STUDY ON DIRECT SHEAR TEST ON SAND WITH THE INCLUSION OF GEOTEXTILE AT DIFFERENT ORIENTATION

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
GEOTECHNICAL ENGINEERING

Submitted by:
ANKIT GOEL
2K17/GTE/06

Under the supervision of

Prof. ANIL KUMAR SAHU

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

JULY,2019

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, Ankit Goel, (2K17/GTE/06) of M.Tech in Geotechnical Engineering, hereby declare that the project dissertation entitled **" STUDY ON DIRECT SHEAR TEST ON SAND WITH THE INCLUSION OF GEOTEXTILE AT DIFFERENT ORIENTATION**" which is submitted by me to the Department of Civil Engineering of Delhi Technological University, Delhi in fulfilment of the project dissertation of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **(ANKIT GOEL)**
Date: **2K17/GTE/06**

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the project dissertation entitled **" STUDY ON DIRECT SHEAR TEST ON SAND WITH THE INCLUSION OF GEOTEXTILE AT DIFFERENT ORIENTATION"** which is submitted by Ankit Goel, (2K17/GTE/06) of M.Tech in Geotechnical Engineering of Delhi Technological University, Delhi in fulfillment of the project dissertation of Master of Technology, is a record of the project work carried out by him under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi
Date:

(Prof. ANIL KUMAR SAHU)
SUPERVISOR & PROFESSOR
Department of Civil Engineering

ACKNOWLEDGEMENT

I thank god almighty for bestowing his blessings and grace in completion of report for project dissertation. I express my sincere thanks to the University Management. My sincere thanks also go to vice chancellor Prof. Yogesh Singh and to head of department Prof. Nirendra Dev. As I write this acknowledgement, I must clarify that this is not just a formal acknowledgement but also a sincere note of thanks and regard from my side. I feel a deep sense of gratitude and affection for those who were associated with the course and without whose co-operation and guidance this course could not have been conducted properly. Words fail me to express my regards towards my guide Prof. Anil Kumar Sahu, Civil Engineering Department, Delhi Technological University, Delhi for giving me guidance throughout this Project, which really instilled in me the requisite confidence. I also express my deep gratitude to Prof. A. Trivedi, Prof. A.K. Gupta and Prof. A. K. Shrivastav, Department of Civil Engineering and all the Faculty member of Civil Engineering Delhi Technological University, Delhi for the pains taken by them to go through the manuscript and giving his useful suggestions. Last but not the least, I would like to thank my family and friends who stimulated me to bring this work to a successful close.

ANKIT GOEL
2K17/GTE/06
Department of Civil Engineering
Delhi Technological University

ABSTRACT

In civil engineering applications, materials are widely used to reinforce retaining walls, roads, highways, and railway ballasts. Therefore, studying the geotextile-soil interaction under Direct Shear is important for any successful design. Soil-reinforcement interaction mechanism has an utmost importance in the design of reinforced soil structures. This mechanism depends on the soil properties, reinforcement characteristics and elements (soil and reinforcement) interaction. In this work the shear strength of an interface between Yamuna sand and two non-woven geotextiles of different strength was characterized through direct shear tests. A series of direct shear tests were conducted to investigate the interface behaviour of soil/geosynthetics. Geotextile is placed at different orientation in shear box and its effect is analysed accordingly. The test equipment, soils, and geosynthetics properties are described. The influence of geotextile in soil and its effect on shear strength parameters i.e. Angle of Internal Friction and the friction and shear behaviour of sand – geotextile interference is discussed by analysing tests results.

CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS & ABBREVIATION

ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
b/w	Between
IS	Indian standards
CBR	California bearing ratio
C_c	Coefficient of curvature
C_u	Coefficient of uniformity
c/c	Centre to centre
c	Cohesion of soil (kN/m2)
d	Soil particle diameter
DSA	Direct shear apparatus
DST	Direct shear test
D_{10}	Effective size of sand
D_{30}	30 % of the soil particles are finer than this size
D_{50}	Mean grain size
D_{60}	60 % of the soil particles are finer than this size
G	Specific gravity
GSD	Grain size distribution
GT1	Light weight geotextile
GT2	Heavy weight geotextile
GTJ	Geotechnical testing journal
σ	Normal stress (kN/m2)
τ	Shear Stress (kN/m2)
ϕ	Angle of internal friction
ρ	Density

CHAPTER 1

INTRODUCTION

In earlier time, when the construction site has unsuitable soil exercise was substitution of loose soil or implementing appropriate basis which may affect the economics of the construction project. In modern engineering ground improvement are done in these types of problems. One of the emerging methods is reinforcing the soil with geo-synthetics. when used to increase the soil strength they have many advantages.

1.1 General

Henri Vidal a French architect who first introduce the earthed which is strengthened with reinforcement in 1963. The concept of reinforced soil was accident thought about by him while playing with his daughter on beach. He saw his daughter making sand castle at sea shore using her hair pins to prevent it from collapsing after seeing this Henri got the idea of reinforced earth structure. He used fabric fabricated from a rough material of backfill which is strengthened using strips which are linearly flexible in nature usually placed horizontally on account that its development, bridge abutments, seawalls, retaining walls, slabs are the area of civil engineering where reinforced soil has extensive use. His approach of reinforced soil was adopted globally and the overall variety of reinforced structure.

The reinforcement which is flexible in nature interacting with soil resist the shear stress with the help of friction. Because of this shear stress on interfere zone strain is generated, thus pressure tensile in nature is mobilizes. If the tensile pressure is exceeding the tensile capability of the geo-textile, failure takes place. If the deformation is excessive or interface is clean, it is in all likelihood that a slip takes place among soil and reinforcement- pullout failure.

Geo-textiles are artificial fiber textile instead of natural material like silk. Biodegradation does not affect the geo textile. One of the important factors which allow the use of geo textile is they are of porous nature thus allow the flow of water fabrication of geotextile is done from polypropylene and polyester. Properties of polypropylene which allow its use in geotechnical application is its unit weight (lighter than the water), thus is consider to be really long lasting. Properties offer by polyester which is used in making geotextile has high strength and creep and density is also more than water. Woven and non-woven geo-textiles are two different type of geotextiles. Polypropylene and polyester filaments and primary fibers are used in manufacturing of these geo-textiles. Their size is generally 1” to 4” long or a long continuous fiber in layers.

Silt film yarns, multifilament and weaving monofilament are used in manufacturing od woven geo-textile. Flat tapes & Fibrillated yarns are further classification of slit film yarn. Manufacturing of geotextile basically includes two steps. In street stabilization work and sediment control silt films are good but not suitable sub surface drainage as woven geotextile has low permeability.

Fig.1.1 Geotextiles

Geo-textiles with desirable strength in tension can make contributions to load bearing ability of loose soil. Placement of geotextile between the subgrade and stone aggregate not only sere the purpose of separator but also improves the soil bearing capacity of soil. The contact between soil and geo-textile is of maximum status for the modeling and overall consummation of reinforced soil systems. This performance relies upon on the properties of soil and reinforcement, and the interaction among these substances. Further a number of researchers performed DST in order to observe the shearing behavior of soil reinforced using geo-textile.

The study of above discussed interaction constraints, and their progress through the years, additionally related to the variation of the carried-out hundreds, is mainly essential within the geo-textile design reinforced sand systems. In reality, the length of reinforcement depends on the assumed friction coefficient which is apparent in nature.

The soil geo-textile behavior may be complicated because it depends upon various properties of geo-textile which include mechanical, structural and geometrical. The main reason for the soil and geo-textile interaction is skin friction and for soil geogrid interaction is its open structure.

The geogrid has number of different contact process as follows: the roughness b/w the soil particle surface and geo-textile surface, the passive friction organized towards the bearing providers, and the friction due to soil present in reinforcement opening and the rest soil particles. The complexity in the behavior at soil-geo-textile interface is generally determined with the aid of introducing an equal frictional shear pressure that permits comparing a general resistance, noted the whole reinforcement surface.

The reinforcement which is flexible in nature interacting with soil resist the shear stress with the help of friction. Because of this shear stress on interfere zone strain is generated, thus pressure tensile in nature is mobilizes. If the tensile pressure is exceeding the tensile capability of the geo-textile, failure takes place. If the deformation is excessive or interface is clean, it is in all likelihood that a slip takes place among soil and reinforcement- pullout failure.

1.2 Objective of Research:

On the basis of Literature Survey in the field of Soil reinforcing with geo-textile following objectives are to be performed:

a.) To obtain the properties of soil.

b.) To Study of Soil-Geo-textile Interaction and mechanism of soil reinforcement.

c.) To study the effect on shear strength parameters of reinforcing sand using geo-textile placing at different depth and different orientation under direct shear test.

d.) To study the effect of shear strength parameters of reinforcing sand by increasing the no of layers of geo-textile under direct shear test.

CHAPTER 2

LITERATURE REVIEW

Shear strength parameters of soil is evaluated using direct shear test. Considering the fact that 1990, DST has been prolonged to obtained the friction among soils and geo-textile. Shear on geo-textile–soil interfere zone depends upon on a many factor, such as type of geo-textile and applied effective normal stress, grain size distribution of soil, plasticity, unit weight, water content, size of specimen and different constraints.

Jewell et al. (1987) states that during DST tests, number of mechanisms can be mobilized at the geogrid–soil contact. Liu et al. performed study and concluded that the strength of geogrid-soil interface increases due to the passive mechanism. Jewell’s study says that the max bond angle of friction for strong reinforcement must be equal to the angle of shearing resistance obtained from DST.

Jewell (1987) shows in research geo-synthetics and soil relation by using setting the geosynthetic perpendicular to the shearing plane which will characterize the behavior of composite cloth and states that strength of soil successfully increases with this orientation of geo-synthetics.

Marelo (1989) gives his results in which he stated that peak friction angle of reinforced sand will increase and also apparent cohesion is better in this case. Sample size has no huge impact on Shear parameters of soil reinforced with geo-synthetics. He said that geo-textile soil method complements the strength properties of earthen structure as they conduct test on poor soil and concluded that soil may be improve through reinforcement geo-textile this has been proved by using performing one of a kind assesment.

Bathurst (1994) said that when the geogrid is placed at height equal to 0.72h &076h from top surface then we get maximum effect of reinforcement in soil. Stiffness of the grid and type of soil are the main factors which enhance CBR value of soil subgrade.

Moustafa (2004) research the behavior of reinforced Soil which is used as subgrade this subgrade is strengthened with geogrid. Triaxial and unconfined compression and CBR tests have been carried out with the aid of reinforcing the samples at one-of-a-kind depths within the pattern height.

Murthy (2007) stated that properties of soil and characteristics of reinforcement are the main factors on which the entire mechanism of soil reinforcement depends. DST is performed by him in order to categorized siliceous sand and geo-textile with high strength on the basis of their interaction behavior and strength performance.

Vieira (2008) carried out on a large-scale direct shear equipment. From the DST results, they can say that the shear strength value obtained from large scale DST apparatus are overestimated i.e. it overestimate the behavior of interface between soil and geotextile as compare to that of conventional DST apparatus.

Toshinori (2008) has evaluated a new type of geotextile to study the properties of interaction between backfill and geosynthetics using DST. Displacement softening and hardening behavior is observed in pure sand and geogrid interface. They take a look at result screen and noted that in most of the cases relationship between normal stress and inferring strength in shear is not linear.

Palmeira (2009) said that soils and geo-synthetics interaction plays an important role in the suggestion of geosynthetic as reinforcing material in various geotechnical application. The complexity in the behavior at soil-geo-textile interface is based on geosynthetic and soil properties and discusses some theoretical numerical and experimental methods for the study and soil-geo-synthetics interaction, with relationship with those substances in which soil is reinforced with geo-synthetics which also affected by boundary conditions of shear apparatus.

Farsakh (2010) gives the impact of moisture content material and dry density on cohesive soil – geo-synthetics interaction using the large-scale direct shear tests in these additionally geo-synthetics is positioned horizontally and frictional resistance provided with the aid of geo-synthetics brought up in cohesion of soil practical leads to increase in strength of soil.

Nicola (2014) studied the various factors which affect the DST results such as effect of box size of the apparatus, have an effect on of establishing length between the 2 halves of shear box and also present the soil-geo-synthetics interaction in Direct Shear test. He states that the test boundary conditions may also have an effect on test conclusions, specially shear boxes of smaller size. The DST may be used to assess shear strength on the interface if large size boxes are used. The soil–geosynthetic contact energy depends on applied pressure in vertical direction at opening of geogrid in comparison of average grain size and on bearing member thickness. Passive resistance in geogrid – soil interface is due to ribs of geogrid which provide shear resistance.

Belen (2015) studied the shear behavior study of geosynthetic interfaces, the geo-textile, generally used for covered landfills. The interface interplay mechanisms rely upon normal stress. At normal stress lesser than 50 kPa, roughness develops at a high degree. At stress greater than 50 kPa interaction develop at a matrix level. For geomembranes, the gap among the unevenness of the surface plays important role in the development of the interaction. The nearer these irregularities are, the better will be the results. However, these irregularities should maintain at a critical spacing in order to avoid uniformity.

Biswas (2015) give a technical research in which he studies the behavior of sand and clay subgrade reinforced with geogrid and he further gives his theory over the interfering behavior between them. model checks have been executed on a circular footing of one hundred fifty mm dia (d) resting on cubical bed of dimension 1 mm. He considers clay subgrade for his experiment having various undrained shear strengths taken from six to sixty kilopascal. The outcomes show that performance of footing increases when sand and clay subgrade is reinforced with planar geogrid which further depends on strength of subgrade and thickness of layer.

Shukla (2016) studied the consequences of the series of triaxial tests performed at the low plastic sandy clay strengthened with geo-textiles. The checking out turned into accomplished on soil by means of various the quantity of geo-textile layers, confining pressure, form of geo-textile material and percentage of geo-textiles. Use of woven geo-textile increases the cohesion intercept of soil, whereas non-woven geo-textile increases the friction perspective of soil. Peak shear energy elevated linearly with increase in confining pressure, but beyond a certain limit.

Philip (2016) provides number of results of undrained compression monotonic in nature on reinforced sand in particular to examine their confining pressure effect on the mechanical behavior of sand and geo-textile interface. The triaxial assessments had been achieved on specimens of sand prepared at free relative density 30% with and without layer of geo-textile. The obtained outcomes display that high surrounding pressure can restrict the dilation of sand and extra impact on reinforcement efficiently.

Awdhesh (2016) provides the impact on of various varieties of geo-synthetics and soil on behavior of soil-geosynthetic interfere zone investigated through DST and pullout test. Three specimen each of cohesionless soil and geosynthetic material were used in the experiments and conclusion was made that soil particles penetrates in the geo-synthetics and this penetration results in higher interface friction in case of non-woven geo-textile in comparison to woven geo-textile. Particle size of soil highly effect the angle of friction.

Jose (2018) focuses on interaction behavior among soil and geo-synthetics and performance of reinforced soil shape and stated that interplay process depends on properties of soil, reinforced features and inter-relationship among materials.

Observation were made by the researchers in laboratory tests results in DST that on placing reinforcement parallel to the interfere zone which is parallel to the failure plane induces for the shear box in test of interface behavior of granular soil with different type of geo-synthetics positioned horizontal and favorable results got here as strength parameters increases.

CHAPTER 3

MATERIALS AND METHODS

This chapter details the method followed to achieve the desired objectives of the study. The test materials, the soil classification method, the testing schedule and experimental procedures are discussed. To maintain the consistency DST were performed on soil sample by placing geotextile at different orientation with same normal loads.

3.1 Material Used

The soil used for test is Yamuna sand which is found at bank of river Yamuna. Grain Size Distribution (GSD) curve of Yamuna sand indicates that the sand contains 75 to 80% of particles in the range of 0.1 mm to 0.3 mm with insignificant clay and silt content (2-4%). Value of uniformity coefficient (C_u) and curvature coefficient (C_c) are listed in Table 4.1 and the soil may be classified as uniformly graded sandy soil as per IS: 1498-1970. To find Specific Gravity of sand pycnometer test is performed and following results are obtained is listed in Table 3.1.

Fig.3.1 Yamuna Sand Sample

Fig.3.2 Sieve Set

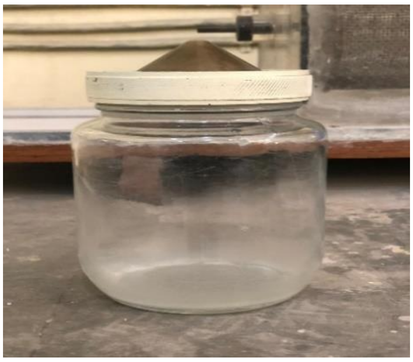

Fig.3.3 Empty Pycnometer

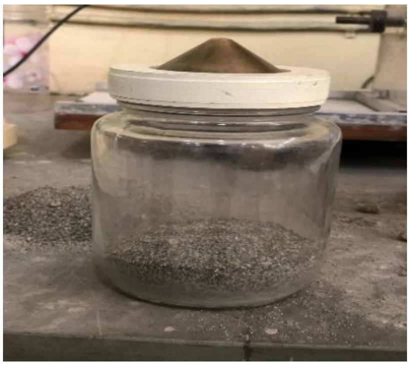

Fig.3.4 Pycnometer with Sand

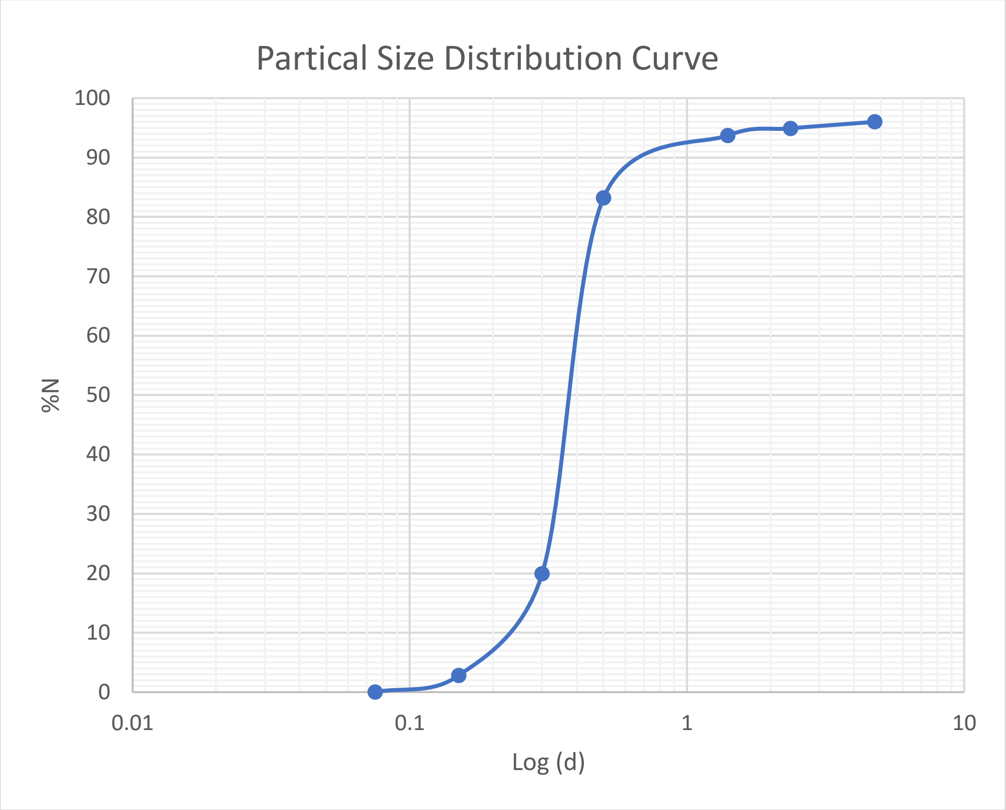

Fig.3.5 Particle Size Distribution

Table 3.1 Properties of Sand

Parameters	Value
D_{10}(mm)	0.16
D_{30}(mm)	0.24
D_{50}(mm)	0.30
D_{60}(mm)	0.32
C_u	1.93
C_c	1.10
Specific Gravity	2.64

Two type of geosynthetic were used in experimental program which is non-woven geo-textile. Fig. 3.6 and fig.3.7 are the images of different geo-textile used for soil reinforcement. These geo-synthetics used were bought from Sieb Geo-textiles, a company from Delhi. Polyester based non-woven geotextile is used. In Table 3.2, the parameters of two type of geo-synthetics used is listed as per manual provided by company. The light weight non-woven geo-textile is denoted by **GT1** and the heavy weight non-woven geo-textile is denoted by **GT2.**

Fig.3.6 GT1

Fig.3.7 GT2

Table 3.2 Properties of Geo-textiles

Properties	**GT1**	**GT2**
Mass per unit area (g/m^2)	150	200
Tolerance	-8%	-8%
Thickness (mm)	≥ 1.3	≥ 1.7
Width Tolerance	-0.5%	-0.5%
Break Strength (kN/m)	4.5	6.5
Elongation at Break	25-100%	25-100%
CBR Bursting Strength (kN)	≥ 0.6	≥ 0.9
Equivalent Opening Size (mm)	0.07-0.2	0.07-0.2

3.2 Methodology

a.) Apparatus

- Shear box (6 cm * 6 cm)
- Container of shear box
- Grids plates and porous stones
- Sieve set, temping rod and weighing balance
- Load cell
- Horizontal and Vertical Displacement Measuring Rods.

Fig.3.8 Direct Shear Stress Apparatus

b.) Sample Preparation

Sand sample passing through 4.75 mm sieve is taken for test. Quantity of sand should be 1kg and it should be air dried sample.

Fig.3.9 Sand Sample on Weighing Balance

c.) Procedure

1.) First of we measure the size of the shear box, after that upper and lower part of the box is fix using clamping screws and a porous stone is placed at bottom of the share box.

2.) A perforated grid plate and a serrated grid plates are placed over porous stone for drained and undrained test respectively.

3.) Initially 1 kg air dried soil is weighed on weighing machine after that soil is filled in the shear box in three layers and every layer must be compacted by using tamping rod after that grid plate, porous stone and loading pad must be placed in order on soil sample

4.) Place the Geo-textile according to the required orientation i.e. horizontal, vertical and in different numbers.

5.) Shear box containing sand sample is the placed in container and loading frame is mounted over it. Horizontal proving ring is in contact with the upper part of the box.

Fig.3.10 Geo-textile Placed Horizontally

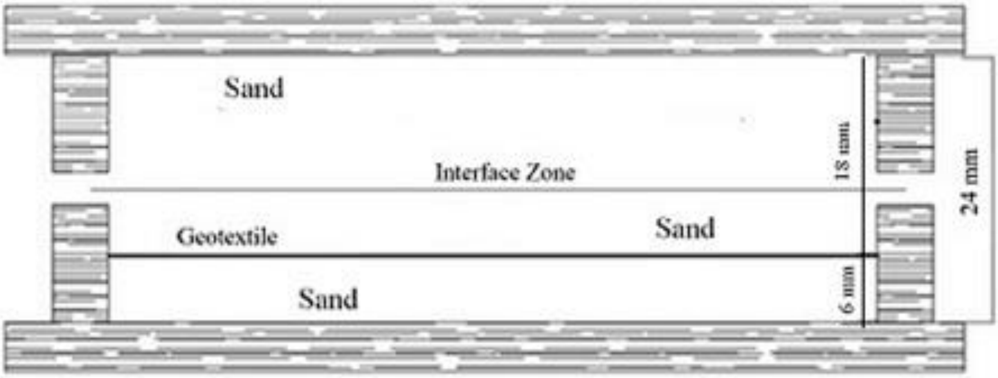

Fig. 3.11 Geo-textile placed at centre of lower part

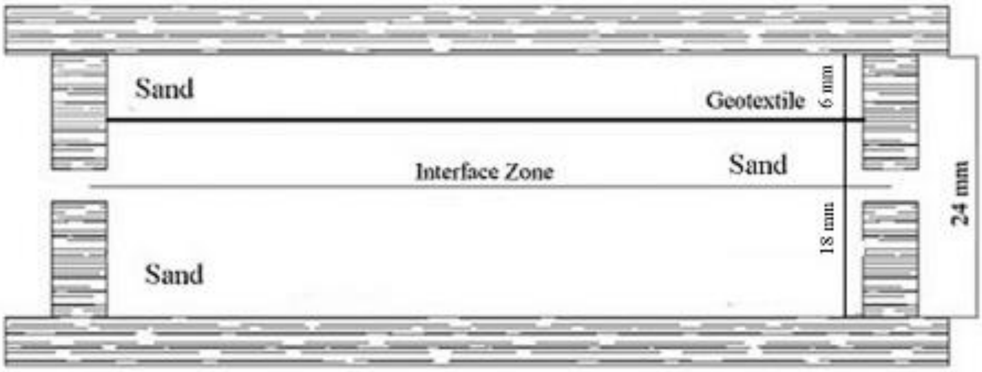

Fig. 3.12 Geo-textile placed at centre of upper part

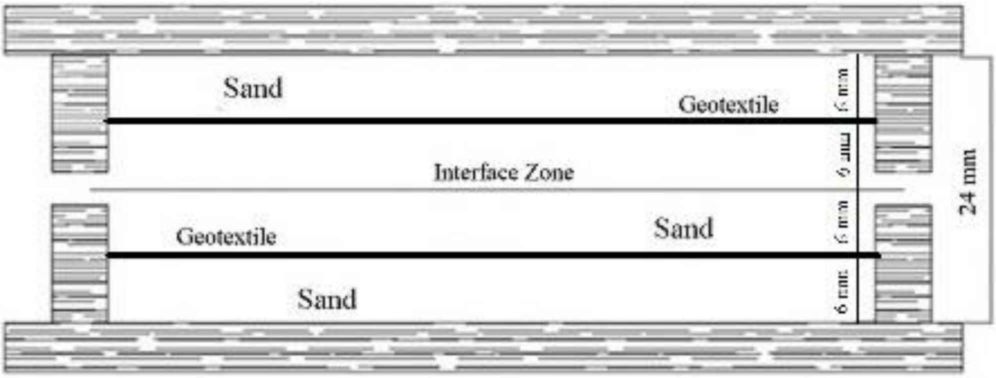

Fig. 3.13 Geo-textile placed at centre of upper & lower part

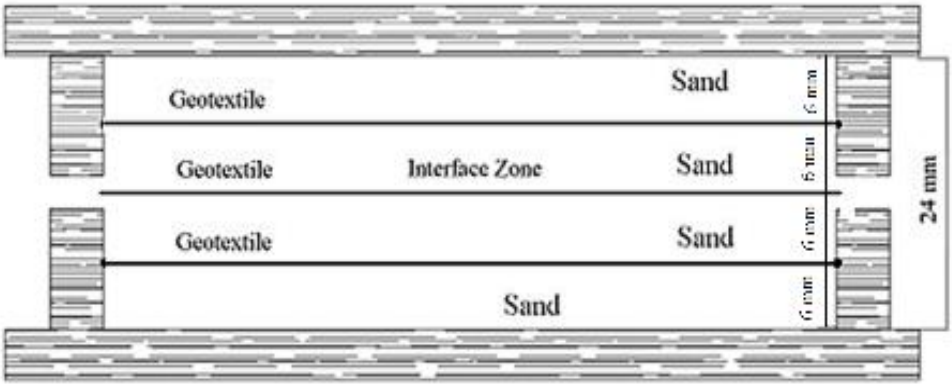

Fig. 3.14 Geo-textile placed at 6 mm c/c

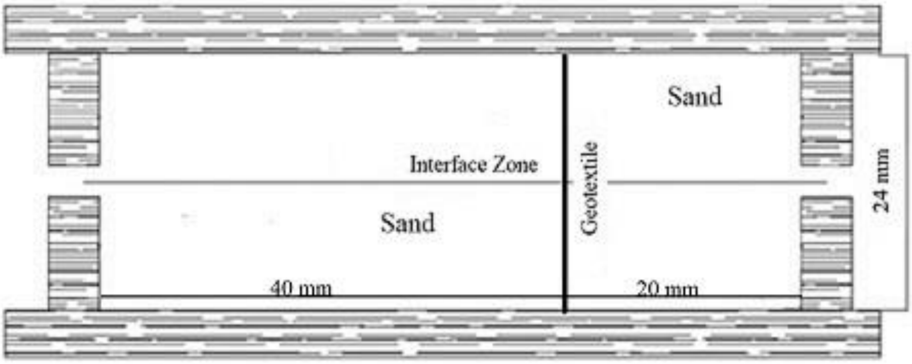

Fig. 3.15 Geo-textile placed at 20 mm from right

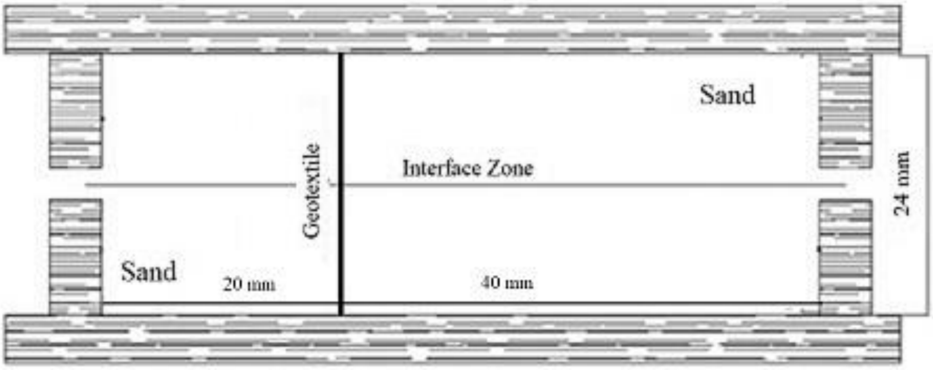

Fig. 3.16 Geo-textile placed at 40 mm from right

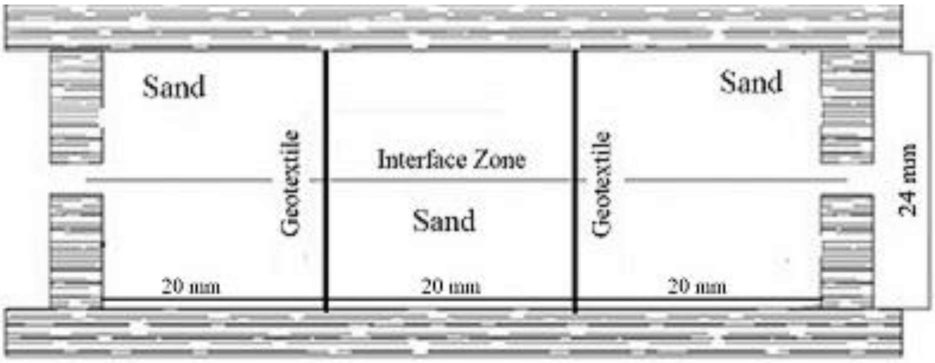

Fig. 3.17 Geo-textile placed at 20 mm c/c

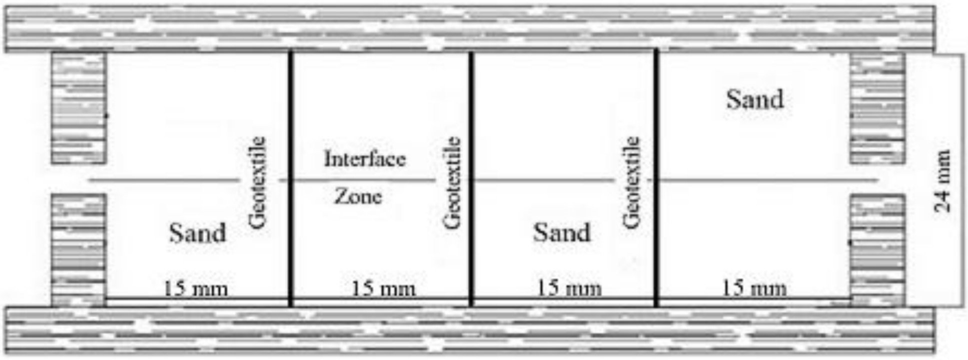

Fig. 3.18 Geo-textile placed at 15 mm c/c

Fig. 3.19 Shear Box Filled with Sand

6.) Adjust the proving ring to zero and set the vertical displacement gauge before this clamping screws should be removed from the shear box.

7.) Value of normal stress is predefined to (50 kN/m2,100 kN/m2,150 kN/m2).

Fig.3.20 Shear Box Placed Inside DSA

8.) 1.25mm/min constant rate of strain is applied with a constant speed motor is started. Gauge readings are taken until the horizontal shear load reaches to peak value and then falls, or the horizontal displacement reaches 20% of the specimen length.

9.) These steps are repeated with different sample reinforced with different number of layers and different orientation of geotextile.

d.) Precautions

- Proving ring should be in proper contact with upper part of the shear box.
- Before application of shear load clamping screws should be removed.
- The test should be done under constant strain rate.

Fig.3.21 Failed Geo-textile Pieces

Fig. 3.22 Shear Box

Fig. 3.23 Shear Box After Shearing

CHAPTER 4

RESULTS AND DISCUSSION

This chapter discusses the application of the readings generated from the direct shear test and present the corresponding curve required for determination of angle of internal friction which is an important parameter contribution the shear strength of sand and are used in design of structures.

4.1 Soil without Reinforcement

Table 4.1 Soil without Reinforcement

σ (kN/m^2)	τ (kN/m^2)
0	2.07
50	8.98
100	14.32
150	19.23

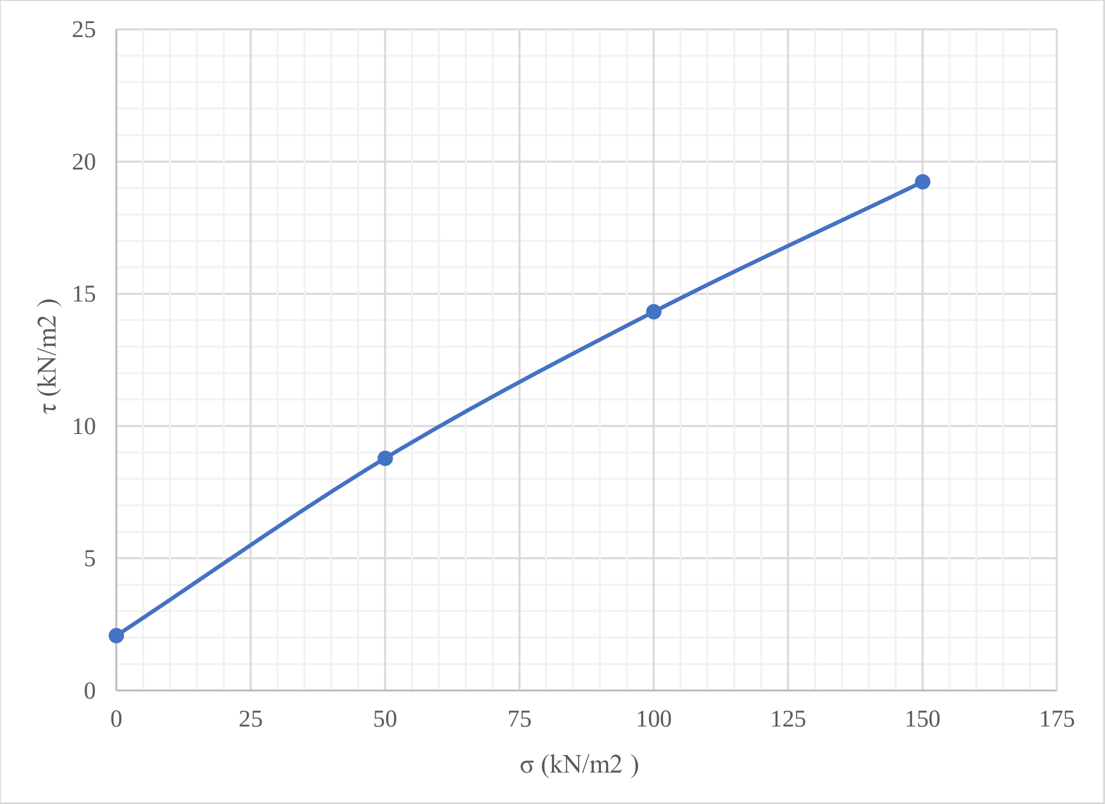

Fig.4.1 Soil without Reinforcement

For unreinforced sand curve is drawn b/w σ and shear stress as shown in fig.4.1. From the curve the value of angle of shearing resistance is found to be **31.5^0**.

4.2 Soil with Reinforcement

4.2.1 Light Weight Non-Woven Geo-textile as Reinforcement (GT1)

1.) GT1 (Placed parallel to shearing plane at centre of lower part of shear box)

Table 4.2 GT1 placed at centre of lower part

σ (kN/m^2)	τ (kN/m^2)
0	1.61
50	8.17
100	13.45
150	18.06

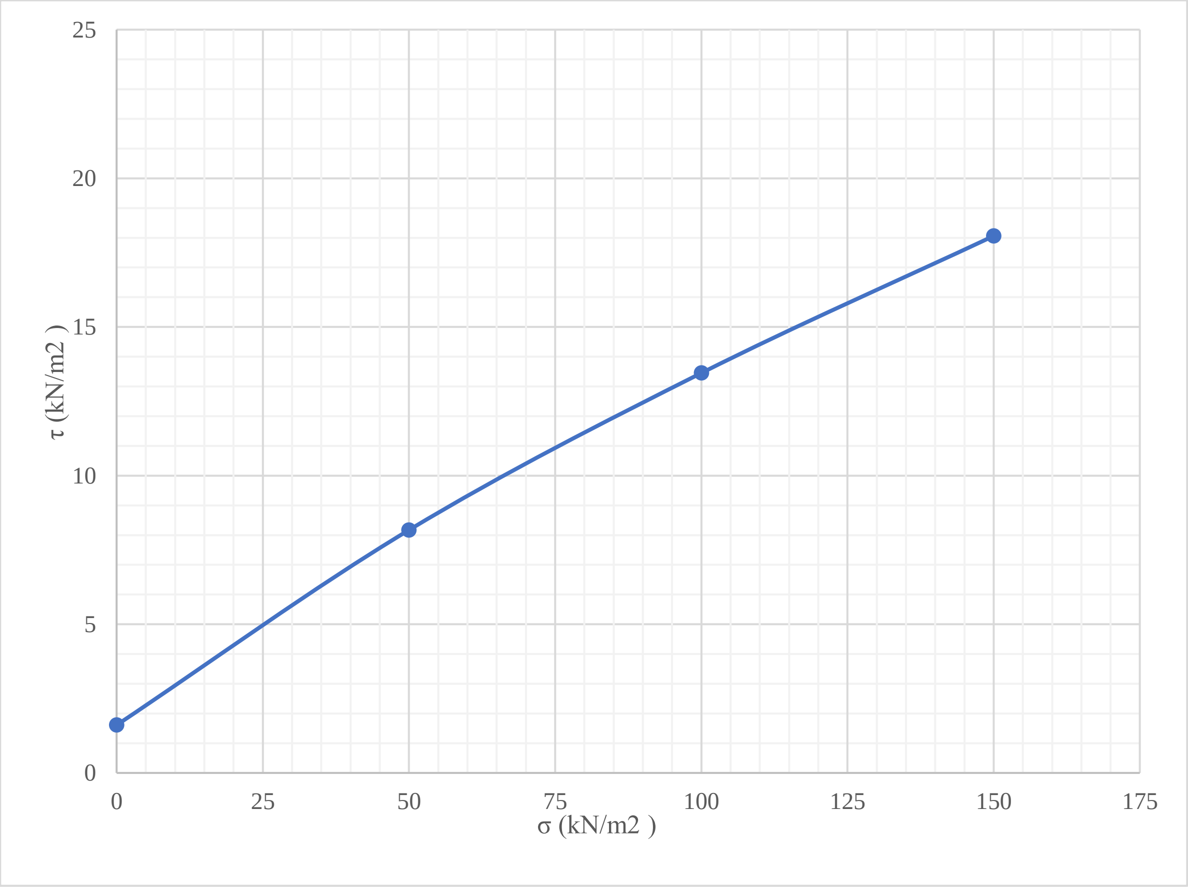

Fig.4.2 GT1 placed at centre of lower part

For geo-textile-sand arrangement as shown in fig.3.11 curve is drawn b/w stress as shown in fig.4.2. From the curve the value of angle of shearing resistance is found to be **32.5^0** which is more than that of unreinforced soil.

2.) GT1 (Placed parallel to shearing plane at centre of upper part of shear box)

Table 4.3 GT 1 placed at centre of upper part

σ (kN/m^2)	τ (kN/m^2)
0	3.19
50	10.23
100	15.67
150	20.09

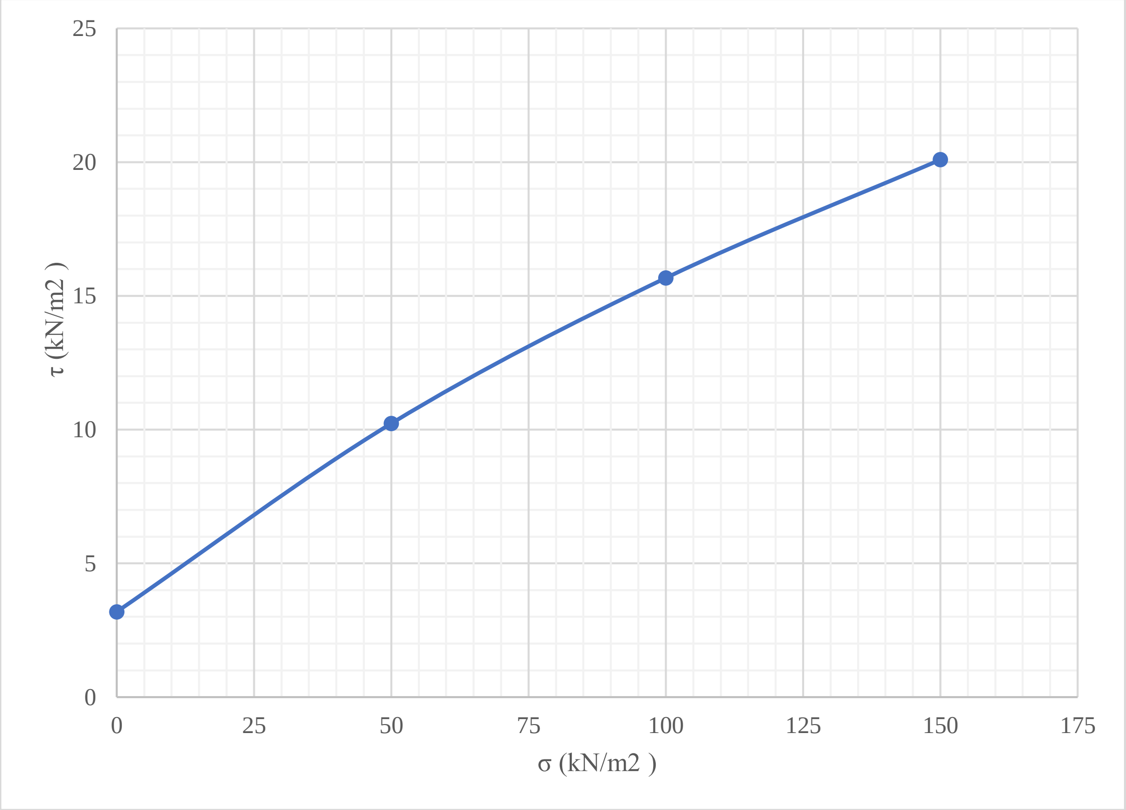

Fig. 4.3 GT1 placed at centre of upper part

For geo-textile-sand arrangement shown in fig.3.12 curve is drawn b/w stress as shown in fig.4.3. From the curve the value of angle of shearing resistance is found to be **33^0**.

3.) GT1 (Placed parallel to shearing plane at centre of upper and lower part of shear box)

Table 4.4 GT1 placed at upper and lower part

σ (kN/m^2)	τ (kN/m^2)
0	1.58
50	8.44
100	13.32
150	17.78

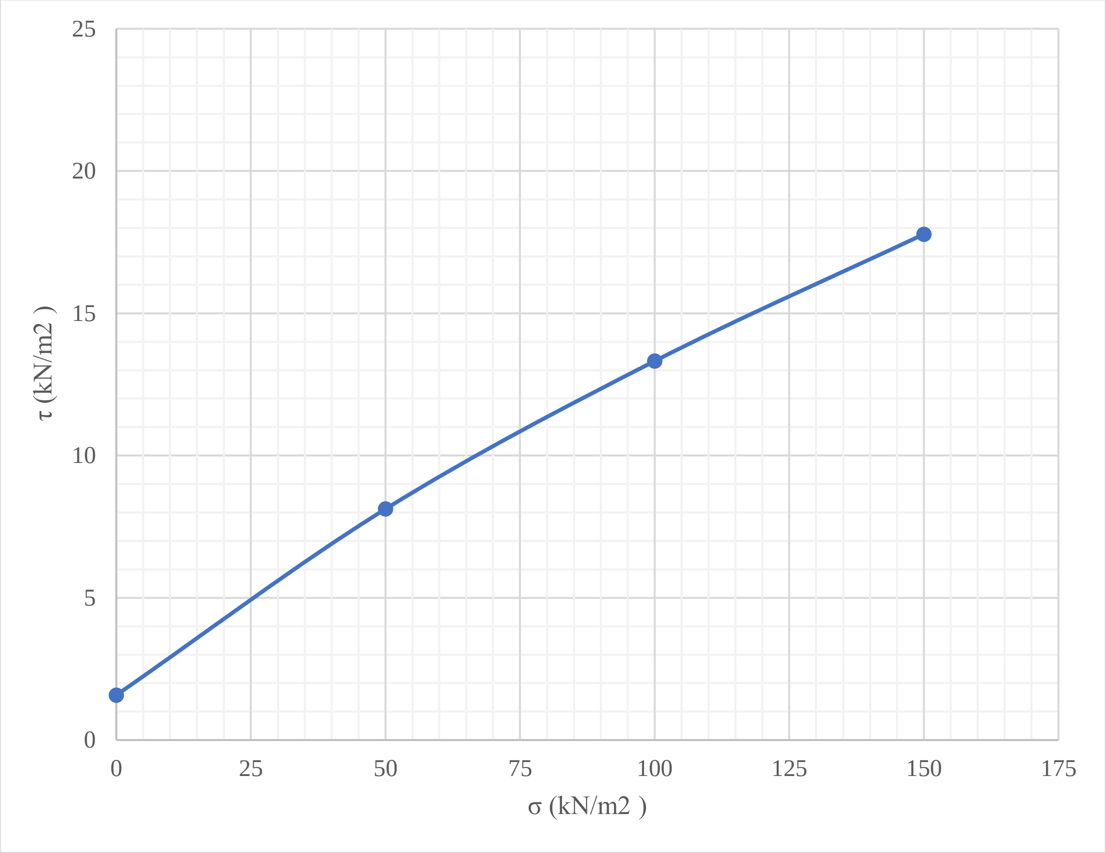

Fig. 4.4 GT1 placed at upper and lower part

After providing 2 layers of geo-textile as shown in fig.3.13 curve b/w normal stress and shear stress is drawn. From that curve fig.4.4 the value of angle of internal friction is calculated as **33.5^0** which quite better than that of previous cases.

4.) GT1 (Placed at 6mm c/c)

Table 4.5 GT1 placed at 6 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	3.09
50	10.83
100	16.94
150	21.38

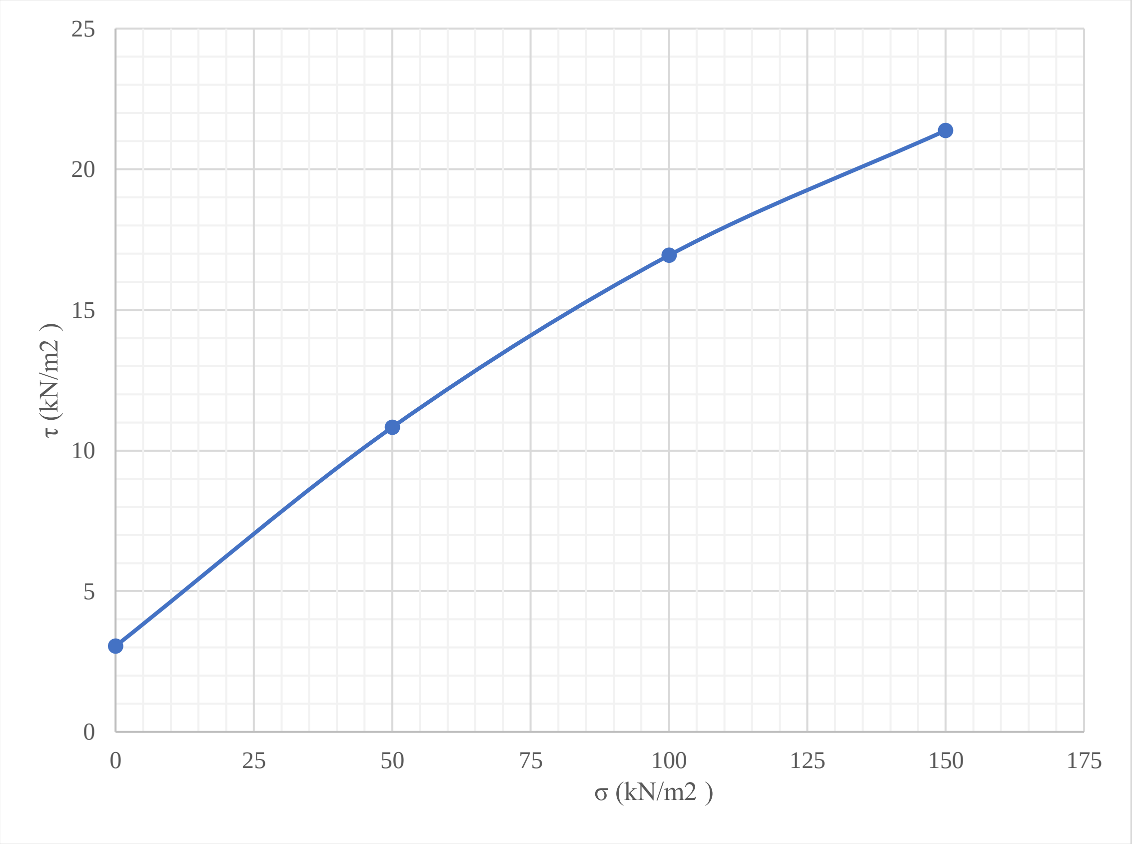

Fig. 4.5 GT1 placed at 6 mm c/c

As we are increasing the no of layers in this case, here provided three layers of geo-textile as shown in fig. 3.14 and the corresponding fig.4.5 is drawn which shows the value of angle of shearing resistance is **37^0** which is considerably maximum in case of horizontal orientation.

5.) GT1 (Placed perpendicular to shearing plane placed at 2cm from right of shear box)

Table 4.6 GT 1 placed at 20 mm from right

σ (kN/m^2)	τ (kN/m^2)
0	6.88
50	14.67
100	21.50
150	25.89

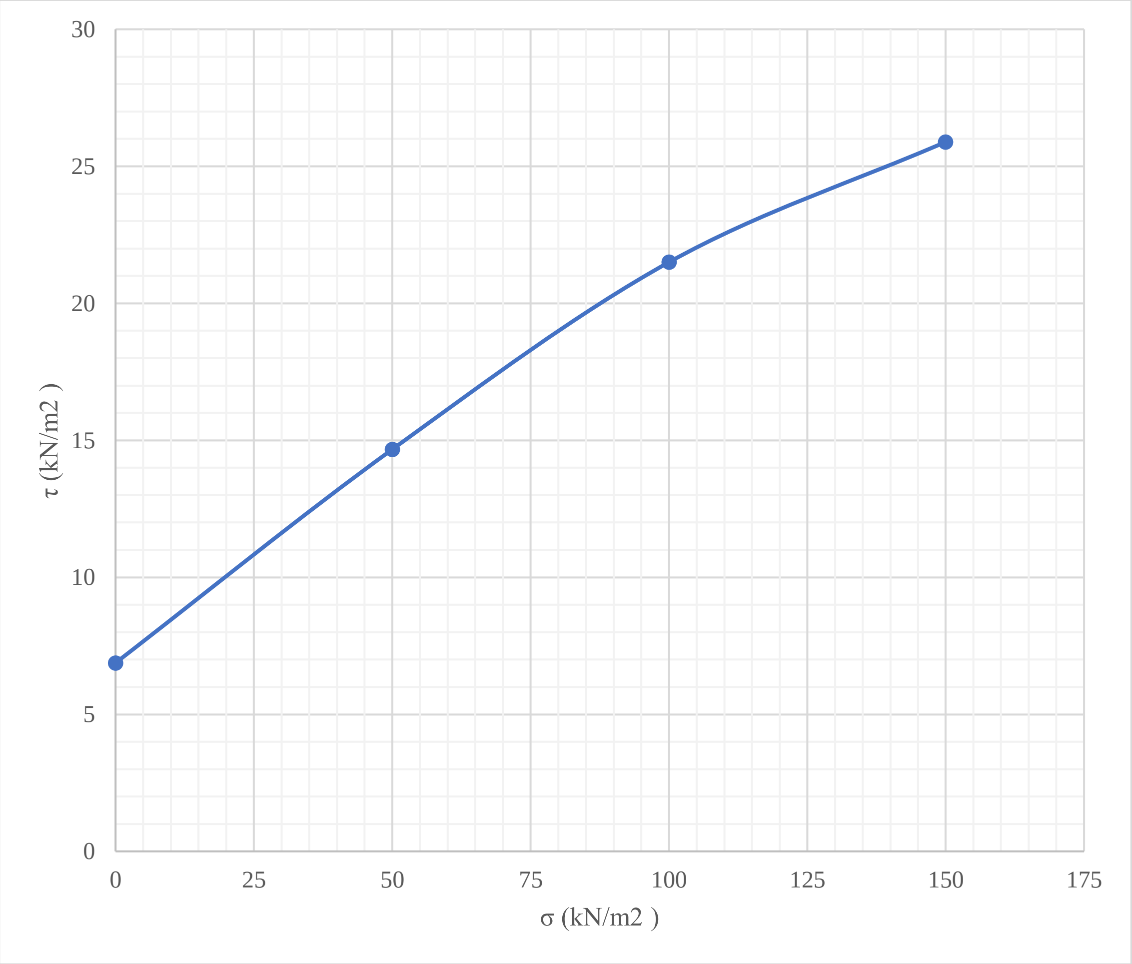

Fig. 4.6 GT1 placed at 20 mm from right

Now the orientation is perpendicular and the geo-textile is placed as shown in fig. 3.15. The curve is drawn as fig 4.6 and angle of shearing resistance is obtained which is equal to **38^0** and this value shows that strength is far better than that of all horizontal cases.

6.) GT1 (Placed perpendicular to shearing plane placed at 4cm from right of shear box)

Table 4.7 GT 1 placed at 40 mm from right

σ (kN/m^2)	τ (kN/m^2)
0	6.12
50	15.07
100	21.28
150	24.95

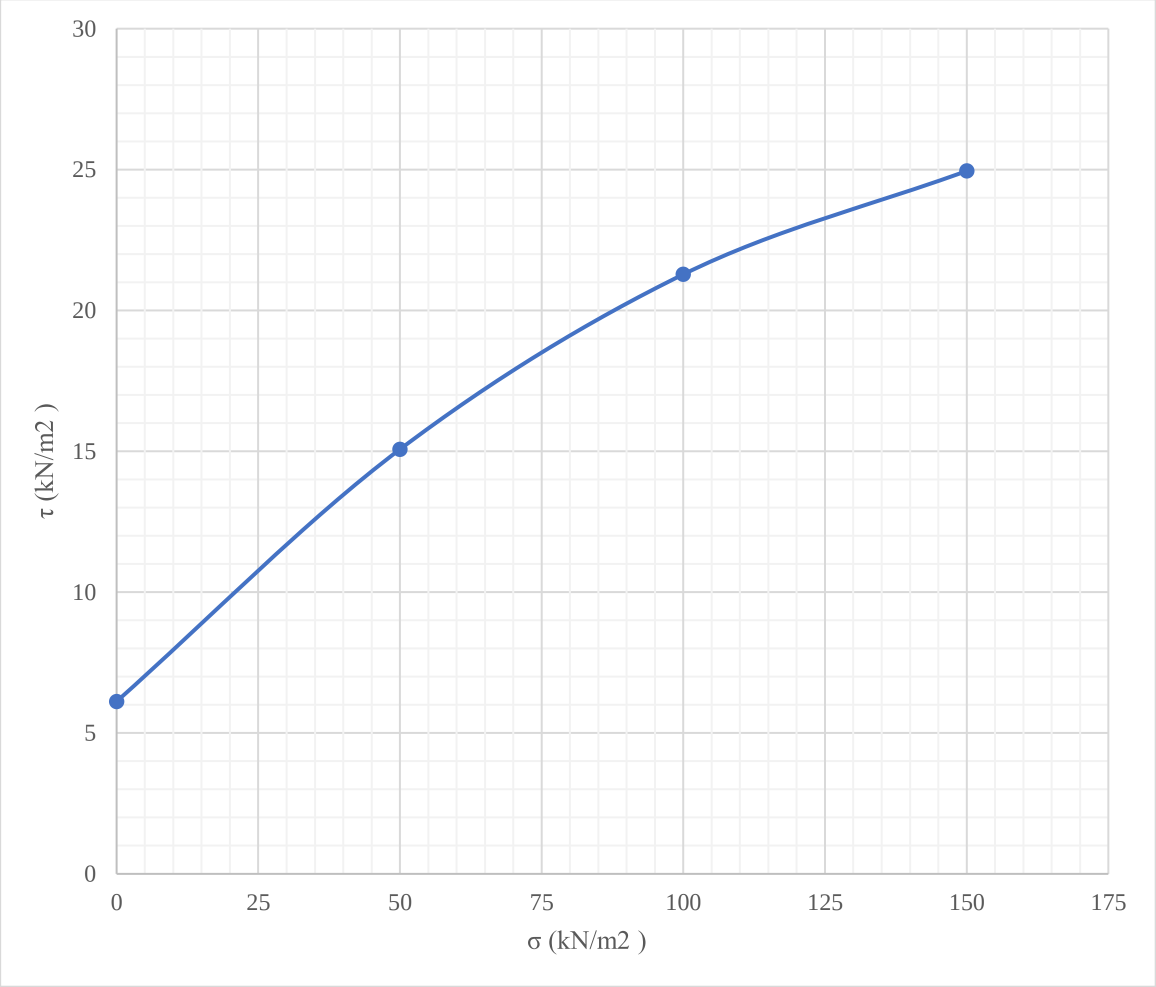

Fig. 4.7 GT1 placed at 40 mm from right

Curve for arrangement in fig.3.16 is presented in fig.4.7 which gives the value of angle of shearing resistance equals to **40.5^0**.

7.) GT1 (Placed perpendicular to shearing plane at spacing of 2cm c/c of shear box)

Table 4.8 GT1 placed at spacing of 20 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	9.07
50	17.35
100	23.44
150	26.78

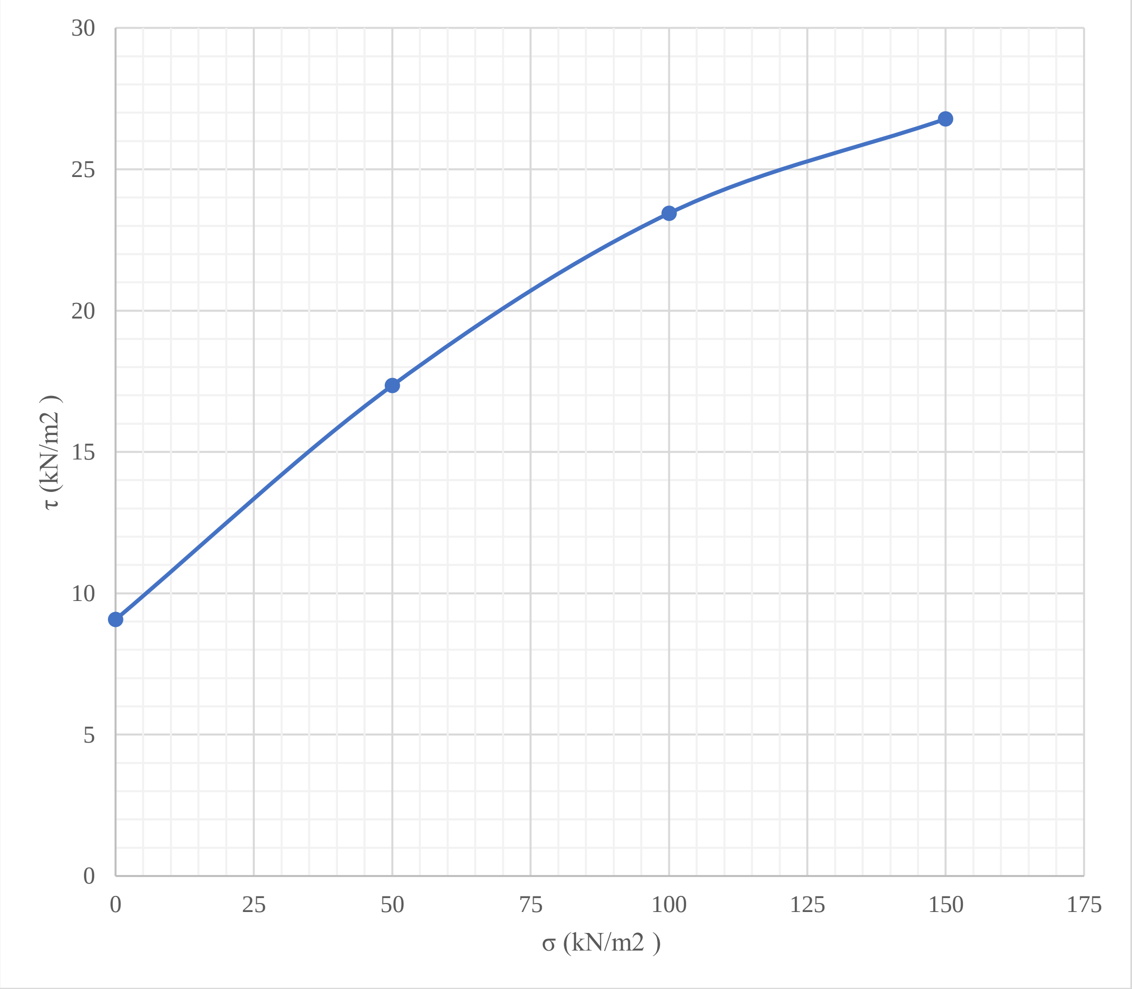

Fig. 4.8 GT1 placed at spacing of 20 mm c/c

After increasing the number of layers of geo-textile as shown in fig.3.17 the value of angle of shearing resistance so obtained from the curve shown in fig.4.8 is **41^0**.

8.) GT1 (Placed perpendicular to shearing plane at spacing of 1.5cm c/c of shear box)

Table 4.9 GT 1 placed at spacing of 15 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	7.63
50	16.87
100	24.19
150	28.66

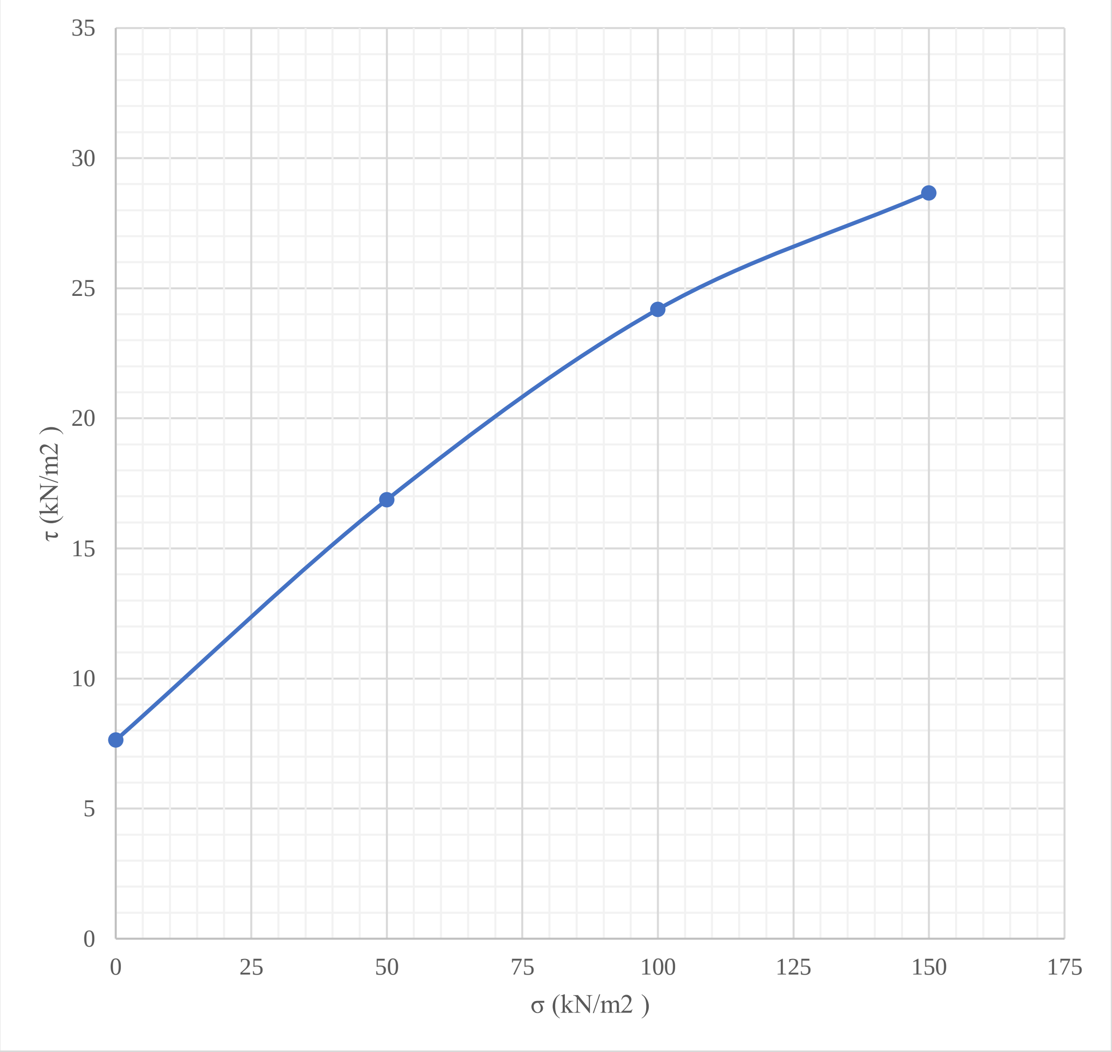

Fig. 4.9 GT1 placed at spacing of 15 mm c/c

After decreasing the spacing of geo-textile strips the value angle of internal friction is found to be **41.5^0** which is quite good than previous results in case of light weight geo-textile.

4.2.2 Heavy Weight Non-Woven Geo-textile as Reinforcement (GT2)

1.) GT2 (Placed parallel to shearing plane at centre of lower part of shear box)

Table 4.10 GT2 placed at centre of lower part

σ (kN/m^2)	τ (kN/m^2)
0	5.47
50	13.51
100	19.67
150	24.19

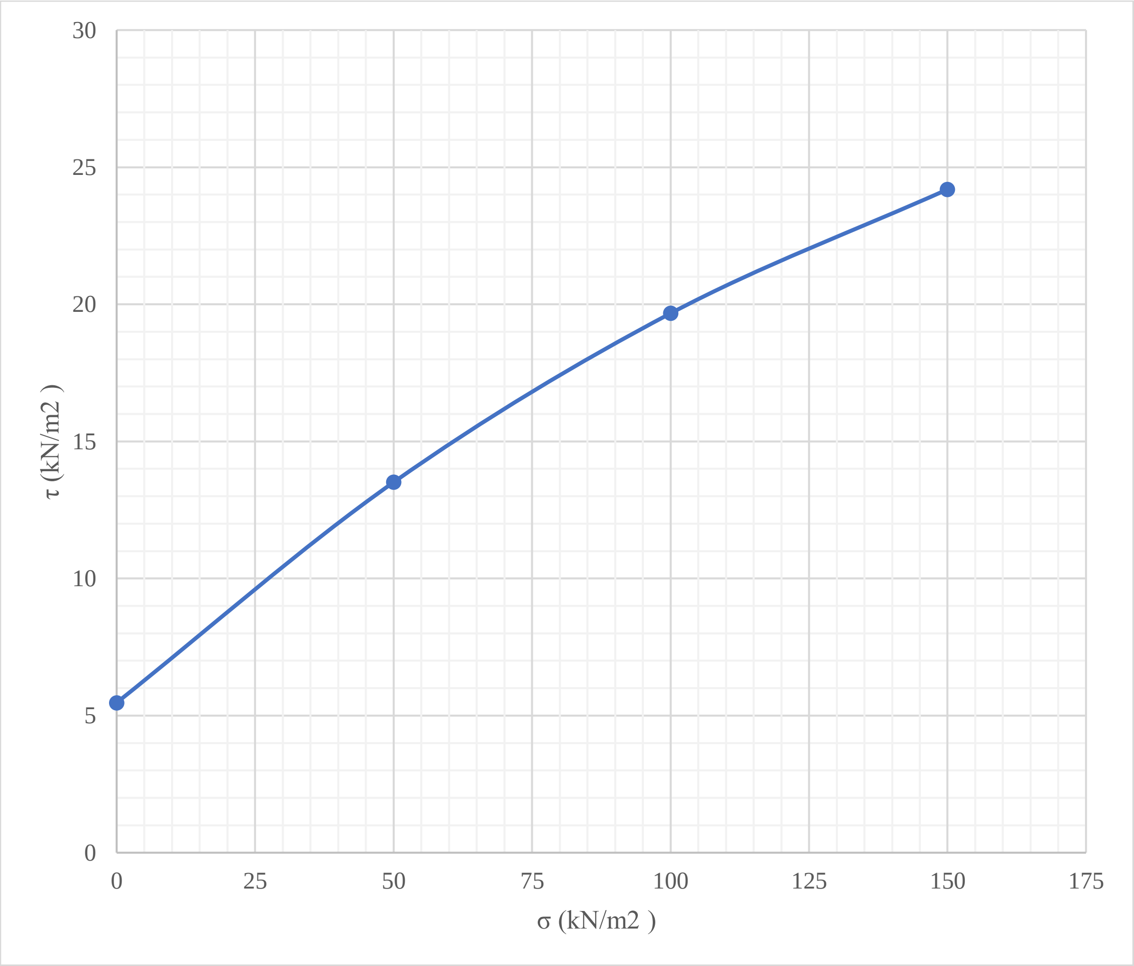

Fig. 4.10 GT2 placed at centre of lower part

For geo-textile-sand arrangement as shown in fig.3.11 curve is drawn b/w stress as shown in fig.4.10. From the curve the value of angle of shearing resistance is found to **37^0**.

2.) GT2 ((Placed parallel to shearing plane at centre of upper part of shear box)

Table 4.11 GT2 placed at centre of upper part

σ (kN/m^2)	τ (kN/m^2)
0	7.72
50	17.09
100	23.87
150	28.93

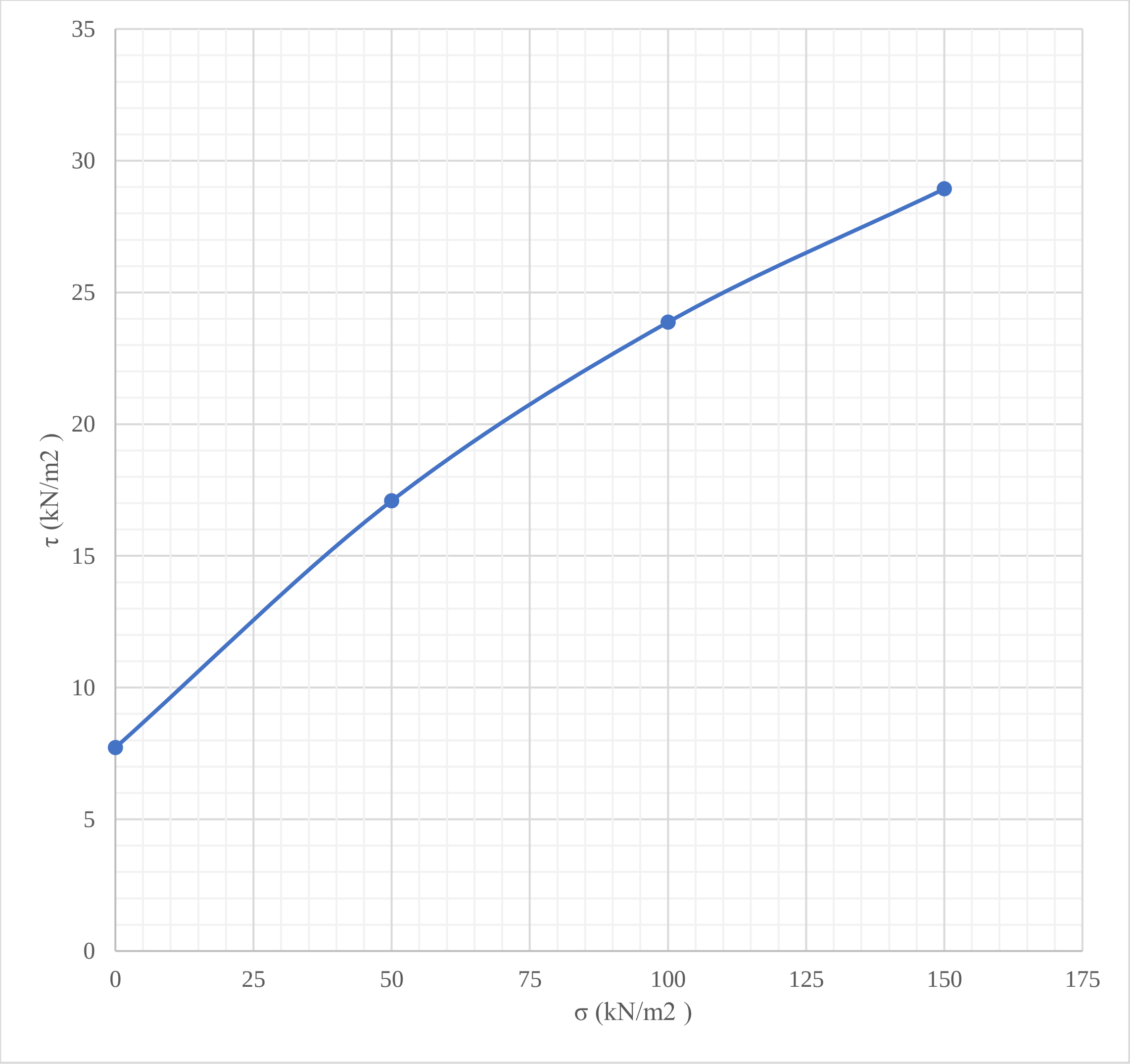

Fig. 4.11 GT2 placed at centre of upper part

For geo-textile-sand arrangement shown in fig.3.12 curve is drawn b/w stress as shown in fig.4.11. From the curve the value of angle of shearing resistance is found to be **40.5^0**.

3.) GT2 (Placed parallel to shearing plane at centre of upper and lower part of shear box)

Table 4.12 GT2 placed at centre of upper and lower part

σ (kN/m^2)	τ (kN/m^2)
0	9.07
50	19.23
100	25.55
150	29.88

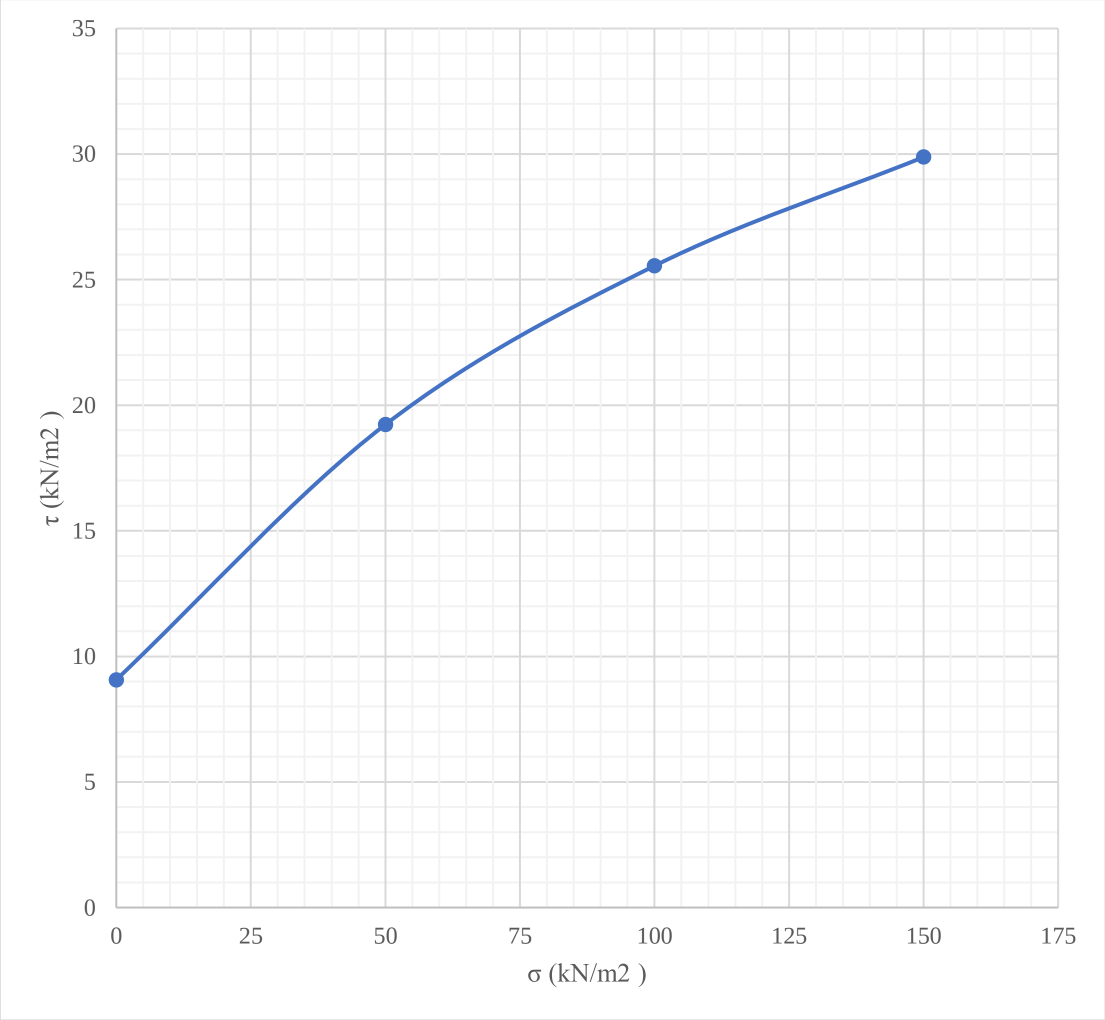

Fig.4.12 GT2 placed at centre of upper and lower part

After providing 2 layers of geo-textile as shown in fig.3.13 curve b/w normal stress and shear stress is drawn. From that curve fig.4.12 the value of angle of internal friction is calculated as **41.5^0**.

4.) GT2 (Placed at 6mm c/c)

Table 4.13 GT2 placed at 6 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	12.47
50	22.62
100	29.18
150	34.07

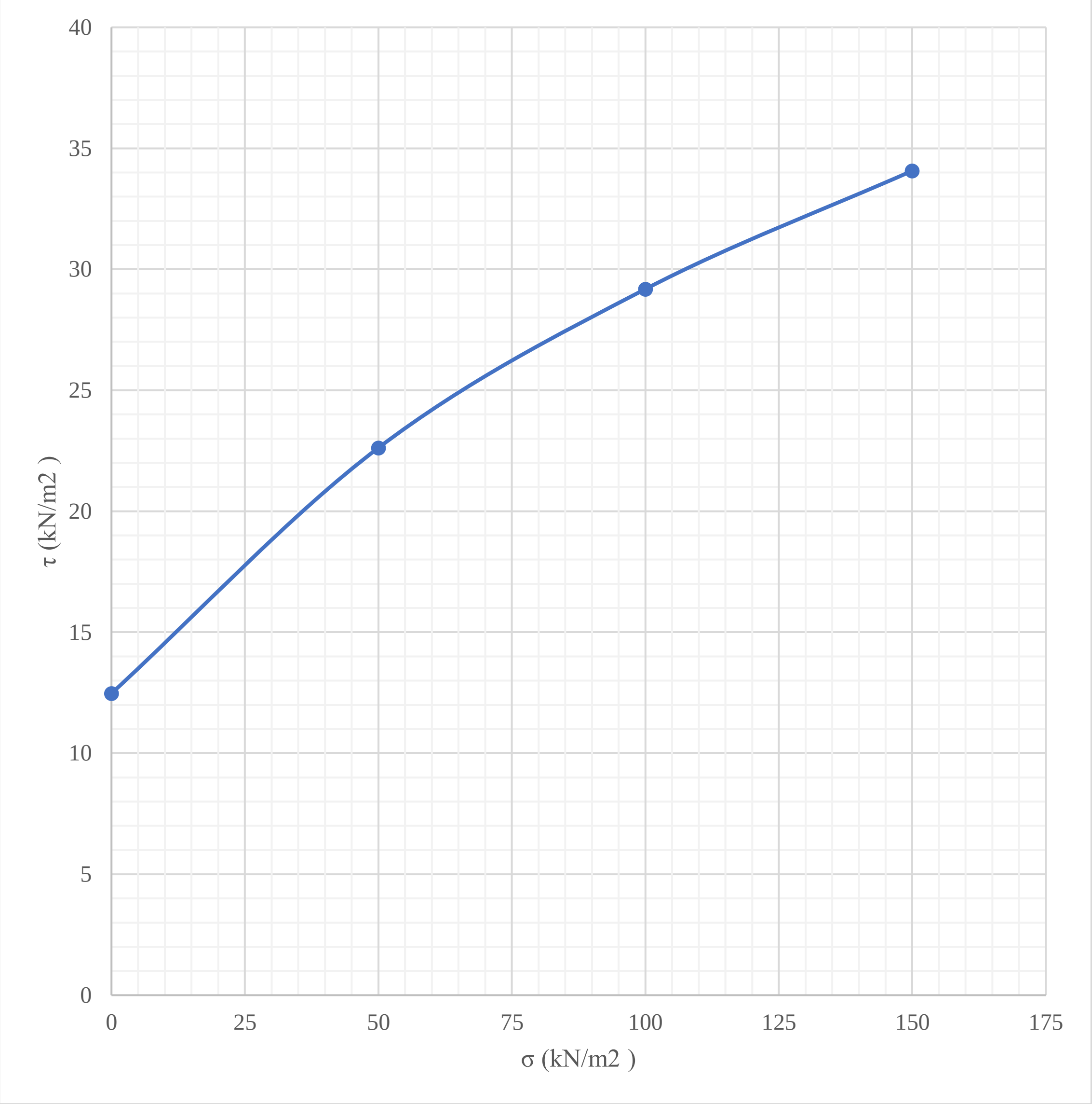

Fig.4.13 GT2 placed at 6 mm c/c

As we are increasing the no of layers in this case, here provided three layers of geo-textile as shown in fig. 3.14 and the corresponding fig.4.13 is drawn which shows the value of angle of shearing resistance is **42^0** which is maximum in all case of horizontal orientation.

5.) GT2 (Placed perpendicular to shearing plane placed at 2cm from right of shear box)

Table 4.14 GT2 placed at 20 mm from right

σ (kN/m^2)	τ (kN/m^2)
0	11.21
50	20.65
100	28.12
150	32.07

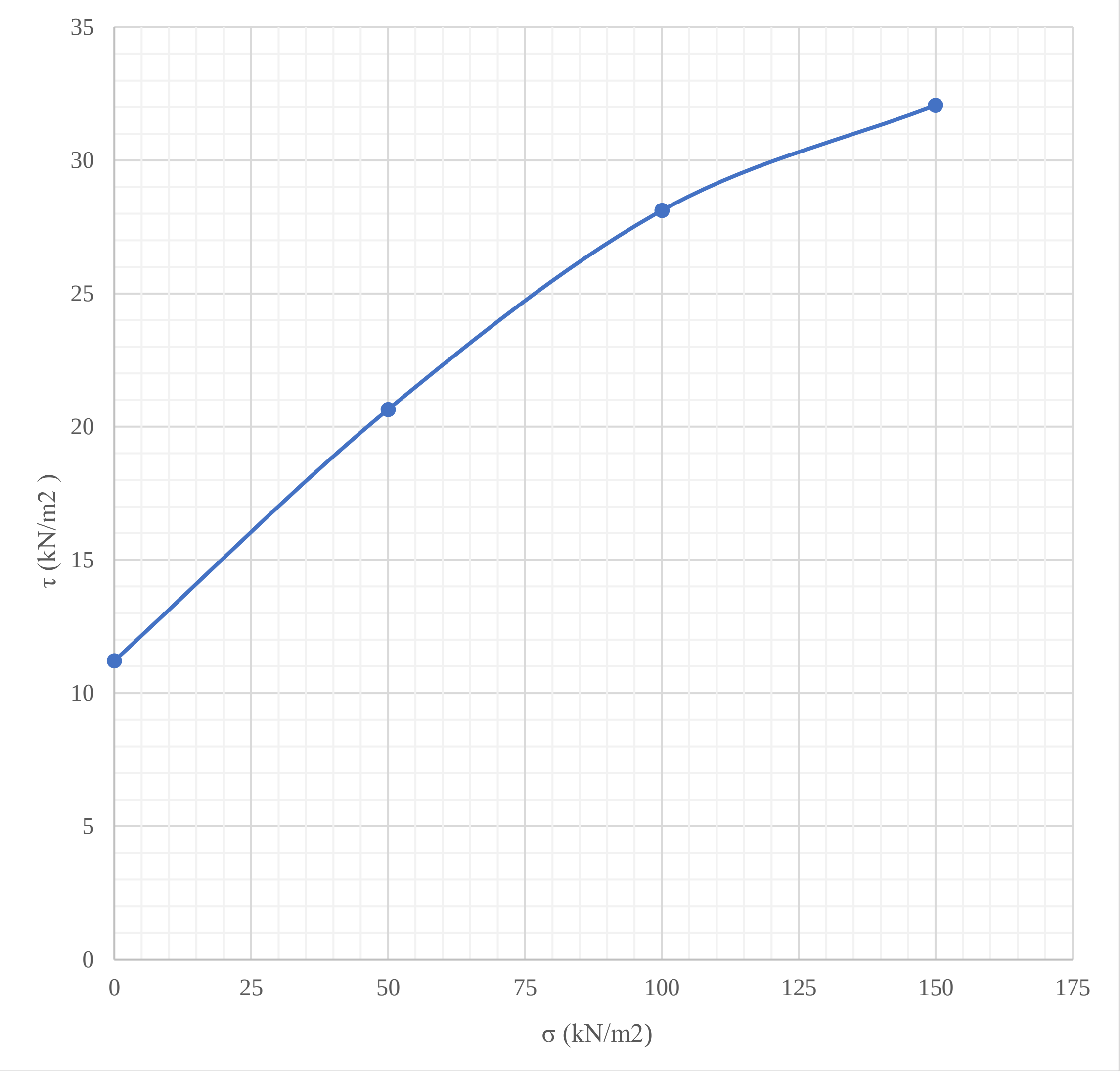

Fig.4.14 GT2 placed at 20 mm from right

Now the orientation is perpendicular and the geo-textile is placed as shown in fig. 3.15. The curve is drawn as fig 4.14 and angle of shearing resistance is obtained which is equal to **42.5^0** and this value shows that strength is far better than that of all horizontal cases.

6.) GT2 (Placed perpendicular to shearing plane placed at 4cm from right of shear box)

Table 4.15 GT2 placed at 40 mm from right

σ (kN/m^2)	τ (kN/m^2)
0	11.15
50	21.66
100	28.04
150	32.28

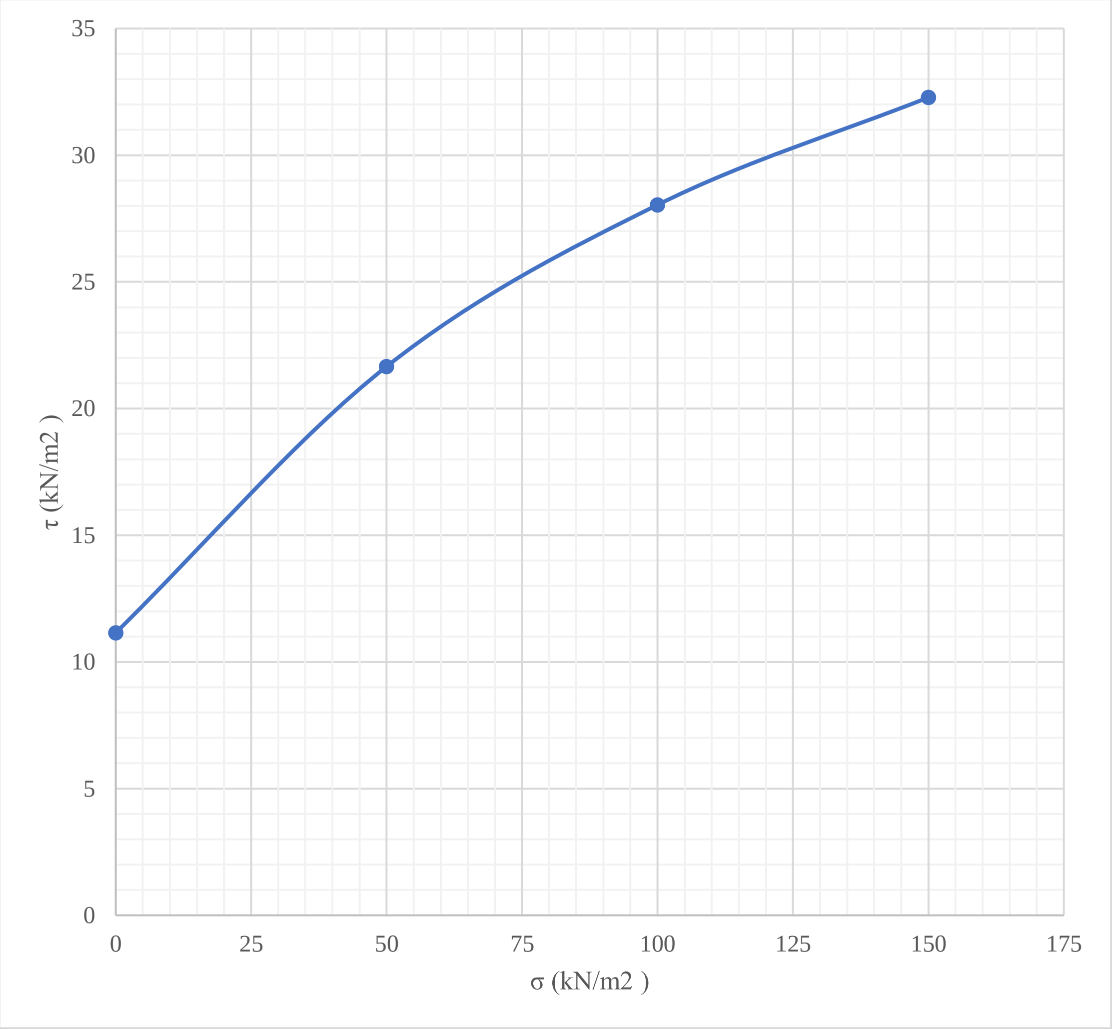

Fig.4.15 GT2 placed at 40 mm from right

Curve for arrangement in fig.3.16 is presented in fig.4.15 which gives the value of angle of shearing resistance equals to **43^0**.

7.) GT2 (Placed perpendicular to shearing plane at spacing of 2cm c/c of shear box)

Table 4.16 GT2 placed at spacing of 20 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	14.55
50	26.19
100	34.37
150	41.12

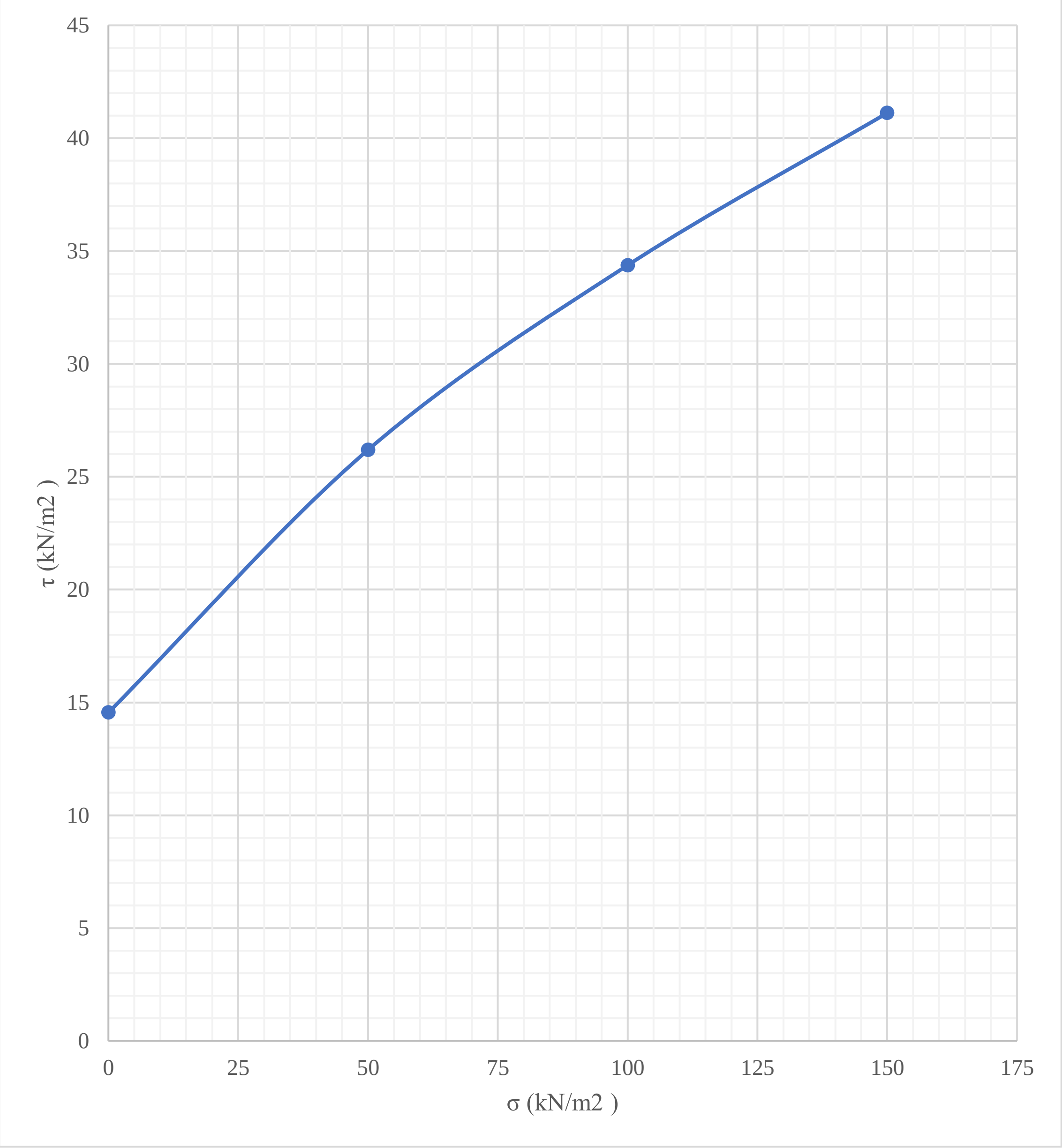

Fig.4.16 GT2 placed at spacing of 20 mm c/c

After increasing the number of layers of geo-textile as shown in fig.3.17 the value of angle of shearing resistance so obtained from the curve shown in fig.4.16 is **44.5^0**.

8.) GT2 (Placed perpendicular to shearing plane at spacing of 1.5cm c/c of shear box)

Table 4.17 GT2 placed at spacing of 15 mm c/c

σ (kN/m^2)	τ (kN/m^2)
0	10.67
50	22.14
100	28.86
150	32.91

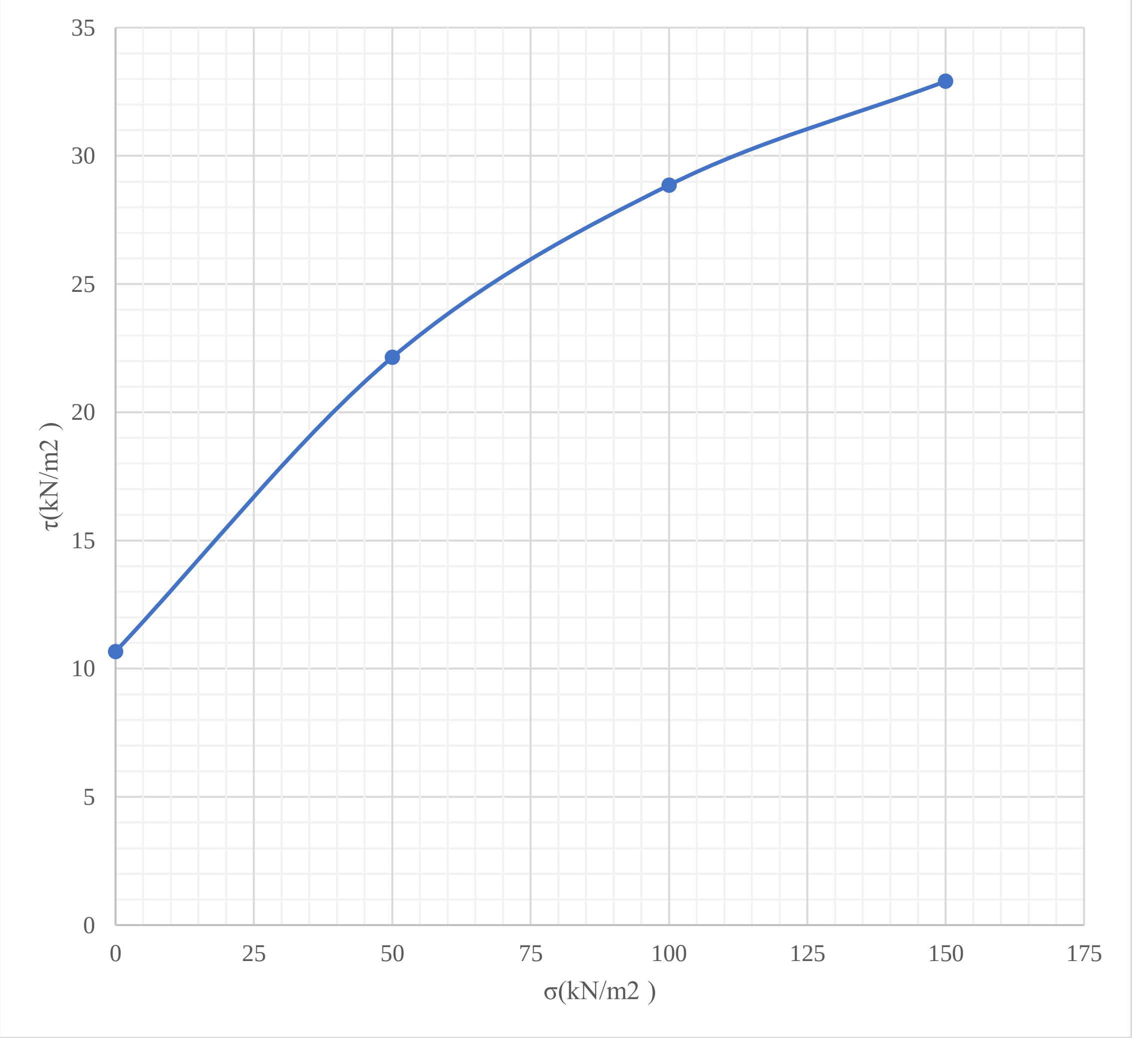

Fig.4.17 GT2 placed at spacing of 15 mm c/c

After decreasing the spacing of geo-textile strips as shown in fig. 3.18. From the curve angle of internal friction is obtained as **46.5^0** which is better than previous results which we got in case of heavy weight geo-textile as well as light weight geo-textile.

Table 4.18 DSA Test Result

S.No.	Cases	Angle of Internal Friction
1	Soil without Reinforcement	31.5^0
2	GT1 placed at Centre of Lower Box	32.5^0
3	GT1 placed at Centre of upper Box	33^0
4	GT1 (Two layered)	33.5^0
5	GT1 (Three layered)	37^0
6	GT1 placed at 20 mm from right	38^0
7	GT1 placed at 40 mm from right	40.5^0
8	GT1 placed at 20 mm c/c	41^0
9	GT1 placed at 15 mm c/c	41.5^0
10	GT2 placed at Centre of Lower Box	37^0
11	GT2 placed at Centre of upper Box	40.5^0
12	GT2 (Two layered)	41.5^0
13	GT2 (Three layered)	42^0
14	GT2 placed at 20 mm from right	42.5^0
15	GT2 placed at 40 mm from right	43^0
16	GT2 placed at 20 mm c/c	44.5^0
17	GT2 placed at 15 mm c/c	46.5^0

During the application of load when particle of sand start moving in forward direction then on the surface of geo-textile and opposite force generates as per the law of motion this opposite force is more than that of force generated b/w the surface of two particle of sand this opposite force is known as friction force which results in increase of angle of internal friction which finally contribute to the shear strength of sand .

From the table 4.18, We can easily see that how the frictional behavior of sand effected by the inclusion of geo-textile. when shearing is applied io the sample soil start moving outside horizontally and vertically which leads to earlier failure of sample that we called as shear failure. In order to reduce this outward movement of sand during the application of load we provide reinforcement in different orientation. In case of horizontal placement of geo-textile, which resist the motion of soil in vertical direction leads to increase in strength of sand where as in case of vertical orientation the horizontal movement of sand reduces which further increase the shear parameters of sand and which finally contribute to the enhancement of strength of sand.

CHAPTER 5

CONCLUSIONS

Following are the conclusions of study of geotextile reinforced soil composite and effect on the shear strength and shear strength parameters determined using DST. The material used are two non-woven geo-textiles made of polyester with different orientation.

- The continued increase in shear resistance was observed due to the presence of geotextile in sand sample.
- Angle of Internal friction found to be 31.5^0 in case of unreinforced soil.
- Providing reinforcement at interfere zone result in increase in gap b/w the shear boxes which leads to reduction in confinement of the sand and geotextile that's why didn't show better results compare to that of reinforcement provide at centre of upper and lower shear boxes.
- Increasing the no of layers of reinforcement frictional resistance of sample increases considerably which finally shows higher shear strength compared to previous cases.
- Internal friction angle in case of GT1 is found to be 37^0 and 42^0 in case of GT2 is found to be 42^0 and 46.5^0 in case of horizontal and perpendicular orientation reinforced with 3 layers.

REFERENCES

1. Altun, S.M. and Farsakh P.K. (2010). "Mechanical behaviour of sand - geo-textile interface." *Scientia Iranica.*,19(4),1044-1051.
2. Athanasopoulos, G.A. (1993). "Effect of particle size on the mechanical behavior of sand-geo-textile composites." *Geo-textiles and Geomembranes.,* 12(3), 255-273.
3. Bathurst, R.J. (1994). "Large-Scale triaxial compression testing of geocell-reinforced granular soils." *Geotechnical Testing Journal,* GTJODJ., Vol. 16, NO. 3
4. Biswas, B.M. (2015). "Shear strength behavior of geo-textile/geomembrane interfaces." *Journal of Rock Mechanics and Geotechnical Engineering.,* 7 ,638-645.
5. Belen, M.X., and Javadi, A.A. (2015). "Triaxial tests of sand reinforced with 3D inclusions." *Geo-textiles and Geomembranes*.,24, 201–209.
6. Das, B.M. (2008). Advance Soil Mechanics, 3rd Ed., Taylor & Francis, Missouri.
7. Gray, D.H. and Ohashi, H. (1983). "Mechanics of fiber reinforcement in sand." *ASCE, Jounral of Geotechnical Engineering.*, 109(3), 335-353.
8. Haeri, S.M. (2000). "Effect of geo-textile reinforcement on the mechanical behavior of sand." *Geo-textiles and Geomembranes*., 18, 385-402.
9. Jewell, R.A. & Wroth, C.P. (1987). "Direct shear tests on reinforced sand." *Geotechnique*., 37(1) ,53-68.
10. Jotisankasaa, A. (2018). "Shear strength of interfaces between unsaturated soils and composite geo-textile with polyester yarn reinforcement." *Geo-textiles and Geomembranes.,* 46 ,338–353.
11. Jose, D. (2018). "Shear strength behavior of different geosynthetic reinforced soil structure from direct shear test." *International Journal of Geosynthetics and Ground Engineering*.
12. Koerner, R.M. (2005). Designing with Geo-synthetics, 5th Ed., Pearson, USA.
13. Krishna, A.M. (2015). "Behavior of geogrid reinforced foundation system supported on clay subgrades of different strengths." *International Journal of Geosynthetics and Ground Engineering.*20(1), 15-23.
14. Kurre, P. and Praveen, G.V. (2018). "Study of triaxial behavior of geo-textile reinforced marginal soil without and with cement modification for subgrade construction of pavements." *Int. Journal of Engineering Research and Application.*

15. Latha, G.M. and Murthy, V. S. (2007). “Effects of reinforcement form on the behavior of geosynthetic reinforced sand.” *Geo-textiles and Geomembranes.,* 25,23–32.
16. Nejad, A.A. (2017). “Influence of particle shape on the shear strength and dilation of sand-woven geo-textile interfaces.” *Geo-textiles and Geomembranes.,* 45,54-66.
17. Pal, S.K. (2015). “Shear strength of fly ash reinforced with non-woven and woven geotextiles.” *International Journal of Engineering Research and Technology (IJERT).*, 2(4), 278-290.
18. Palmeira, E.M. (2009). “Soil–geosynthetic interaction: Modelling and analysis.” *Geo-textiles and Geomembranes.,*27 ,368–390.
19. Philip, A.S. (2016). “Study on strength behaviour of soil using geotextile.” *International Journal of Engineering Research & Science (IJOER).,*7(2),239-269.
20. Shukla, R.P. and Gupta, A. K. (2016) “The effect of geo-textiles on low plastic sandy clay.” *6th Asian Regional Conference on Geo-synthetics – Geo-synthetics for Infrastructure Development.*

STUDY ON DIRECT SHEAR TEST ON SAND WITH THE INCLUSION OF GEO TEXTILE AT DIFFERENT ORIENTATION

ORIGINALITY REPORT

3%	0%	1%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Delhi Technological University Student Paper	1%
2	Nicola Moraci, Giuseppe Cardile, Domenico Gioffrè, Maria Clorinda Mandaglio, Lidia Sarah Calvarano, Laura Carbone. "Soil Geosynthetic Interaction: Design Parameters from Experimental and Theoretical Analysis", Transportation Infrastructure Geotechnology, 2014 Publication	1%
3	"Geosynthetics in Civil and Environmental Engineering", Springer Nature, 2009 Publication	<1%
4	Submitted to University of Oklahoma Student Paper	<1%
5	Submitted to University of East London Student Paper	<1%
6	Submitted to Universiti Teknologi MARA Student Paper	<1%

7	www.gettarget.com Internet Source	<1%
8	Submitted to Higher Education Commission Pakistan Student Paper	<1%

Exclude quotes	On	Exclude matches	< 10 words
Exclude bibliography	On		