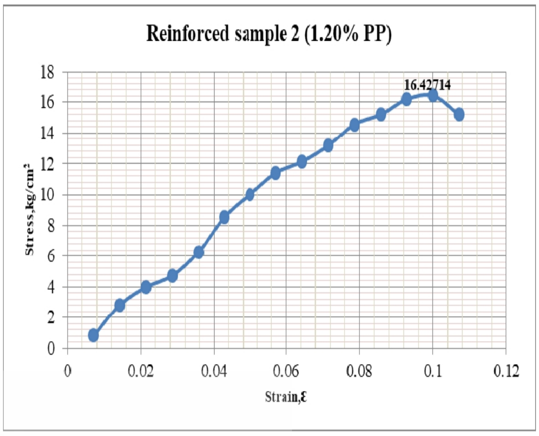


Figure 4.2.4.7 Graphs of soil reinforced with 1.2% of PP fibres

Average UCS of soil sample reinforced with 1.0 % of PP fibres (q_u) = 15.4052 kg/cm^2

Cohesion of soil sample reinforced with 1.0 % of PP fibres (c) $= \frac{q_u}{2} = \frac{1\ .4}{2}$ = 7.7026 kg/cm^2

From the above graphs and value of cohesion of soil of all the sample it can be observed that the strength of soil gets increased as the proportion of PP fibregoes increasing but after optimum dosage of PP fibre the get decreases on further increasing the proportion of PP fibre. In the above results, plain soil sample has compressive strength of 10.87415 kg/cm^2. When the sample is reinforced with 0.6% of PP fibre the strength obtained is 14.15295 kg/cm^2 which getsfurher improved when the PP fibre proportion gets 0.8%. From 0.8% reinforcement the compressive strength gets 19.53148 kg/cm^2. But at 1.0% and 1.2% the strength obtained are 16.87202 kg/cm^2 and 15.94052 kg/cm^2 respectively, which are less than the strength obtain with 0.8% PP fibre.

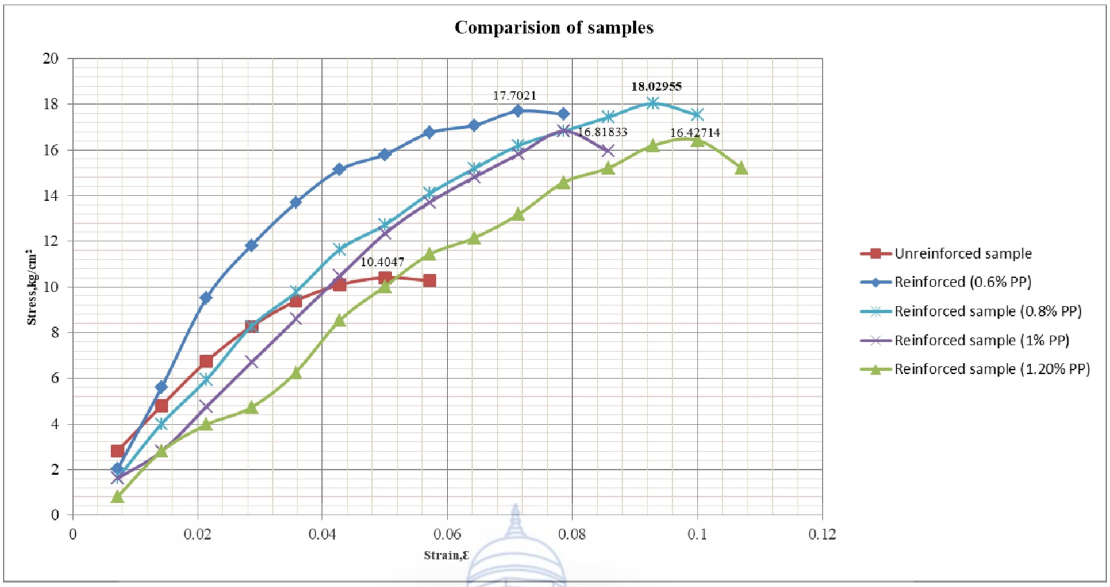


Figure 4.2.4.8 Comparison of Strength of samples

Table 4.2.6 Strength of sample w.r.t. proportion of PP

Samples % PP	Plain	0.6	0.8	1	1.2
q_u	10.87415	14.15295	19.53148	16.87202	15.94052

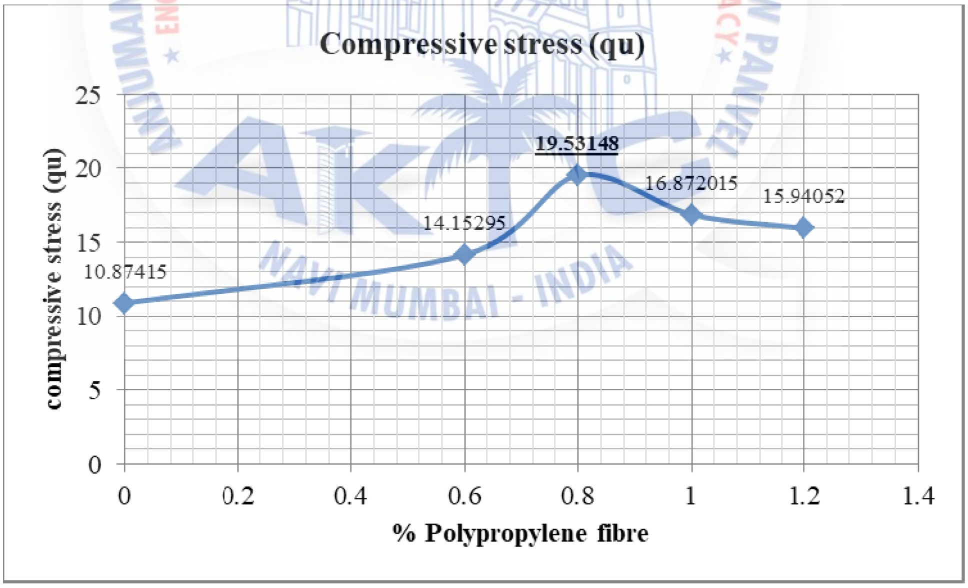


Figure 4.2.4.9 Compressive stress of samples

So, when the fibre length of 24mm used with soil similar properties proportion of 0.8% of PP must give better strength

Chapter 5

Summary and Conclusions

5.1 Summary

Soil reinforcement is one of the soil improvement techniques. Soil may be weak in strength that's why it is necessary to improve its strength to build infrastructure on it. Reinforcement of fibres in soil is one of the methods of soil reinforcement . In this study Polypropylene fibres are used. Specific 24mm length of fibre is used to study its effect on UCS of soil. Soil sample were collected from Bhiwandi. Test to determine the soil characteristics has been performed. The test are (i) sieve analysis (ii) Atterberg's limit (iii) shrinkage limit (iv) standard proctor test (v) UCS test .From that soil has been classified as Well graded sand with silt. The soil has a shrinkage limit of 36% . From Standard proctor test OMC and MDD of soil was determined as 25% and 1.55 kg/cm^3 respectively. UCS test were also performed. For UCS test proportion of fibre reinforcement of 0.6%, 0.8%, 1.0%, 1.2% are adopted. Plain sample without reinforcement was also tested. Two samples of each type were tested. Water content was kept at 30% throughout the test. Graphs were prepared for each sample for better understanding. Results are obtained as the strength gets improve when fibre proportion gets increases to a certain point. After that the strength gets decreases.

5.2 Conclusions

5.2.1 Classification of soil

The soil contains 10.5% of fines particles. Therefore according to border line cases (dualsymbol) the soil has been classified as Well graded sand with silt (SW-SM).

5.2.2 OMC and MDD

Standard proctor test has given the Optimum moisture content (OMC) and Maximum Dry Density (MDD) as 25% and 1.55 kg/cm^3.

5.2.3 Unconfined Compressive Strength

Mixing of fibre with low water content is difficult. For homogeneous mixture water content should be optimum. As 25 % water content is optimum, 5% more water i.e. 30% is added for mixing of fibre. From UCS test we can conclude that the strength of soil gets increases as the PP fibres are added. The proportion of PP fibre should be optimum because after optimum dosage strength of soil gets decreases.

From the above study we can conclude that the optimum dosage for soil having similar properties and characteristics must be 0.8 % of 24mm length PP fibres by weight of soil.

5.3 Future Scope

This study deals with constant length of fibre and constant water content. Further study can be done with different lengths of fibres with varying water content. Different lengths of fibres can also be mix together and can be use as reinforcement.

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APPENDIX

Readings for UCS for All samples are as follow:

(I) Plain sample 1:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
Plain	50	1.4	0.05	32.2	0.007142	11.4215	2.8192
	100	2.4	0.1	55.2	0.0142	11.5033	4.7986
	150	3.4	0.15	78.2	0.02142	11.5882	6.7482
	200	4.2	0.2	96.6	0.02857	11.6735	8.27515
	250	4.8	0.25	110.4	0.03571	11.7599	9.3878
	300	5.2	0.3	119.6	0.04285	11.8476	10.0948
	350	5.4	0.35	124.2	0.050	11.9368	**10.4047**
	400	5.4	0.4	124.2	0.05714	12.0828	10.2790744

(II) Plain Sample 2:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
Plain	50	3	0.05	69	0.007142	11.4215	6.0412
	100	4.8	0.1	110.4	0.0142	11.5033	9.5972
	150	5.4	0.15	124.2	0.02142	11.5882	10.7177
	200	5.6	0.2	128.8	0.02857	11.6735	11.0335
	250	5.8	0.25	133.4	0.03571	11.7599	**11.3436**
	300	5.8	0.3	133.4	0.04285	11.8476	11.2596

(III) 0.6% Reinforced Sample 1:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
0.6%	50	0.4	0.05	9.2	0.00714	11.4215	0.8054
	100	0.8	0.1	18.4	0.0142	11.5033	1.59954
	150	1.2	0.15	27.6	0.02142	11.5882	2.3817
	200	1.4	0.2	32.2	0.02857	11.6735	2.7583
	250	1.8	0.25	41.04	0.03571	11.7599	3.4898
	300	2	0.3	46	0.04285	11.8476	3.8826
	350	2.4	0.35	55.2	0.050	11.9368	4.6243
	400	2.8	0.4	64.4	0.05714	12.0828	5.3298
	450	3.2	0.45	73.6	0.06428	12.1200	6.07260
	500	3.6	0.5	82.8	0.07142	12.2132	6.7795
	550	3.8	0.55	87.4	0.07857	12.3080	7.1010
	600	4.2	0.6	96.6	0.08571	12.4041	7.7877
	650	4.6	0.65	105.8	0.09285	12.5017	8.4628
	700	4.8	0.7	110.4	0.1	12.6011	8.7611
	750	5.2	0.75	119.6	0.1071	12.7013	9.4163
	800	5.4	0.8	124.2	0.1142	12.8031	9.7007
	850	5.8	0.85	133.4	0.12142	12.9083	10.3344
	900	6	0.9	138	0.12857	13.0142	**10.6038**
	950	5.8	0.95	133.4	0.13571	13.12198	10.1661487

(IV) 0.6% Reinforced Sample 2:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
0.6%	50	1	0.05	23	0.00714	11.4215	2.0137
	100	2.8	0.1	64.4	0.0142	11.5033	5.59839
	150	4.8	0.15	110.4	0.02142	11.5882	9.5269
	200	6	0.2	138	0.02857	11.6735	11.8216
	250	7	0.25	161	0.03571	11.7599	13.6905
	300	7.8	0.3	179.4	0.04285	11.8476	15.1423
	350	8.2	0.35	188.6	0.050	11.9368	15.799
	400	8.8	0.4	202.4	0.05714	12.0828	16.7510
	450	9	0.45	207	0.06428	12.1200	17.079
	500	9.4	0.5	216.2	0.07142	12.2132	**17.7021**
	550	9.4	0.55	216.2	0.07857	12.3080	17.5658

(V) 0.8% Reinforced Sample 1:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
0.80%	50	0.8	0.05	18.4	0.00714	11.4215	1.610997
	100	2	0.1	46	0.0142	11.5033	3.998853
	150	3	0.15	69	0.02142	11.5882	5.954333
	200	4.2	0.2	96.6	0.02857	11.6735	8.275153
	250	5	0.25	115	0.03571	11.7599	9.778995
	300	6	0.3	138	0.04285	11.8476	11.64793
	350	6.6	0.35	151.8	0.05	11.9368	12.71698

	400	7.4	0.4	170.2	0.05714	12.0828	14.08614
	450	8	0.45	184	0.06428	12.12	15.18152
	500	8.6	0.5	197.8	0.07142	12.2132	16.19559
	550	9	0.55	207	0.07857	12.308	16.81833
	600	9.4	0.6	216.2	0.08571	12.4041	17.42972
	650	9.8	0.65	225.4	0.09285	12.5017	**18.02955**
	700	9.6	0.7	220.8	0.1	12.6011	17.52227

(VI) 0.8% Reinforced Sample 2:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
0.80%	50	0.4	0.05	9.2	0.00714	11.4215	0.805498
	100	0.8	0.1	18.4	0.0142	11.5033	1.599541
	150	1.2	0.15	27.6	0.02142	11.5882	2.381733
	200	1.6	0.2	36.8	0.02857	11.6735	3.152439
	250	2.4	0.25	55.2	0.03571	11.7599	4.693917
	300	3.4	0.3	78.2	0.04285	11.8476	6.600493
	350	4.2	0.35	96.6	0.05	11.9368	8.092621
	400	5	0.4	115	0.05714	12.0828	9.517661
	450	5.8	0.45	133.4	0.06428	12.12	11.0066
	500	6.6	0.5	151.8	0.07142	12.2132	12.42917
	550	7.4	0.55	170.2	0.07857	12.308	13.8284
	600	8	0.6	184	0.08571	12.4041	14.8338
	650	8.4	0.65	193.2	0.09285	12.5017	15.4539
	700	9.2	0.7	211.6	0.1	12.6011	16.79218
	750	9.8	0.75	225.4	0.1071	12.7013	17.74621
	800	10.6	0.8	243.8	0.1142	12.8031	19.04226
	850	11.2	0.85	257.6	0.12142	12.9083	19.95615
	900	11.6	0.9	266.8	0.12857	13.0142	20.50068

	950	12	0.95	276	0.13571	13.12198	**21.03341**
	1000	11.8	1	271.4	0.14285	13.23123	20.51208

(VII) 1.0% Reinforced Sample 1:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
1%	50	0.8	0.05	18.4	0.00714	11.4215	1.610997
	100	1.4	0.1	32.2	0.0142	11.5033	2.799197
	150	2.4	0.15	55.2	0.02142	11.5882	4.763466
	200	3.4	0.2	78.2	0.02857	11.6735	6.698933
	250	4.4	0.25	101.2	0.03571	11.7599	8.605515
	300	5.4	0.3	124.2	0.04285	11.8476	10.48314
	350	6.4	0.35	147.2	0.05	11.9368	12.33161
	400	7.2	0.4	165.6	0.05714	12.0828	13.70543
	450	7.8	0.45	179.4	0.06428	12.12	14.80198
	500	8.4	0.5	193.2	0.07142	12.2132	15.81895
	550	9	0.55	207	0.07857	12.308	**16.81833**
	600	8.6	0.6	197.8	0.08571	12.4041	15.94634

(VIII) 1.0% Reinforced Sample 2:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
1%	50	0.6	0.05	13.8	0.00714	11.4215	1.208248
	100	1	0.1	23	0.0142	11.5033	1.999426
	150	1.4	0.15	32.2	0.02142	11.5882	2.778689
	200	1.8	0.2	41.4	0.02857	11.6735	3.546494

	250	2.6	0.25	59.8	0.03571	11.7599	5.085077
	300	3	0.3	69	0.04285	11.8476	5.823964
	350	3.4	0.35	78.2	0.05	11.9368	6.551169
	400	4.8	0.4	110.4	0.05714	12.0828	9.136955
	450	5.8	0.45	133.4	0.06428	12.12	11.0066
	500	7	0.5	161	0.07142	12.2132	13.18246
	550	7.8	0.55	179.4	0.07857	12.308	14.57589
	600	8.6	0.6	197.8	0.08571	12.4041	15.94634
	650	9.2	0.65	211.6	0.09285	12.5017	**16.9257**
	700	8.8	0.7	202.4	0.1	12.6011	16.06209

(IX) 1.2% Reinforced Sample 1:

Sample proportion	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain $\varepsilon=(\Delta L/L_0)$	Corrected Area $A=A_0/(1-\varepsilon)$	Compressive stress =P/A (Kg/cm^2)
1.20%	50	0.6	0.05	13.8	0.00714	11.4215	1.208248
	100	1.2	0.1	27.6	0.0142	11.5033	2.399312
	150	1.8	0.15	41.4	0.02142	11.5882	3.5726
	200	2.6	0.2	59.8	0.02857	11.6735	5.122714
	250	3.6	0.25	82.8	0.03571	11.7599	7.040876
	300	4.2	0.3	96.6	0.04285	11.8476	8.15355
	350	5	0.35	115	0.05	11.9368	9.634073
	400	5.6	0.4	128.8	0.05714	12.0828	10.65978
	450	6.2	0.45	142.6	0.06428	12.12	11.76568
	500	6.8	0.5	156.4	0.07142	12.2132	12.80582
	550	7.6	0.55	174.8	0.07857	12.308	14.20214
	600	7.8	0.6	179.4	0.08571	12.4041	14.46296
	650	8.4	0.65	193.2	0.09285	12.5017	**15.4539**
	700	8	0.7	184	0.1	12.6011	14.6019

(X) 1.2% Reinforced Sample 2:

Sample no.	DGR	PRR	Deformation Δ=DGR*G/10 (cm)	Load P=PRR*CF*100 (Kg)	Strain □=(ΔL/L_0)	Corrected Area A=A_0/(1-□)	Compressive stress =P/A (Kg/cm^2)
1.20%	50	0.4	0.05	9.2	0.00714	11.4215	0.805498
	100	1.4	0.1	32.2	0.0142	11.5033	2.799197
	150	2	0.15	46	0.02142	11.5882	3.969555
	200	2.4	0.2	55.2	0.02857	11.6735	4.728659
	250	3.2	0.25	73.6	0.03571	11.7599	6.258557
	300	4.4	0.3	101.2	0.04285	11.8476	8.541814
	350	5.2	0.35	119.6	0.05	11.9368	10.01944
	400	6	0.4	138	0.05714	12.0828	11.42119
	450	6.4	0.45	147.2	0.06428	12.12	12.14521
	500	7	0.5	161	0.07142	12.2132	13.18246
	550	7.8	0.55	179.4	0.07857	12.308	14.57589
	600	8.2	0.6	188.6	0.08571	12.4041	15.20465
	650	8.8	0.65	202.4	0.09285	12.5017	16.1898
	700	9	0.7	207	0.1	12.6011	**16.42714**
	750	8.4	0.75	193.2	0.1071	12.7013	15.21104

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