EFFECT OF GEOTEXTILES ON ENGINEERING PROPERTIES OF SOIL

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CERTIFICATE

This is to certify that the work entitled"**EFFECT OF GEOTEXTILES ON ENGINEERING PROPERTIES OF SOIL "** submitted by **Lakshay Vij (111633) & Nitin Thakur (111712),** in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma to the best of my knowledge.

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ABSTRACT

Geotextiles play an important part in modern civil engineering and other related and unrelated applications. Geotextiles, a newly emerging field, offer great potential in varied areas of applications globally. There has been a phenomenal growth in their use world over for transportation application. Geotextiles are ideal material for infrastructural works such as roads, harbors and many others.

This project aims at observing the effect of using geotextiles on some engineering properties of soil using different variations of non woven with main emphasis on performing proctor compaction test, triaxial test (UU) on clayey soil and observing and analyzing the result obtained for the different arrangements.

The results of the project were positive as the geotextile enhanced the desirable properties of soil, i.e. unit weight at lesser water content and also better cohesion and internal angle of friction values.

2. INTRODUCTION

Geotextiles were one of the first textile products in human history .Excavation of ancient Egyptian sites show the use of mats made of grass and linen. ASTM (1994) states that geotextiles are permeable textile material, used in contact with soil, earth, or any other geotechnical related material as an integral part of project/system.

Geotextiles were one of the first textiles to be used; for roadway construction to stabilize pavements and their edges, particularly for unstable soils Modern geotextiles highly developed, diverse and cost effective ground modification material. Although extensively used in highway construction for past 30 years, it is now also being used in nearly all areas of geotechnical, environment and hydraulic engineering. Requirements are that should allow rain water to penetrate the soil and drain out excess water without erosion of soil. It must also permit material exchange b/w air and soil(for plant growth), etc.

Soil properties vary largely across our nation of varied geographic and geological conditions. Soft soil is distributed widely in our country, it is mainly composed of fine grain, and has the nature of high water content, low shearing stress and permeability, and bad compressibility. If the soft soil problem is not solved, such hazards as whole sliding abutment, damaged bridge abutment, large uneven settlement of structure and bank, water leakage in settlement joint, uneven settlement of roadbed will happen.

Geotextile in soft soil engineering has an important role, mainly because it has such advantages as light weight, good continuity, construction convenient, high tensile strength, corrosion resistance and microbial corrosion. It has good combination with soil.

3. LITERATURE REVIEW

Literature 1

Author, Ajjarapu Sreerama Rao, IGC 2009

"Road Section Reinforced with Jute Geotextile"

Case study of a road section reinforced with jute geotextile has been presented. While water content, void ratio, compression index decreased, dry density, CBR increased. Hence jute geotextile is very desireable for use in pavements for subgrade soil and also good for the economy of nation.

Literature 2

Author, Raju N. Ramakrishna, Dec 16,2010

"Application of polypropylene in Kandaleru reservoir Dam"

Polypropylene is one of the best filter materials for drainage. It has been observed physically for the last 2 years and no problem has been reported for Kandaleru reservoir dam.

Literature 3

Author, Dr. Bipin J Agrawal, May 13, 2011

"Geotextiles as effective tools to solve various geotechnical problems"

Extensive awareness should be created among people about applications of geotextiles. They are effective tools in the hands of the civil engineer that help in solving a variety of geotechnical problem.

4. MATERIALS

Soil sample was from a borrow pit at chainage 146, Himachal Pradesh. The soil was red in colour and had a powdery texture. On sieve analysis, having following properties:

- Effective size, D_{10} of soil = 0.107mm
- Uniformity coefficient, Cu = 13.08
- Coefficient of curvature, Cc = 0.16

- % of gravel = 40.8%
- % of coarse sand = 9.2%
- % of medium sand = 26%
- % of fine sand = 21.7%
- % of silt and clay = 2.3%

Non Woven Geotextile (120 gsm) was acquired from KNCEL, Bilaspur, which is being used for the construction of Kiratpur-Nerchowk expressway.

5. EXPERIMENTAL PROCEDURES

6.1 GRAIN SIZE ANALYSIS

More than 50% of the soil was retained on the 90 micron sieve, so procedure for coarse grained soil was followed for grain size analysis.

Apparatus

1. Balance
2. I.S sieves
3. Rubber pestle and mortar.
4. Mechanical Sieve Shaker

Procedure

a. I.S sieves are selected and arranged in the order as shown in the table.

b. The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.

c. The weight of soil retained on each sieve is recorded.

d. The moisture content of soil if above 5% should be measured and recorded.

Calculation

1. The percentage of soil retained on each sieve wa calculated on the basis of total weight of soil sample taken.
2. Cumulative percentage of soil retained on successive sieve was found.

6.2 LIQUID LIMIT TEST

Apparatus

1. Balance
2. Liquid limit device (Casagrende's)
3. Grooving tool
4. Mixing dishes
5. Spatula
6. Electrical Oven

Procedure

1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is obtained.

2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste which has a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.

3. A portion of the paste is placed in the cup of Liquid Limit device and spread into portion with few strokes of spatula.

4. It is trimmed to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.

5. The soil in the cup is divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimension is formed.

6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only.

7. The number of blows required to cause the groove close for about 1 cm is recorded.

8. A representative portion of soil is taken from the cup for water content determination.

9. Test is repeated with different moisture contents at least three more times for blows between 15 and 35.

Calculation

Graph is drawn showing the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the represents liquid limit. It is usually expressed to the nearest whole number.

6.3 PLASTIC LIMIT TEST

Apparatus

1. Porcelain dish
2. Glass plate for rolling
3. Air tight containers
4. Balance
5. Oven; thermostatically controlled

Procedure

1. Take about 20gm of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (part 1).

2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily molded with fingers.

3. Allow it to season for sufficient time (for 24 hrs) to allow water to permeate throughout the soil mass

4. Take about 10gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 strokes per minute.

5. Continue rolling till you get a threaded of 3 mm diameter.

6. Kneed the soil together to a uniform mass and re-roll.

7. Continue the process until the thread crumbles when the diameter is 3 mm.

8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.

9. Repeat the test to atleast 3 times and take the average of the results calculated to the nearest whole number.

Calculation

Plasticity Index = $I_p = W_L - W_p$

6.4 PROCTOR COMPACTION TEST

Apparatus

1. Proctor mould
2. Rammer
3. Sample extruder
4. Balance
5. Straight edge
6. Graduated cylinder
7. Mixing tools

Procedure

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it to approximately four to six percentage points below expected optimum moisture content.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.5 kg rammer falling through.
3. Remove the collar, trim the compacted soil even with the top of the mould by means of the straight edge and weigh.
4. Divide the weight of the compacted specimen by 1000 cc and record the result as the wet weight γ_{wet} in grams per cubic centimeter of the compacted soil.
5. Remove the sample from the mould and slice vertically through and obtain a small sample for moisture determination.
6. Thoroughly break up the remainder of the material until it will pass a no.4 sieve as judged by the eye. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points and repeat the above procedure for each increment of water added. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

Calculation

Wet density gm/cc =weight of compacted soil / 1000

Dry density = wet density/(1+w)

Where w is the moisture content of the soil.

6.5 UNDRAINED TRIAXIAL COMPRESSION TEST

Apparatus

1. Split Mould
2. Trimming knife
3. Piano wire saw
4. Metal straightedge
5. Metal scale
6. Non-corrodible metal or plastic end-caps
7. Seamless Rubber Membrane
8. Membrane Stretcher
9. Rubber rings.
10. Apparatus for moisture content determination
11. Balance
12. Extruders
13. Apparatus for Triaxial -Test

- Triaxial Test Cell
- Apparatus for applying, measuring and maintaining desired pressure

- **Preparation of Specimen**
- The type of soil specimen to be used for test shall depend on the purpose for which it is tested and may be compacted, remolded or undisturbed

- Remoulded samples were prepared at the optimum moisture content by dynamic method of compaction.
- After the specimen was formed, ends were trimmed perpendicular to the long axis and removed from mould using extruder.
- The specimen for the test shall have a minimum diameter of 38 mm and the Largest particle contained within the test specimen shall be smaller then 1/8 of the specimen diameter. The height to diameter ratio shall be within 2 to 2.5

Procedure

1. The sample is placed in the compression machine and a pressure plate is placed on the top.
2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.
3. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed.
4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.
5. The handle wheel of the screw jack is rotated until the underside of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.
6. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the beginning of the test.

6.6 MOISTURE CONTENT DETERMINATION

Apparatus

Thermostatically controlled oven maintained at a temperature of 110 ± 5ºC

Weighing balance

Air-tight container made of non-corrodible material with lid

Tongs

Procedure

Clean the container, dry it and weigh it with the lid (Weight 'W_1').

Take the required quantity of the wet soil specimen in the container and weigh it with the lid (Weight 'W_2').

Place the container, with its lid removed, in the oven till its weight becomes constant (Normally for 24hrs.).

When the soil has dried, remove the container from the oven, using tongs.

Find the weight 'W_3' of the container with the lid and the dry soil sample.

Calculation

The water content

$w = [W_2-W_3] / [W_3 - W_1]*100\%$

6. OBJECTIVE OF STUDY

Performing following test on soil sample with and without geotextile to analyse and compare results.

Investigation of the soil specimen properties through:

- Sieve analysis
- Liquid limit test
- Plastic limit test

Proctor Compaction Test on:

- Normal soil sample.

- Soil sample with 3 layers of parallel geotextile to the base

Triaxial Test(UU) on:

- Soil sample without geotextile.
- Soil sample with woven geotextile placed uniformly spaced in 2 layers.

Triaxial test(CU) on:

- Soil sample without geotextile.
- Soil sample with woven geotextile placed uniformly spaced in 2 layers.

7. RESULTS AND DISCUSSION

8.1 GRAIN SIZE ANALYSIS(SIEVE ANALYSIS)

The following results were obtained on performing grain size analysis on the soil under consideration:

IS Sieve (no. or size)	Wt. of empty sieve(g)	Wt. of soil + sieve(g)	Wt. retained on each sieve(g)	Cum. Mass retained(g)	Cumulative % retained on each sieve [x]	% finer =100-[x]
4.75mm	418.5	435	16.5	16.5	1.65	98.35
2mm	402	478	76	92.5	9.25	90.75
1mm	374.3	521	146.7	239.2	23.91	76.09
600 mic.	362.8	440.9	78.1	317.3	31.72	68.28
425 mic.	351	399.2	48.2	365.5	36.54	63.46
300 mic.	354.6	378.2	23.6	389.1	38.9	61.1
212 mic.	336.9	371	34.1	423.2	42.31	57.69
150 mic.	357.9	375	17.1	440.3	44.02	55.98
75 mic.	329.8	655.3	325.5	765.8	76.46	23.44

pan	255.9	490.4	234.5	1000.3	100	0

Discussion

Various soil parameters calculated from the result obtained and the graph are as follows:

- Effective size, D_{10} of soil= 0.107mm
- Uniformity coefficient, Cu=13.08
- Coefficient of curvature, Cc=0.16
- % of gravel=40.8%
- % of coarse sand=9.2%
- % of medium sand=26%
- % of fine sand=21.7%
- % of silt and clay=2.3%

We can see that it is a coarse grained soil. Although the clay content was not significant, but the soil showed a lot of clay like properties, which means that it is a very active clay.

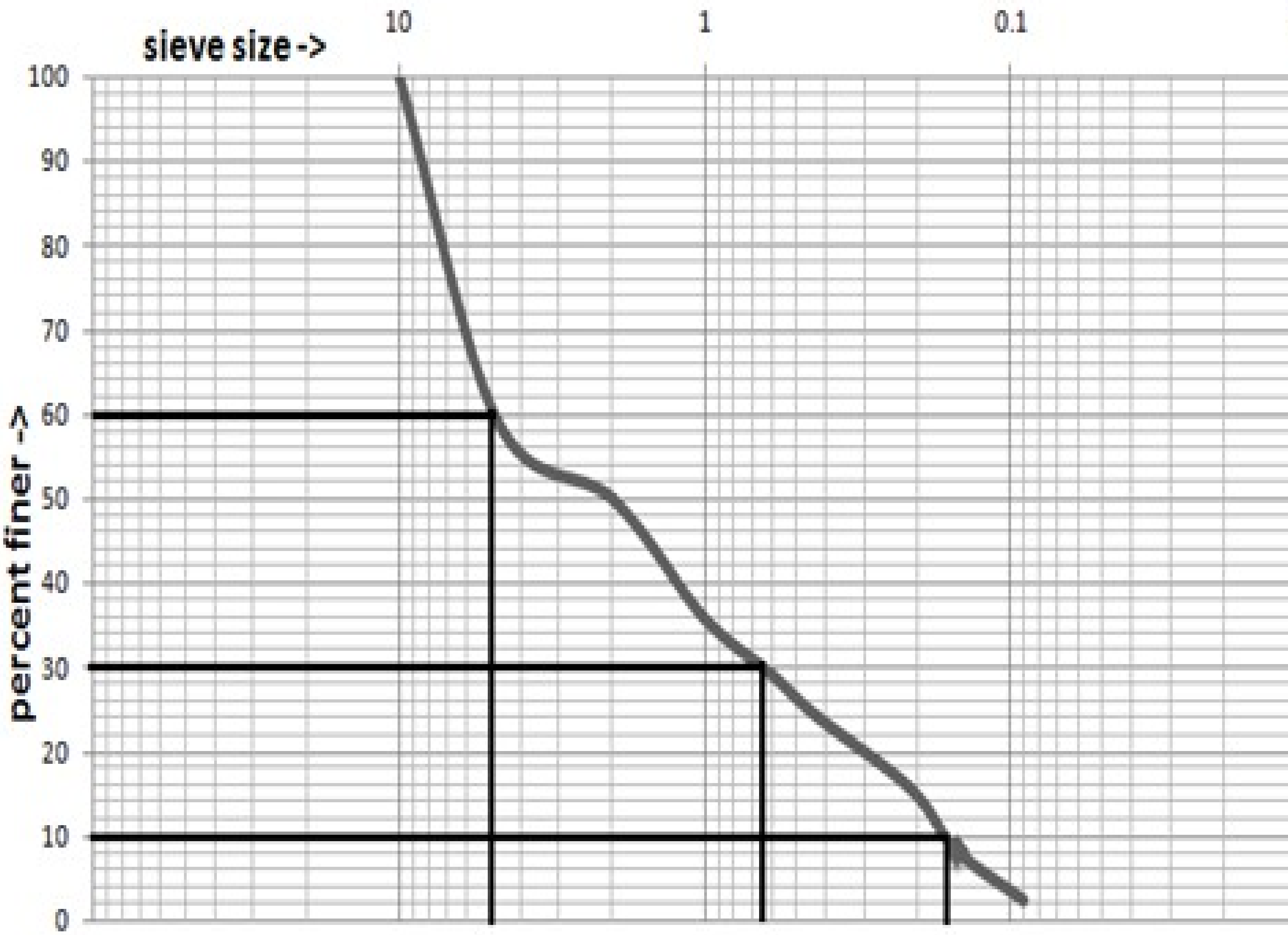

Figure 1: Sieve Analysis Graph

8.2 PLASTIC LIMIT TEST

The following results were obtained on performing plastic limit test on the soil sample

S. No.	Wt. of container (g)	Wt. of container + wet soil (g)	Wt. of container + dry soil (g)	Moisture content (%)
1	18.8	27.2	26.45	9.8
2	17	28.2	27.1	10.89

3	20.3	29.4	28.55	10.3
4	21.9	28.4	27.85	9.24
5	22.3	28.9	28.25	10.92

Plastic Limit, taken as average = 10.18%

8.3 LIQUID LIMIT TEST

Following results were obtained on performing liquid limit test on the soil sample:

S.No.	No. of blows	Empty wt of container W1 (g)	Wt of container + wet sample W2 (g)	Wt of container + dry sample W3 (g)	Water Content (%)	Liquid limit (%)
1	17	20.55	46.4	41.25	24.88	23.96
2	20	19.3	43.95	38.95	25.45	24.91
3	22	22.45	48.7	43.3	25.9	25.57
4	25	21.7	42.65	38.55	24.33	24.33
5	31	19.8	45.25	40.35	23.84	24.36

W_L= Wn/(1.3213 – 0.23 log n)

(for blows b/w 15-35)

Liquid Limit, taken as average = 24.63%

8.4 SOIL CLASSIFICATION

On the basis of results obtained from above experiments, soil was classified as follows:

Plasticity index (I_p) = Liquid Limit(W_L) –Plastic Limit(W_p)

$I_p = W_L - W_p$= 25.63-10.18= 14.45

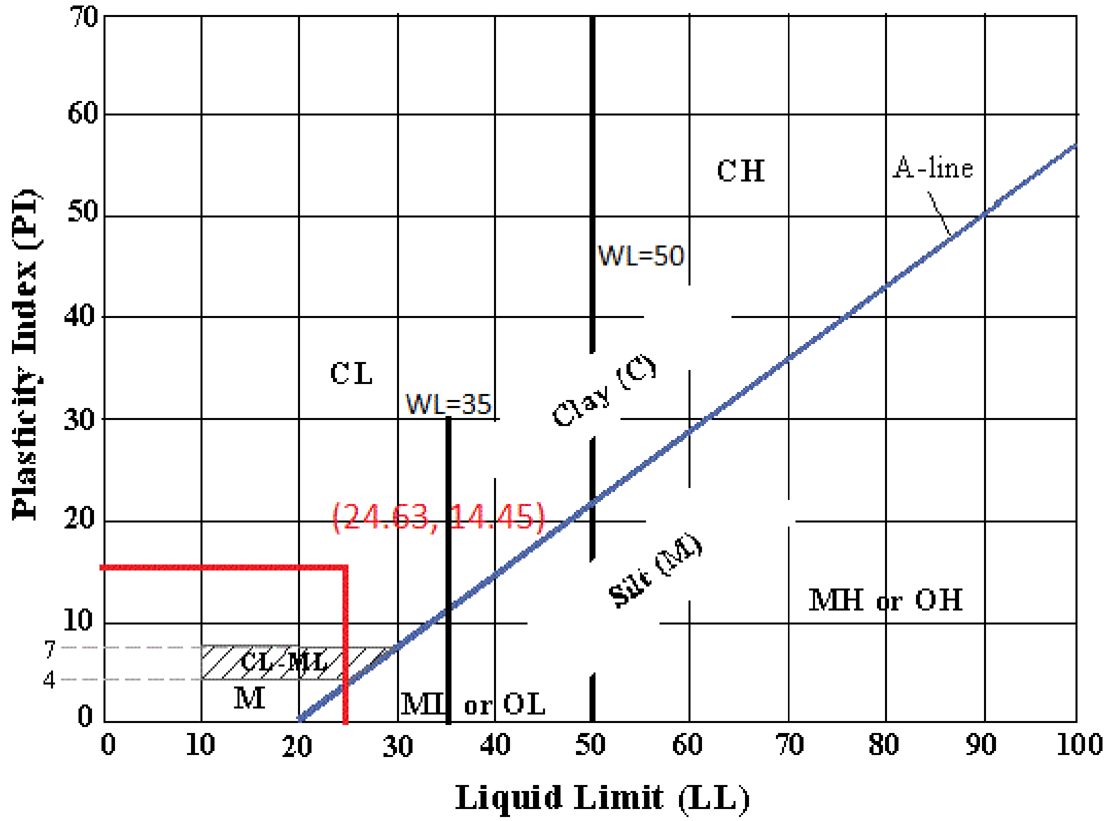

Figure 2: Plasticity Chart for soil classification

On plotting the plasticity index and liquid limit on the plasticity chart, it is found that the intersecting point lies above A-Line and the hatched zone

Thus the soil is classified as **CLAYEY SAND**, symbolized as **SC**.

8.5 PROCTOR COMPACTION TEST

8.5.1 TEST DONE ON SOIL WITHOUT GEOTEXTILE

Determination no.	**1**	**2**	**3**	**4**	**5**
Wt of mould + base in gm (I)	5520	5520	5520	5520	5520
Wt of mould + base + soil compacted in gm(II)	7450	7620	7640	7570	7520
Weight of soil after compaction(W) in gm (II)-(I)	1930	2100	2120	2050	2000
Volume of mould cm^3 (V)	1000	1000	1000	1000	1000
Bulk Density(γ_t)=W/V kN/m^3	1.93	2.1	2.12	2.05	2

Moisture content of the sample(w)	.12	.15	.18	.21	.24
Dry density(γ_d) **$\gamma_d = \gamma_t/(1+w)$ kN/m^3**	1.72	1.83	1.80	1.69	1.61

- On the basis of obtained data, the graph between dry density and water content was plotted and the maximum dry density and optimum moisture content found out.
- From the graph, maximum dry density was obtained as 1.83kN/m^3 and optimum moisture content 16%.

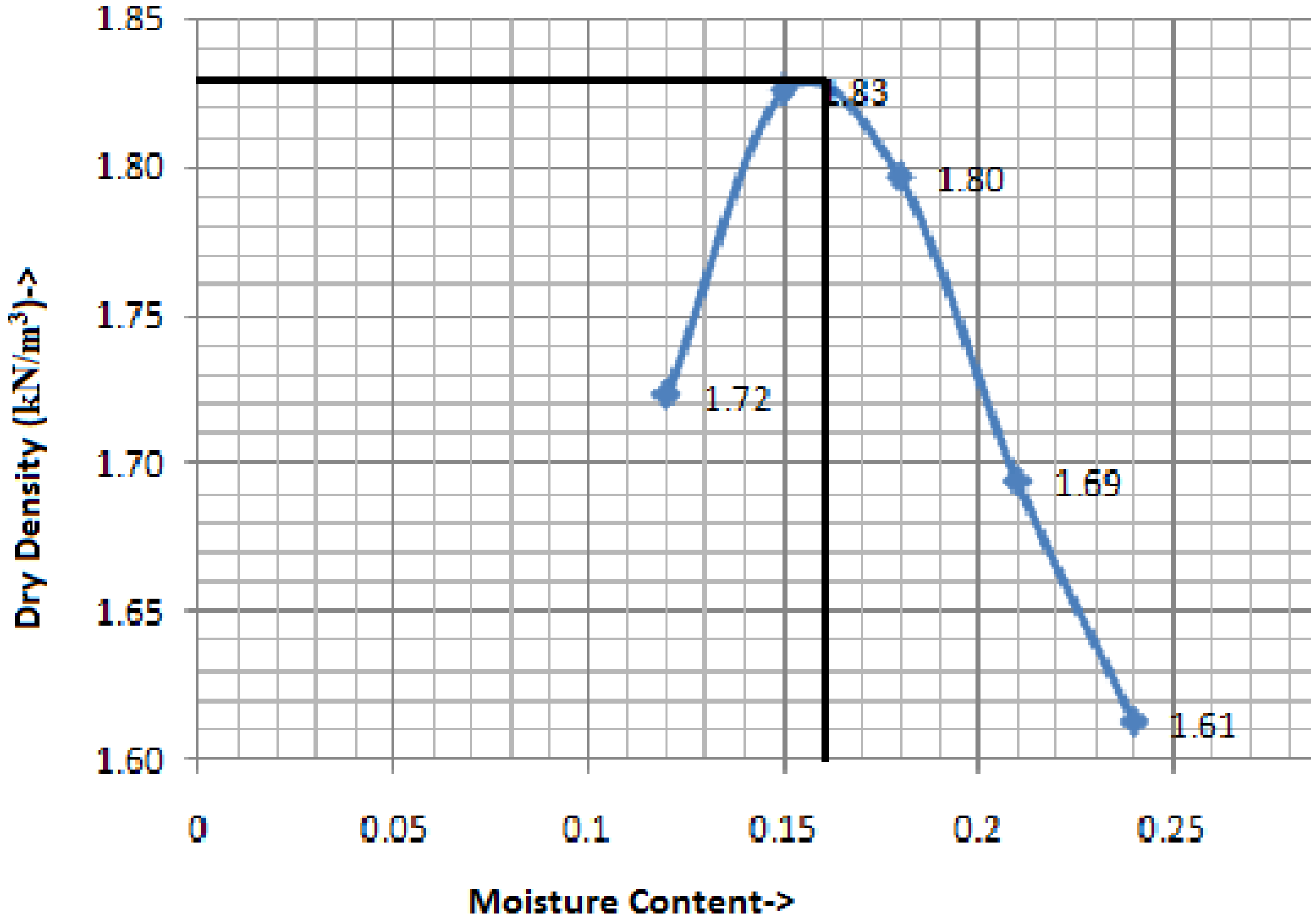

Figure 3: Graph for Proctor Compaction Test without Geotextile

8.5.2 TEST DONE ON SOIL WITH GEOTEXTILE

- 3 layers of geotextile uniformly placed 2.9 cm apart
- First layer at the base
- Second layer 2.9 cm from base
- Third layer 5.8 cm from base

Determination no.	1	2	3	4	5
Wt of mould + base in gm (I)	5520	5520	5520	5520	5520

Wt of mould + base + soil compacted in gm(II)	7400	7540	7490	7420	7410
Weight of soil after compaction(W) in gm (II)-(I)	1880	2020	1970	1900	1890
Volume of mould cm^3 (V)	1000	1000	1000	1000	1000
Bulk Density(γ_{t})=W/V kN/m^3	1.88	2.02	1.97	1.9	1.89
Moisture content of the sample(w)	.12	.15	.18	.21	.24
Dry density(γ_d) **$\gamma_d = \gamma_t/(1+w)$ kN/m^3**	1.68	1.76	1.67	1.57	1.52

From the graph, maximum dry density was obtained as 1.76kN/m^3 and optimum moisture content 15%.

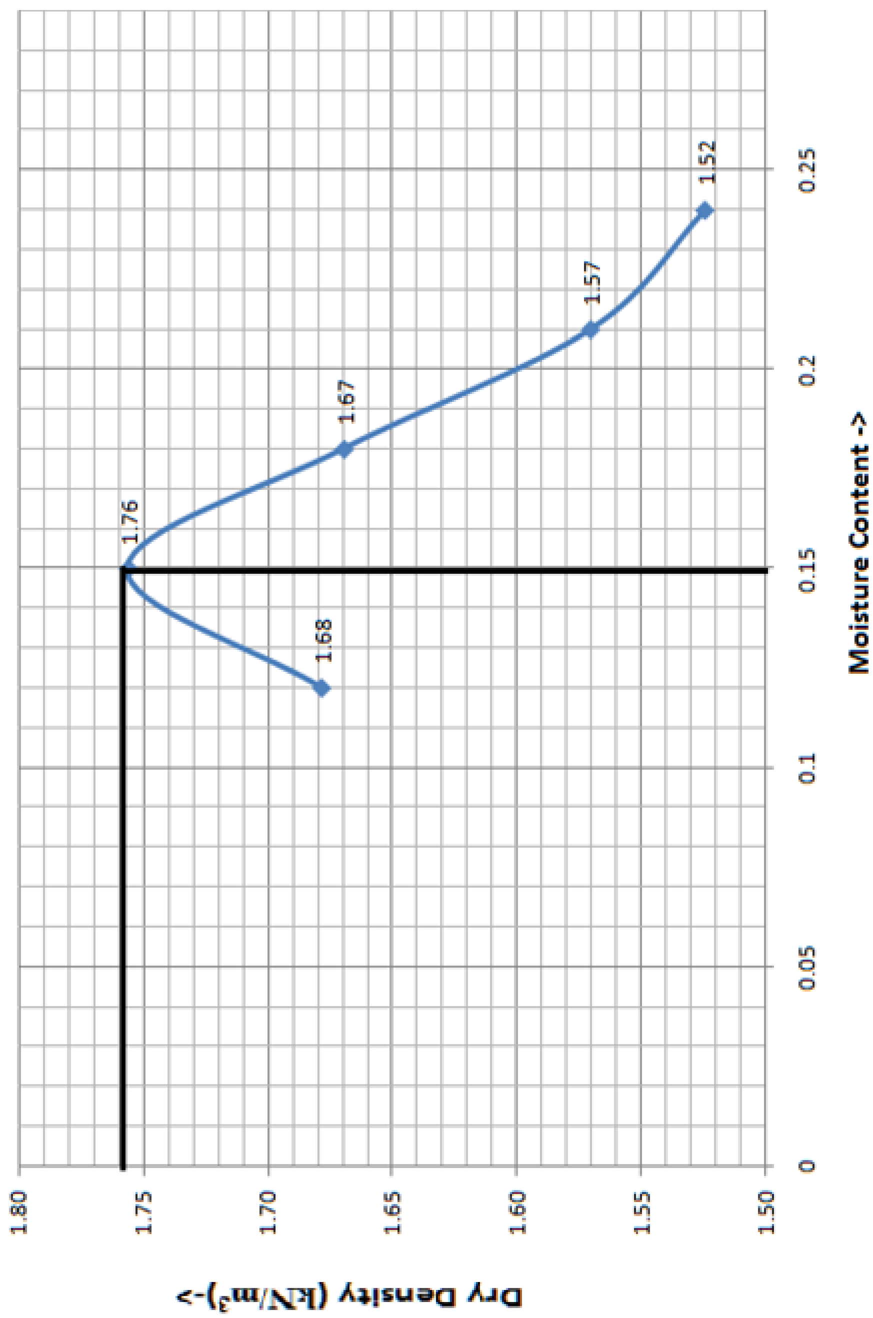

Figure 4: Graph for Proctor Compaction Test with Geotextile placed parallely

8.5.3 TEST DONE ON SOIL WITH GEOTEXTILES PLACED AT AN ANGLE OF 30^0 TO THE BASE

- 3 layers of geotextile uniformly placed 2.9 cm apart

- First layer at the base
- Second layer 2.9 cm from base
- Third layer 5.8 cm from base

Determination no.	**1**	**2**	**3**	**4**	**5**
Wt of mould + base in gm (I)	5520	5520	5520	5520	5520
Wt of mould + base + soil compacted in gm(II)	7410	7510	7490	7460	7450
Weight of soil after compaction(W) in gm (II)-(I)	2190	2290	2270	2240	2230
Volume of mould cm^3 (V)	1000	1000	1000	1000	1000
Bulk Density(γ_t)=W/V kN/m^3	2.19	2.29	2.27	2.24	2.23
Moisture content of the sample(w)	.12	.15	.18	.21	.24
Dry density(γ_d) **$\gamma_d = \gamma_t/(1+w)$ kN/m^3**	1.96	1.99	1.92	1.85	1.80

From the graph, maximum dry density was obtained as 1.76kN/m^3 and optimum moisture content 15%.

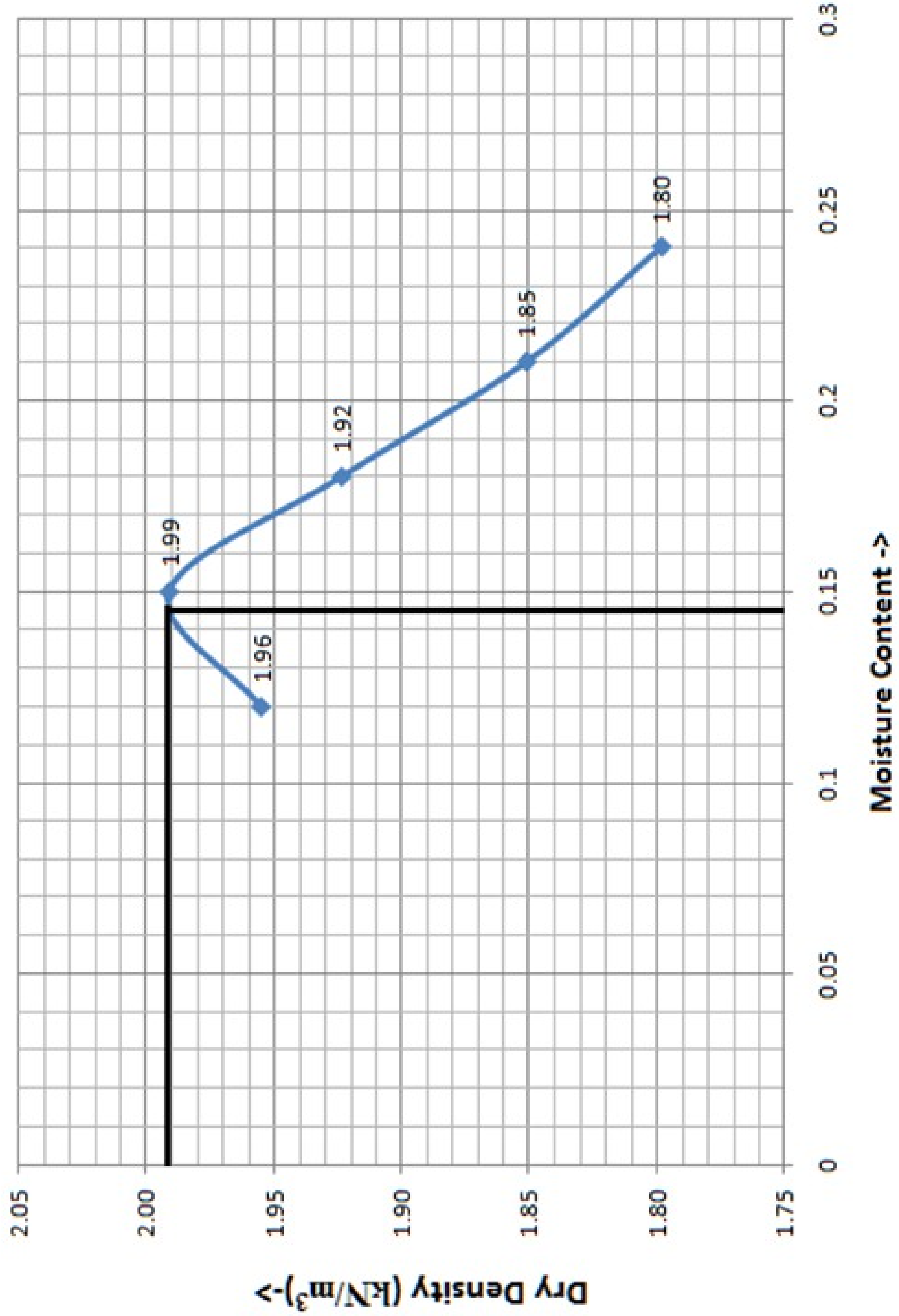

Figure 5: Graph for Proctor Compaction Test with Geotextile at 30^0 angle to the base

DISCUSSION

Increase with respect to test result on soil without geotextile:

Inclination	**% increase ($\gamma_{d\ max}$)**	**% increase OMC**
Parallel	-3.83	-6.25
30^0 to base	8.74	-9.38

It was observed that when geotextile were kept parallel to the base there was not much change in the dry density. Max dry density was found to be 1.76 kN/m^3, although at a lesser moisture content, 15%.

On keeping the geotextile at an angle of 30^0 to base the dry density of soil increased to a value of 1.99 kN/m^3; at moisture content 14%.

Thus it can be concluded that by using non woven geotextile inclined at 30^0 to base, maximum dry density of soil increases by 8.74 % and can be achieved at a lower moisture content (14.5%).

1.6 UNDRAINED TRIAXIAL COMPRESSION TEST

8.6.1 TEST DONE ON SOIL WITHOUT GEOTEXTILE

From the graph obtained by plotting the failure envelope of the Mohr circle from the test results, we find:

- Angle of internal friction = 9.67^0
- C_u = 8.67 N/mm^2

1.6.1 TEST DONE ON SOIL WITH GEOTEXTILE

- Placed parallely in 2 equidistant layers, 2.53 cm apart

From the graph obtained by plotting the failure envelope of the Mohr circle from the test results, we find:

  - Angle of internal friction = 16.69^0
  - C_u = 10.5 N/mm^2

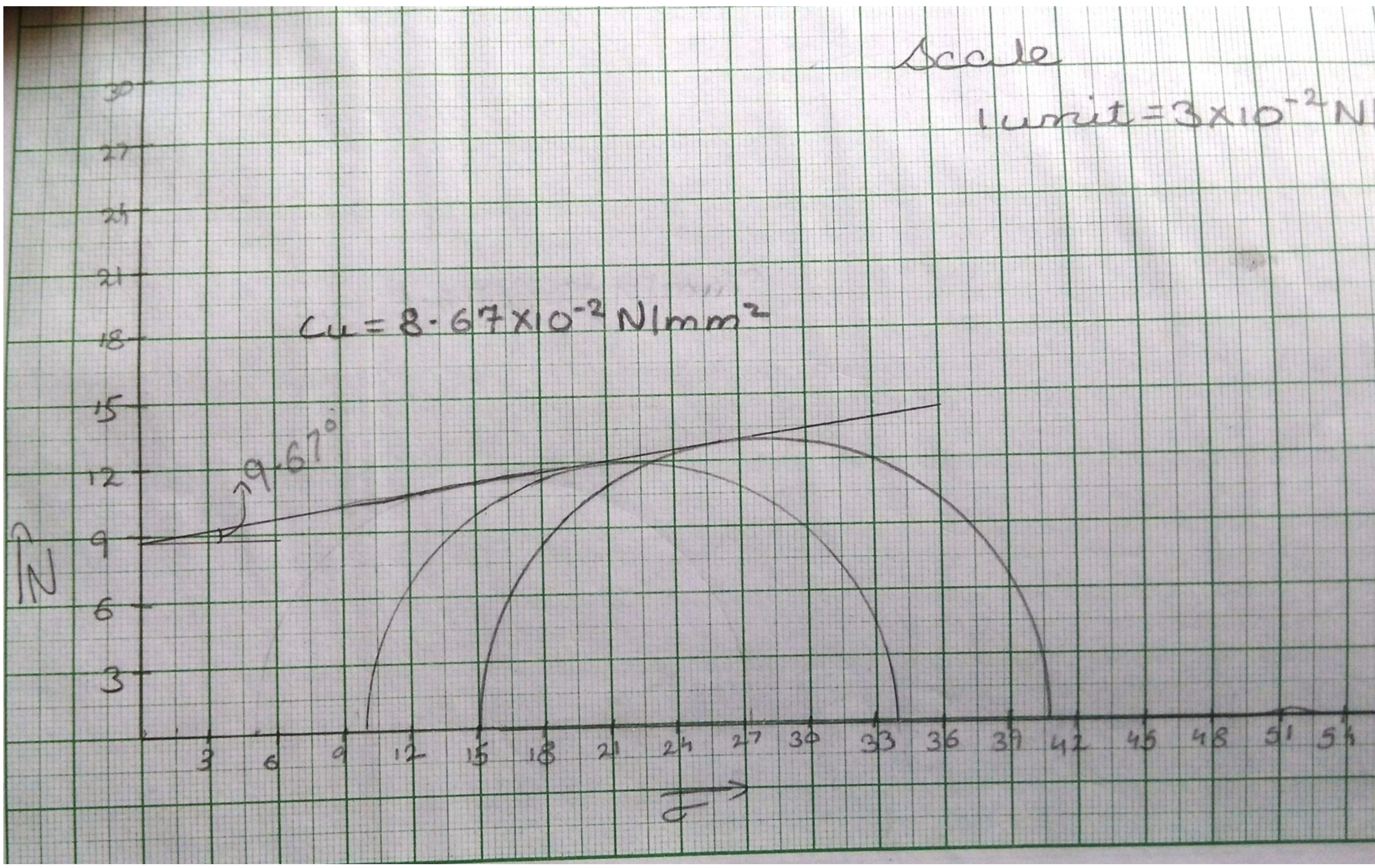

Figure 6: Mohr Circles for specimens without geotextile **Scale: 1 unit= 3 x 10-2 N/mm2**

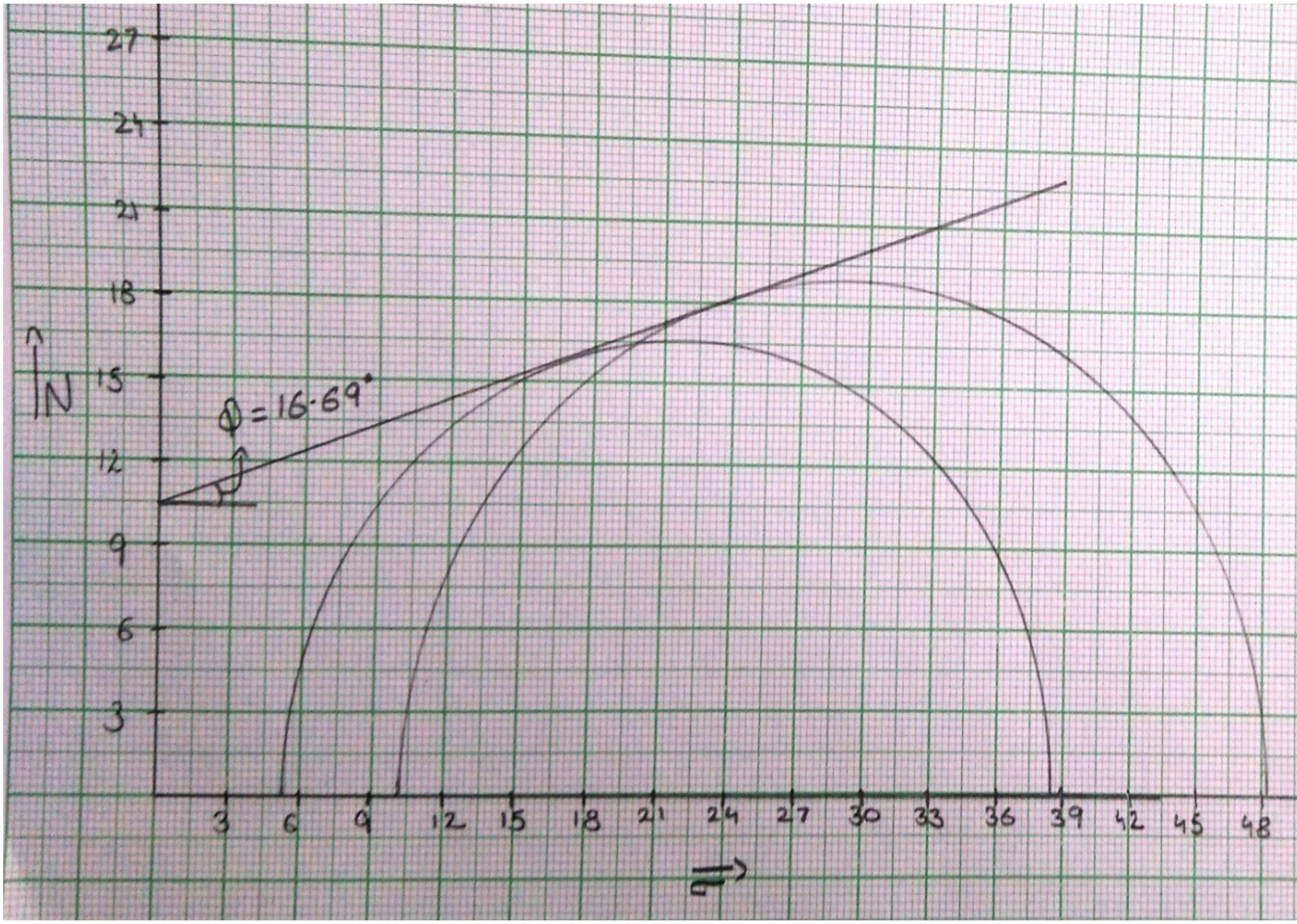

Figure 7: Mohr Circles for specimens with geotextile Scale: 1 unit= 3 x 10-2 N/mm2

Discussion

The deviator stress required for the specimen failure was approximately more for specimen samples with geotextile was used as compared to the specimen samples without geotextile.

Ideal conditions for testing were not achieved as power cuts during the testing were a problem, exposing the specimen to fluctuating pressures at times, which accounts for some undulations in the graphs.

Increase with respect to test result on soil without geotextile:

	Without geotextile	**With geotextile**	**% increase**
C_u	8.67	10.50	21.11
Φ	9.67	16.69	72.61

It can be clearly seen that there has been a slight change in the cohesion value relatively, as there is a significant change in the angle of internal friction.

This would imply that the soil particles can no longer glide over one another like they did in absence of geotextile, making it more stable and suitable for use.

8. CONCLUSION

It can be concluded from the analysis of the test results that inclusion of the non woven 120 gsm geotextile increases the bearing capacity of the clayey sand soil.

By placing the geotextile in 3 layers at 30^0 angles, maximum dry density of the soil increased to 1.99kN/m^3 accounting for 8.74% increase at 9.34% lesser moisture content compared to soil tested without geotextile.

So placing 3 layers of non woven geotextile at 30^0 angles, we can obtain a very high density of soil, which can find its application in various fields, like soil densification and construction of foundations

Due to the decrease in optimum moisture content, this geotextile can also be employed in regions where water availability is scarce or not dependable or temperatures are very high and evaporation is a problem, to achieve desired dry density at lesser moisture content.

Inclusion of the geotextile did show a significant change in the increase of cohesion value, increase of 21.11%; but a profound increase can be seen in the value of internal friction, of 72.61%.

This means that the geotextile and soil system increases the friction coefficient which would in turn increase the slipping resistance of the soil. Again, this property can find its application in a number of fields, especially in soils with very low angles of friction, i.e. in clayey soil, where otherwise the construction becomes very difficult due to lack of friction.

9. SCOPE OF FUTURE WORK

There is a lot to be explored in the world of geotextiles. As we tested our soil for effects of geotextile on engineering properties, other soil types should also be tested. Different varieties of geotextile, other than one used in this project can be used. There can be other variations for arranging the geotextile, i.e at different angles, different number of layers, etc. Also, a number of tests can be done on the soil, like performing the consolidated undrained triaxial test and other tests that model real life scenarios.

10. APPENDIX

Triaxial test with geotextile

Sample 1: σ_3=1 kg/cm^2

Load (N)	Compression (mm)	Vertical Strain ΔL(mm)	Corrected Area(mm2) =1138/ (1-ΔL/L)	Vertical Stress (kg/cm2) =Load/corrected area
20	0	0.000	1138.00	0.18
20	0.27	0.004	1142.06	0.18
40	0.44	0.006	1144.63	0.35
50	0.46	0.006	1144.93	0.44
50	0.60	0.008	1147.06	0.44
70	0.63	0.008	1147.51	0.61
70	0.66	0.009	1147.97	0.61
80	0.70	0.009	1148.58	0.70
90	0.83	0.011	1150.57	0.78
100	0.92	0.012	1151.94	0.87
110	1.03	0.014	1153.63	0.95
110	1.15	0.015	1155.48	0.95
110	1.32	0.017	1158.11	0.95
120	1.34	0.018	1158.42	1.04
120	1.54	0.020	1161.54	1.03
130	1.63	0.021	1162.94	1.12
150	1.71	0.023	1164.19	1.29
150	1.82	0.024	1165.92	1.29
160	1.94	0.026	1167.81	1.37
160	2.05	0.027	1169.55	1.37
170	2.14	0.028	1170.97	1.45
170	2.23	0.029	1172.40	1.45
180	2.24	0.029	1172.56	1.54
180	2.39	0.031	1174.95	1.53
190	2.50	0.033	1176.71	1.61
200	2.67	0.035	1179.44	1.70
200	2.81	0.037	1181.69	1.69
200	2.88	0.038	1182.82	1.69
200	3.00	0.039	1184.77	1.69
220	3.02	0.040	1185.09	1.86
220	3.17	0.042	1187.53	1.85
220	3.38	0.044	1190.97	1.85
220	3.52	0.046	1193.27	1.84
230	3.65	0.048	1195.41	1.92
230	3.74	0.049	1196.90	1.92
250	3.82	0.050	1198.23	2.09

250	3.96	0.052	1200.56	2.08
250	4.11	0.054	1203.06	2.08
250	4.28	0.056	1205.91	2.07
270	4.36	0.057	1207.26	2.24
270	4.6	0.061	1211.32	2.23
270	4.75	0.063	1213.87	2.22
270	4.92	0.065	1216.77	2.22
270	5.06	0.067	1219.17	2.21
270	5.19	0.068	1221.41	2.21
270	5.36	0.071	1224.35	2.21
270	5.42	0.071	1225.39	2.20
270	5.00	0.066	1218.14	2.22
300	6.67	0.088	1247.48	2.40
300	6.84	0.090	1250.55	2.40
300	6.93	0.091	1252.18	2.40
300	7.11	0.094	1255.45	2.39
300	7.27	0.096	1258.37	2.38
300	7.65	0.101	1265.37	2.37
280	8.09	0.106	1273.57	2.20
250	9.66	0.127	1303.71	1.92

Triaxial test without geotextile

Sample 2: σ_3= 1.5 kg/cm^2

Load (N)	Compression (mm)	Vertical Strain ΔL(mm)	Corrected Area(mm^2) =1138/(1-ΔL/L)	Vertical Stress (kg/cm^2) =Load/corrected area
20	0.00	0.00	1138.00	0.18
20	0.26	0.00	1141.85	0.18
20	0.42	0.01	1144.29	0.17
40	0.44	0.01	1144.58	0.35
40	0.57	0.01	1146.60	0.35
40	0.60	0.01	1147.03	0.35
60	0.63	0.01	1147.47	0.52
60	0.67	0.01	1148.05	0.52
70	0.79	0.01	1149.93	0.61
70	0.87	0.01	1151.24	0.61
70	0.98	0.01	1152.84	0.61
80	1.09	0.01	1154.60	0.69
80	1.25	0.02	1157.09	0.69
100	1.27	0.02	1157.39	0.86
100	1.65	0.02	1163.22	0.86
130	1.74	0.02	1164.73	1.12

130	1.83	0.02	1166.07	1.11
150	1.95	0.03	1167.93	1.28
160	2.08	0.03	1169.96	1.37
160	2.19	0.03	1171.82	1.37
160	2.29	0.03	1173.35	1.36
170	2.39	0.03	1174.89	1.45
180	2.40	0.03	1175.06	1.53
200	2.56	0.03	1177.63	1.70
200	2.68	0.04	1179.52	1.70
210	2.86	0.04	1182.45	1.78
220	3.01	0.04	1184.88	1.86
220	3.08	0.04	1186.09	1.85
220	3.21	0.04	1188.19	1.85
230	3.23	0.04	1188.53	1.94
230	3.39	0.04	1191.16	1.93
230	3.62	0.05	1194.86	1.92
230	3.77	0.05	1197.34	1.92
230	3.91	0.05	1199.65	1.92
230	4.00	0.05	1201.25	1.91
230	4.09	0.05	1202.68	1.91
270	4.24	0.06	1205.19	2.24
280	4.29	0.06	1206.08	2.32
300	4.31	0.06	1206.42	2.49
300	4.33	0.06	1206.75	2.49
300	4.35	0.06	1207.09	2.49
300	4.37	0.06	1207.43	2.48
310	4.53	0.06	1210.07	2.56
310	4.66	0.06	1212.25	2.56
310	4.77	0.06	1214.29	2.55
300	4.93	0.06	1216.96	2.47
310	4.99	0.07	1217.91	2.55
310	4.60	0.06	1211.32	2.56
290	6.14	0.08	1237.96	2.34
800	6.29	0.08	1240.73	2.26

Triaxial test with geotextile

Sample 1: σ_3=1 kg/cm^2

Load (N)	Compression (mm)	Vertical Strain ΔL(mm)	Corrected Area(mm^2) =1138/(1-ΔL/L)	Vertical Stress (kg/cm^2) =Load/corrected area
20	0.00	0.000	1138.00	0.18
30	0.00	0.000	1138.00	0.26

40	0.00	0.000	1138.00	0.35
50	0.25	0.003	1141.76	0.44
60	0.62	0.008	1147.36	0.52
70	0.78	0.010	1149.80	0.61
80	0.89	0.012	1151.48	0.69
90	0.96	0.013	1152.56	0.78
100	1.25	0.016	1157.03	0.86
120	1.46	0.019	1160.29	1.03
120	1.79	0.024	1165.45	1.03
120	2.05	0.027	1169.55	1.03
130	2.36	0.031	1174.47	1.11
130	2.56	0.034	1177.67	1.10
140	2.79	0.037	1181.37	1.19
150	2.93	0.039	1183.63	1.27
160	3.06	0.040	1185.74	1.35
160	3.33	0.044	1190.15	1.34
160	3.56	0.047	1193.93	1.34
170	3.78	0.050	1197.56	1.42
170	3.95	0.052	1200.39	1.42
180	4.01	0.053	1201.39	1.50
190	4.07	0.054	1202.39	1.58
200	4.13	0.054	1203.40	1.66
210	4.17	0.055	1204.07	1.74
210	4.24	0.056	1205.24	1.74
230	4.28	0.056	1205.91	1.91
240	4.32	0.057	1206.58	1.99
250	4.35	0.057	1207.09	2.07
250	4.40	0.058	1207.93	2.07
260	4.46	0.059	1208.95	2.15
260	4.58	0.060	1210.98	2.15
270	4.65	0.061	1212.17	2.23
280	4.73	0.062	1213.53	2.31
290	4.79	0.063	1214.55	2.39
290	4.84	0.064	1215.40	2.39
300	4.91	0.065	1216.60	2.47
310	4.97	0.065	1217.63	2.55
310	4.98	0.066	1217.80	2.55
320	5.01	0.066	1218.31	2.63
320	5.05	0.066	1219.00	2.63
330	5.11	0.067	1220.03	2.70
360	5.21	0.069	1221.75	2.95
360	5.26	0.069	1222.62	2.94
370	5.31	0.070	1223.48	3.02

380	5.40	0.071	1225.04	3.10
390	5.55	0.073	1227.65	3.18
400	5.61	0.074	1228.70	3.26
410	5.74	0.076	1230.97	3.33
410	5.81	0.076	1232.20	3.33
400	5.87	0.077	1233.25	3.24
380	5.90	0.078	1233.78	3.08
370	6.00	0.079	1235.54	2.99
360	6.10	0.080	1237.31	2.91
350	6.25	0.082	1239.97	2.82
330	6.70	0.088	1248.02	2.64

Sample 2: σ_3=1.5 kg/cm^2

Load (N)	Compression (mm)	Vertical Strain ΔL(mm)	Corrected Area(mm^2) =1138/(1-ΔL/L)	Vertical Stress (kg/cm^2) =Load/corrected area
20	0	0.000	1138.00	0.18
30	0	0.000	1138.00	0.26
40	0.21	0.003	1141.15	0.35
50	0.36	0.005	1143.42	0.44
60	0.52	0.007	1145.84	0.52
70	0.89	0.012	1151.48	0.61
80	1.07	0.014	1154.25	0.69
90	1.19	0.016	1156.10	0.78
10	1.29	0.017	1157.65	0.86
120	1.46	0.019	1160.29	1.03
120	1.59	0.021	1162.32	1.03
120	1.72	0.023	1164.35	1.03
130	1.86	0.024	1166.55	1.11
130	1.97	0.026	1168.28	1.11
140	2.06	0.027	1169.71	1.20
150	2.17	0.029	1171.45	1.28
160	2.73	0.036	1180.40	1.36
170	2.97	0.039	1184.28	1.44
180	3.16	0.042	1187.37	1.52
170	3.33	0.044	1190.15	1.43
170	3.47	0.046	1192.44	1.43
180	3.59	0.047	1194.42	1.51
190	3.68	0.048	1195.91	1.59
200	3.75	0.049	1197.07	1.67
210	3.81	0.050	1198.06	1.75
210	3.86	0.051	1198.89	1.75
230	3.95	0.052	1200.39	1.92
240	4.04	0.053	1201.89	2.00
250	4.13	0.054	1203.40	2.08
260	4.19	0.055	1204.40	2.16

270	4.26	0.056	1205.58	2.24
280	4.32	0.057	1206.58	2.32
290	4.38	0.058	1207.60	2.40
300	4.43	0.058	1208.44	2.48
310	4.51	0.059	1209.79	2.56
320	4.57	0.060	1210.81	2.64
330	4.63	0.061	1211.83	2.72
340	4.73	0.062	1213.53	2.80
350	4.84	0.064	1215.40	2.88
360	4.95	0.065	1217.28	2.96
370	5.01	0.066	1218.31	3.04
380	5.07	0.067	1219.34	3.12
390	5.11	0.067	1220.03	3.20
400	5.16	0.068	1220.89	3.28
400	5.24	0.069	1222.27	3.27
410	5.31	0.070	1223.48	3.35
420	5.38	0.071	1224.70	3.43
430	5.42	0.071	1225.39	3.51
440	5.51	0.073	1226.95	3.59
450	5.58	0.073	1228.17	3.66
460	5.65	0.074	1229.40	3.74
470	5.73	0.075	1230.80	3.82
470	5.98	0.079	1235.19	3.81
460	6.24	0.082	1239.79	3.71
440	6.53	0.086	1244.97	3.53
430	6.89	0.091	1251.45	3.44

Photographs

Site visit, the geotextile being put to use at KNCEL project, chainage 146

Geotextiles placed perpendicular to the surface and geogrids placed parallel to the surface

A roll of geotextile being opened at site

During triaxial test UU

Prepating specimen

Setting up instruments

Before

After

During triaxial test, CU

Soil Saturation under process

Cell pressure diminishing effect

Oil imbalance. affecting further research in the project

During other tests

Proctor Compaction Test

Specimens for testing

Some samples from plastic limit testing

Some samples from liquid limit testing

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