PULLOUT TEST ON GEO-GRID REINFORCED SOIL

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CANDIDATE'S DECLARATION

I, Himanshu Kumar, roll number 2K15/GTE/09, student of M.Tech. (Geotechnical engineering) hereby declare that the project dissertation titled **"Pullout Test on Geo-grid Reinforced Soil"** which is submitted to Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree 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.

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CERTIFICATE

I hereby certify that the Project dissertation titled "**Pullout Test on Geogrid Reinforced Soil"** which is submitted by [Himanshu Kumar], 2K15/GTE/09, [Department of Civil Engineering] ,Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology**,** is a record of project work carried by the student 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.

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ABSTRACT

Reinforced soil is used in the construction of embankments and retaining walls since past few years. This report focuses on the structural behavior of the geogrid under pull-out loading conditions. An experimental investigation was carried out considering the effect of length of the geogrid, effect of surcharge, effect of height of soil above geogrid and moisture content. Load displacement response was monitored during pull-out test and results are compared and analyzed. Experiment was carried out considering 15cm and 8cm height of soil over 35cm x 35cm and 35cm x 40cm size of geogrid with and without rigid plate on the top layer of the soil and it was observed that as the length of geogrid increases value of friction coefficient increases and when the height of soil over the geogrid increases value of friction coefficient decreases. It was also find out that if we use dry soil pull out strength of the soil will be less as compare to moist soil. When we use dry soil, some vertical deformation takes place before failure which can be directly observed and the failure takes place sudden, not continuous as in moist soil. With increase in height of soil and length of geogrid pull-out strength of the soil increases and value of coefficient is less than one in all the cases.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Reinforced soil is used for stabilization of retaining wall, slopes, embankment and bearing capacity improvement of weak soil. They provide lateral resistance to the soil due to friction by the reinforced structure such as geogrid and geotextiles within the soil. Benedito, Jorge found that their anchorage capacity is due to both bearing resistance and friction. Pull-out resistance of geogrid has two components one in longitudinal direction called interface shear resistance and one in transverse direction called passive resistance along the transverse ribs. Pull-out test apparatus is used to obtain the resistance offered by the reinforcement against the pull-out load (ASTM D6706(2012)).Leonard carried their experiment on pull out test apparatus, used air pressure bags on the top of soil to compress the soil uniformly at higher rate at the top of soil, to prevent vertical displacement while carrying out the pull-out test and they applied load through jacking mechanism and the load cell used have the capability of 45kN for the pull-out load and by the air pressure bags up to load 70kN/m^2 can be applied. They increased their load with 0.033kN increments continuously. Marucoabramento and Whittle carried out experiments for the planner soil reinforcement subjected to oblique pull-out force. Measurements of tensile stress distributions were obtained for steel and nylon sheet embedded with in the sand. Flexible pressure bags and rigid top plate was used over the box and the pull-out load was applied. Juran and Christopher studied on geo-synthetic reinforced soil wall. Sugimoto and Alagiyawanna studied geogrid pull-out experiment in laboratory pullout test apparatus has the finite element modeling on laboratory pullout tests. The pullout tests on the finite element model (FEM), analyses were carried out on two types of geogrids having different value of stiffness in sand under different overburden pressures. Bergado et al conducted laboratory and field pull-out tests, using steel reinforcements in the form of grid with frictional backfill soils. The laboratory pull-out tests are performed using a large-scale pull-out apparatus designed especially for this study. We have applied here rigid solid plate on the top of the soil to uniformly compress the soil as overburden pressure and to prevent the vertical deformation if occurs. We applied the comparatively low surcharge (plate on top for particular height of soil above geogrid) of magnitude 1.07kN/m2 and we increase the load with 20N increment continuously until the failure takes place and, analyzed the load-deflection curves after considering the effect of surcharge, effect of height and length of the geogrid. At failure, considered the variation in magnitude of apparent friction coefficient during the pull load test after considering all the effects as mentioned above. Size of the box used for pull out carried out for investigation 70cm x 40cm x 50cm. As par ASTM D6706 pull out test box have the minimum dimension 610mm x 400mm x 300mm. This paper also provides information about pull out strength on both dry and moist soil, in which major part of silt and fine sand. Naturally at the field lateral load acts due to surcharge or due to the seismic activity and These reinforced materials provide resistance to the lateral load and increases the bearing resistance of the soil.

Objective

Experimental study was carried out on pull-out test on geo-grid reinforced soil

Main objective of the experiment are as follows:

i. To observe the effect of length of geo-grid on pull-out strength.
ii. To observe the effect of surcharge (a rigid plate on top of soil) on pull- out strength.
iii. To observe the effect of moisture content on pull-out strength.
iv. To observe the effect of overburden of soil over the geogrid.
v. Evaluation of coefficient of friction in various cases as mentioned above.

To full-fill the objective, the experiment was carried-out which is represented in this report.

CHAPTER 2

LITERATURE OVERVIEW:

In this chapter we have given brief history about the pullout test on reinforced soil by the researchers using the geotextiles and geo-grid.

2.1 RESEARCHERS AND BRIEF HISTROY OF THEIR WORK

Porbha and Goodings (1997) carried out experiment on 24 reduced scale models on soil reinforced with woven geotextile. The soil wall considered at the slope of 1H:6V within the model and loaded to failure under increasing self-weight in the geo-technical under Centrifuge load. Models were constructed on firm or rigid foundations and different lengths of reinforcement were tested. No pullout failure was observed in any models. 2 LVDTs were used to find the deflection on the face of the wall. Silicon

was used on the top of the surface to observe the failure surface over the top. Dimension of the model was (300mm x 400mm x 300mm). It was found that failure takes place due to the excessive displacement at the face of the wall.

Jurn and Christohoper (1998) studied on geo-synthetic reinforced soil retaining wall. Laboratory model shows that there are fundamentally three types of failure mechanisms of the reinforced soil structures

1. Breakage of the reinforcements,
2. Sliding of the reinforcements.
3. Excessive facing displacements.

The results of the laboratory model study on performance, behavior and failure mechanism of reinforced soil retaining wall by using non-woven geotextile, woven geo-textile and plastic grids.

The models were built in a box 110cm x 150 cm x 90cm. A lawyer of soil on foundation was provided to lateral confinement of the first lawyer of facing elements and then the model walls were build, simulating the model structure is like actual structure. The facing of the wall made up of plastic elements (variable height Sv).

Jayawickrama et al., (2014) performed experiments to find out the resistance on steel mechanically stabilize earth.

They used 287 pull-out tests on steel reinforcement used for stabilization of earth walls. Results focuses on the evaluation of pull-out resistance factors for steel strips and welded steel grid reinforcement embedded within gravelly backfill. Mechanically stabilized earth test box has the dimensions of 360cm x 360cmx 120cm and an applied overburden capacity equal to 12 m of soil fill.

The researchers evaluated pullout resistance factors for both strip and welded grid reinforcements for a variety of independent variables including overburden pressure, reinforcement length, grid size and grid geometry including both transverse and longitudinal bar spacing. The results shows that pullout resistance factors for both strips and welded grids in compacted gravelly backfill are higher than those obtained for reinforcements embedded in sandy backfill. he results obtained for welded grids indicate that transverse and longitudinal bar spacing have significantly influence on the pull-out resistance capacity.

Family, et al. (1994) found the behavior of geo-grid under pull-out test experimentally.

Structural behavior of geo-grids under a pull-out loading condition, three types of geo-grid are used, of different length, load displacement

response at different locations along the length of geo-grid is monitored during pull- out.

Hydraulic jack of 110 kN capacity was used during the pull-out test and the air bags used to provide the uniform pressure capacity up to 70 kN/m^2. Size of the model as shown in fig given below, failure modes involve the geo-grid tension failure, junction failure and sheet pull-out failure.

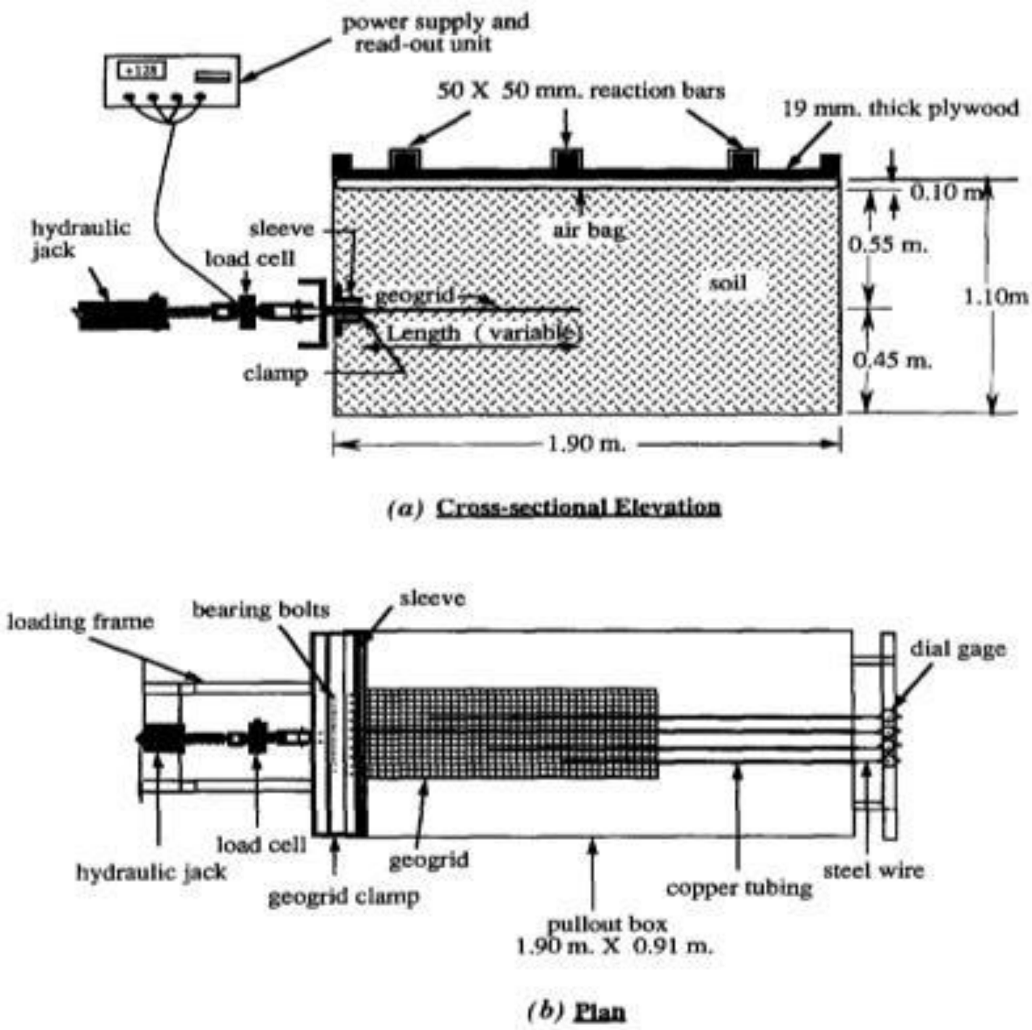

Fig 2.1 Pull-out test apparatus

Source: Experimental behavior of polymeric geogrid from ASCE library

Model used by the researchers

Marucoabramento and Whittle (1995) carried out experiments for the soil reinforcement subjected to oblique pull-out force. Measurements of tensile stress distributions were obtained for thin steel and nylon sheet embedded in sand. The steel reinforcement is inextensible, with linear stress distribution and load-elongation behavior. Flexible pressure bags and rigid top plate used over the box and the pull-out load is applied and it was found that embedded length influences the bond resistance at large displacements at the soil reinforcement close to the wall.

Shanthasnupatra and Shahu (2012), analyzed Pull-out capacity of sheet reinforcement subjected to pullout force.

Pasternak model makes the oblique pullout analysis more real. The orientation of the reinforcement at the pullout end is found to be different from the direction of the pullout force and depends on the shear modulus of the sub grade soil.

A study was carried out to evaluate the effect of many factors, such as the modulus of the sub grade reaction, angle of interface shear resistance, shear modulus of the sub grade and the obliquity of the pull-out on the magnitude and direction of the reinforcement force.

Chenarapu and Umashankar (2017) carried out pullout test to find the resistance of reinforcement. Existing design procedures consider the pullout resistance of reinforcement against the axial pull-out load. However, the kinematics of failure clearly establish that the reinforcement is pulled obliquely along the slip surface. The response of reinforcement to oblique pull-out is equal to a application of axial and transverse components of oblique pull. In this research paper, details were provided for experimental test setup used to examine the response of smooth metal strip reinforcement subjected to transverse pullout load at one end. A large-size test chamber of dimensions length, width and height with an arrangement to conduct transverse pullout of reinforcement is developed. The pullout response of smooth metal strip reinforcements to transverse pull was obtained for three different normal stresses of 17, 52, and 87kN/m^2.

Sugimoto and Alagiyawanna (2003) studied geogrid pullout behavior in laboratory pullout tests and finite element modeling of the

laboratory pullout tests. The pullout tests and the finite element method analyses were carried out on two geogrid types with different stiffness in compacted sand under different overburden pressures. The pullout test results show that the geogrid behavior can be categorized into three types, based on the bond stress distributions. The models results shows reasonable agreement not only with the pullout force against the geogrid displacement but also with the distributions of geogrid displacements, strains, tensile forces, and bond stresses along the geogrid length during deformation.

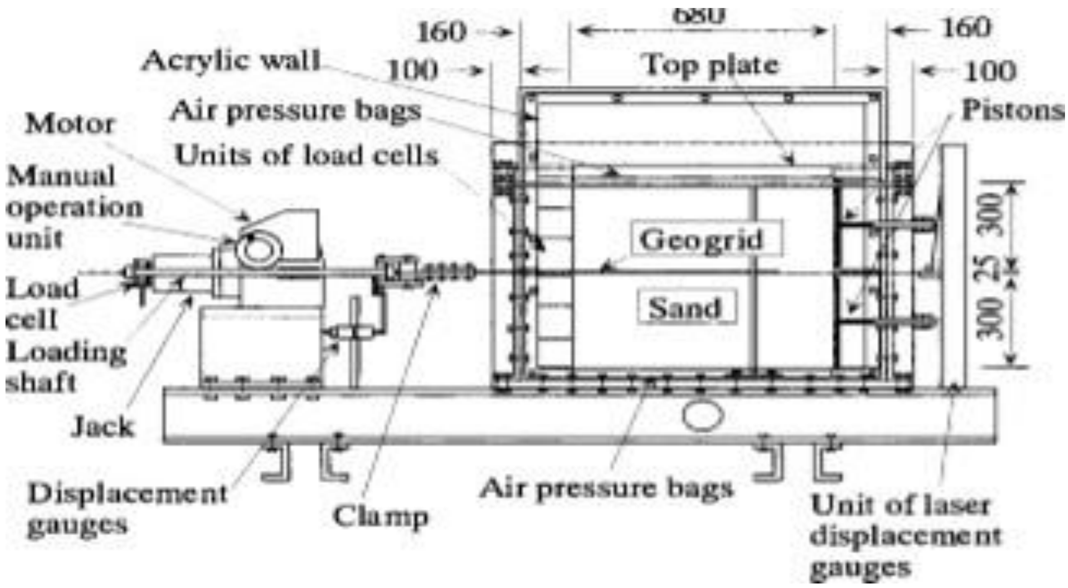

Fig 2.2 Pull-out test apparatus

Source: Pullout behavior of geogrid by test and numerical analysis from ASCE Library Model used by the researchers.

Bergado et al. (1992) conducted laboratory and field pullout tests using steel grid reinforcements with cohesive-frictional backfill soils. The laboratory pullout tests are performed using a large-scale pullout apparatus designed for this study. The field pullout tests was performed on the reinforcements embedded in a full-scale reinforced test wall or embankment system that utilize three different locally available, low quality, cohesive-frictional backfill soils namely 1. clayey sand 2. lateritic soil 3. weathered clay in the three sections along its length. It is observed that the magnitudes of the mobilized field pullout resistances as well as the strains induced in the reinforcing elements are strongly influenced by the response of the wall/embankment system to the subsoil movements.

Teixeira et al. (2007) evaluated the soil-geogrid interaction, conducted to quantify the overall pullout resistance of geogrids. An experimental testing program was conducted in this investigation using both large scale and newly developed individual-rib pullout devices. The large-scale pullout tests were conducted using coated geogrid specimens with and without transverse ribs. On the other hand, the individual-rib pull-out tests were conducted using individual longitudinal and transverse ribs. A stress transfer model was implemented to predict the results of large-scale pullout tests using the parameters obtained from the individual-rib pullout tests. For the geogrids used in this investigation, the development for passive mechanisms at the front of geogrid transverse ribs was found to influence significantly the interface shear mechanisms that develop along longitudinal rib.

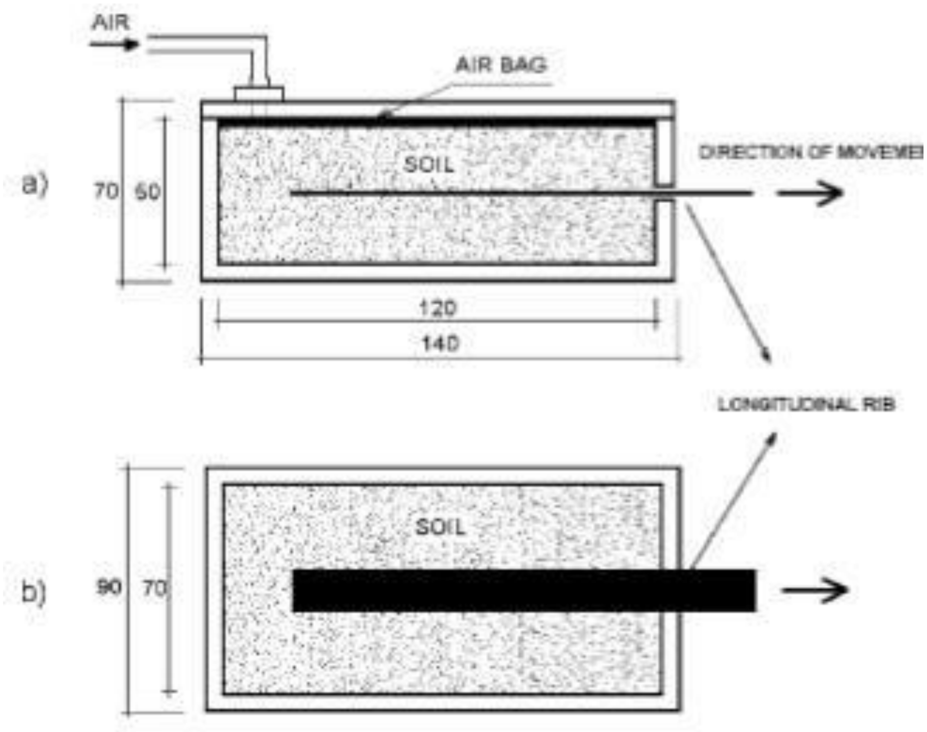

Fig 2.3 Longitudinal rib pull-out test device

(a.) elevation view

(b.) plan view

Source: Pullout resistance of individual longitudinal and transverse ribs from ASCE library Model used by the researchers.

CHAPTER 3

EXPERIMENTAL BEHAVIOR OF GEOGRID IN PULL-OUT TEST

Manufacturing of the physical model

The laboratory experimental apparatus used for pull-out has the dimension of (700mm x 400mm x 500mm) with iron side wall which exceeds the minimum dimension provided by the ASTM D6706. As par ASTM D6706 pull out test box have the minimum dimension (610mm x 400mm x 300mm) and over the box rigid plates was applied, which is representative of actual field condition. 4cm sleeve is front of the wall through which the pull-out load is applied. At the height of 25 cm from the bottom of the box, equally spaced three pulleys is provided on the iron rod and wire is connected to the geo-grid within the soil and stand over which load is increased. The pulleys are provided at equal spacing so that the geo grid come out the box uniformly. Over the stand the load is increased with 20N or 40N increment continuously until the failure takes place. Surcharge plate has a magnitude of 1.07 kN/m^2.

Soil Properties

Sieve Analysis

Sieve analysis is done to find the relative proportion of different grain sizes which forming a soil mass.

Procedure

1. Select the sieve as par IS specification and perform the sieve analysis test.
2. Different size sieves are arranged from top to bottom in decreasing order 425µ, 355µ, 300µ, 212µ, 180µ, 125µ, 75µ, 63µ, 45µ, pan.

Take 500 gm of the soil sample and it is placed in upper sieve and it for at least 10 min manually or by the mechanical shaker.

3. Weight of the soil is recorded over the different sizes of sieve.

4. And the percentage of the weight retained over the sieves is recorded in terms of total weight of the soil.

Fig 3.1 a Sample used in laboratory for sieve analysis

Fig 3.1 b Sieves arranged for classification of the soil particles

Table 1
Classification of soil size particles

IS Sieve In µ	**weight retained on each sieve**	%on each sieve	Cumulative %	% finer
425 **µ**	80	20	20	80
355 **µ**	60	12	32	68
300 **µ**	92	18.4	50.4	49.6
212 **µ**	62	12.4	62.8	37.2
180 **µ**	96	19.2	82	18
125 **µ**	44	8.8	90.8	9.2
75 **µ**	25	5	95.8	4.2
63 **µ**	8	1.6	97.5	2.5
45 **µ**	6	1.2	98.7	1.3
Pan	3.6	0.72	99.42	

From IS CODE 1498(1970) particles size ranges are as follow:

Clay particles have the range < 2 µ

Silt particles range 2µ to 75 µ

Sand particles range

Fine sand particles 75µ to .425mm

Medium sand particles .425 to 2 mm

Coarse sand particles 2 to 4.75 mm

It is cleared from the sieve analysis that it is the mixture of fine sand and silt and the remaining particles very small particle are clay particle.

Maximum dry density and OMC

Proctor test

The proctor test is a laboratory experiment to determine the maximum dry density and corresponds OMC of the soil. A mould having a volume 942cc with diameter 10.6cm and height of 11.6cm is used, which have detachable collar and base plate. A hammer of 5cm diameter and 2.5kg weight is used for compacting the soil.

Procedure

1. Take a oven-dried sample, approximately 3 kg in the pan. Thoroughly mix the sample with sufficient water with water content of 5-6 % approximately in grams.

2. Weight 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.

3. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh.

4. Divide the weight of the compacted soil specimen by 942 cc and record the result as the bulk density of the soil

   Bulk unit weight = weight of the soil inside the mould / volume of the mould

$$\Upsilon_d = \Upsilon / (1+w)$$

Υ_{d}= dry unit weight of the soil

G= Specific gravity of the soil

From the above formula we find the dry density of the soil.

5. Remove the sample from mould and take sample for determining the water content of the soil.

   From this we find the moisture content of the soil sample w= (weight of the moist soil - weight of the dry soil sample) / weight of the dry soil

6. 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.

7. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

Fig 3.2 (a) Soil sample preparation for proctor test

Fig 3.2 (b) Soil sample compaction with the hammer 25 blows for each lawyer of the soil

Test 1

Weight of the soil in pan 3000gm

Then water is added in the sample

Weight of the mould = 1960 gm

Weight of the soil +mould =4010 gm

Weight of the soil = 2050

Volume of the mould 942 cc

Bulk density = 2000 ÷ 942 = 2.12

Water content of the sample 11.4 %

Dry density = ϒ / (1 + w)

= 2.12 / 1.114

=1.92 g/cc

Test 2

Weight of the soil in pan 3000gm

Then increased water is added

weight of the mould =1960

weight of the soil +mould = 4028

weight of the soil 2068 gm

volume of the mould 942

Bulk density = 2068 ÷ 942= 2.195

water content of the soil sample14.3%

Dry density of the soil = ϒ /(1+w)

= 2.195 / 1.143

=1.97 g/cc

Test 3

Weight of the soil in pan 3000 gm

then increased water is added

Weight of the mould = 1960 gm

Weight of the soil + mould =3996 gm

Weight of the soil = 2036

Volume of the mould 942 cc

Bulk density = 2036 ÷ 942 = 2.16

Water content of the sample 16.2%

Dry density = ϒ / (1 +w)

= 2.16 / (1 + .612)

=1.85 g/cc

w %	$ϒ_d$
11.4	1.92
14.3	1.97
16.2	1.85

It is clear from the experimental results that the maximum dry density is approx. 1.97g/cc and water content is 14.3%

Specific gravity

Specific gravity is needed to determine the void ratio and degree of saturation of the soil.

It is the ratio of unit weight of equal volume of soil solid to that of distilled water.

Procedure

1. Take the density bottle and clean it with distilled water or alcohol.
2. Weight the empty bottle $w_{1.}$
3. Put the 10 to 20gm soil sample in the bottle and the weight of empty bottle and dry soil w_2 is determined.
4. Then add 10ml water to soak the soil completely for 2 hours.
5. Then fill remaining part of the density bottle completely with water at temp T^0 C and note down the weight $w_{3.}$
6. Then remove the soil sample and water from the density bottle empty it after that we fill it completely with distilled water and note down the weight $w_{4.}$

Weight of the empty bottle= $w_1 =$ 0.698 kg

Weight of the dry soil + bottle = $w_2 =$ 1.106 kg

Weight of the soil + water + and density bottle completely fill $w_3 =$ 1.659 kg

weight of bottle +water completely fill the density bottle $w_4 =$1.407 kg

weight of the water having volume equal to the soil solid= $(w_2 - w_1) - (w_3 - w_4)$

$$= 0.408 - 0 .252 = 0.156$$

$$G = (w_2 - w_1) \div ((w_2 - w_1) - (w_3 - w_4)) = 2.62$$

Experimental Procedure

In this procedure soil was filled inside the box up to the sleeve in to the different compacted layers, then a layer of geogrid is spread over the soil at the point of sleeve. Wires connects geo-grid and the stand ,it passes through three equally spaced pulleys and over the stand weight was increased with 20N or 40N increment continuously and the deflection is noted down with the help of dial gauge at the front of the wall up to the failure, means it come out of the box. Soil is filled in the form of compacted layers above the geogrid at different-2 depth and effect of length of geogrid, effect of surcharge (rigid plate) over load deformation curves is noted down. Pull-out test can also be performed to obtain the value of apparent friction coefficient at maximum pull-out load after considering all the effects as mentioned above.

Fig 3.3: Apparatus used to find out the pull -out strength

Then coefficient of apparent friction is given by:

P= f /N

f =P/ 2σ LW= dynamic load /static load

N= Total normal force over the geogrid

T = maximum pull-out load

σ = normal intensity at reinforcing strip level= ϒZ +q

ϒ =unit weight of the soil

Z = depth of the reinforcing strip level

L =length of reinforcing strip

W = width of reinforcing strip

q =intensity of uniformly distributed surcharge on the soil surface

We have multiplied it by 2 because we have two surfaces over which the overburden pressure acts.

REINFORCEMENT AND ITS PHYSICAL AND MECHANICAL PROPERTIES

Geogrid used for determining the pull-out strength is manufactured at Saint-Gobain. Geogrid is a high strength open fiberglass grid coated with elastomeric polymer and adhesive glue. Every component of the matrix is stable for ultraviolet degradation and it is inert to chemicals. Properties of the geogrid is shown below in the table which has been taken from company.

Table 2

Physical and Mechanical Properties of geogrid

Property	**value**	**Test method**
Tensile strength (MD x XD) Ultimate	115 x 115 +/-15 kN/m	ASTM D6637 EN-ISO 10319:2008
Tensile elongation (Ultimate)	2.5 +/-.5%	ASTM D6637 EN-ISO 10319:2008
Secant Stiffness EA@ %1 strain (MD x XD	4600x 4600 +/-600 N/mm	ASTM D667 EN-ISO 10319:2008
Young’s modulus E	73000 MPa	
Mass per unit area	450 g/cm^2	ASTM D5261

		ISO 9864
Melting point	>232^0 C	STM D276 EN-ISO 3146
Damage during Installation	<5%	INTERNAL TEST METHOD
Roll width	1.5 m	
Roll length	100 m	
Roll area	150 m^2	
Adhesive backing	pressure sensitive	
Material	Fiber glass reinforcement with modified polymer coating and Pressure sensitive adhesive backing	
Grid size	12.5 mm x 12.5 mm	0.5 x 0.5 in

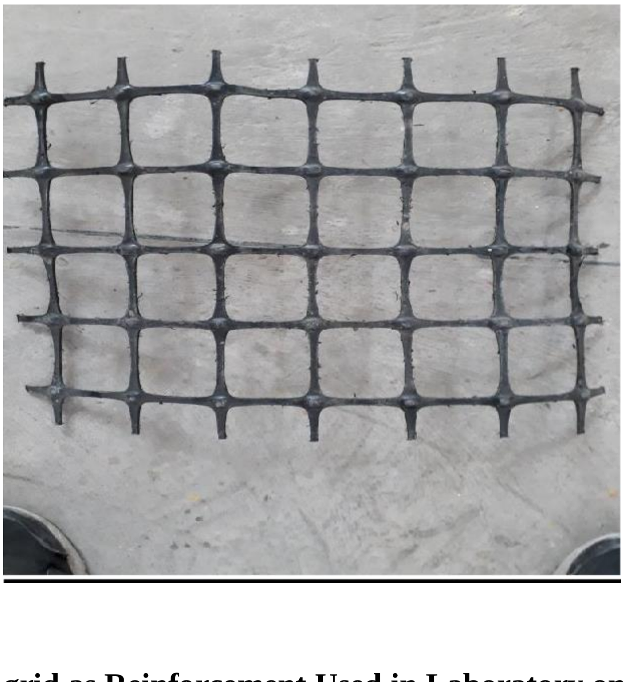

Fig 3.4: Geo-grid as Reinforcement Used in Laboratory on Pull out test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experiment was carried out on the soil at 12% moisture content

4.1.1 Different types of load vs deformation curves in various cases

In the laboratory the experiments were carried out to perform the pull-out test. The load deformation curves are drawn in different conditions, which are shown in the tables and figures given below:

Table 4.1: Experimental program of pull-out test on the soil at moisture content of 12 %

1.	**Size of geogrid**	**35cm x 35cm**	**35cm x 40cm**	**For both sizes of geo-grid, all four cases overburden height 15cm,8cm, surcharge 0 and 1.07 kN/m^2 considered**
2.	**Overburden above geogrid**	**15 cm**	**8 cm**	**For both height, all four cases sizes 35cm x 35cm and 35 cm x 40 cm and surcharge 0 and 1.07 kN/m^{2}considered**
3.	**Surcharge**	**0**	**1.07 kN/m^2**	**For both surcharge 0 and 1.07 kN/m^2, all four cases sizes 35cm x35 cm and 35cm x 40 cm**

Table 4.2 : When the overburden of the soil above the geo-grid 15 cm without surcharge (35cmx 35cm)

LOAD(N)	DEFLECTION(mm)
60	0.1
100	0.5
120	1
160	1.2
180	1.4
200	1.75
220	1.85
240	2
260	2.2
280	2.4
300	2.6
320	2.7
340	3.1
360	3.6
380	4.2
420	4.5

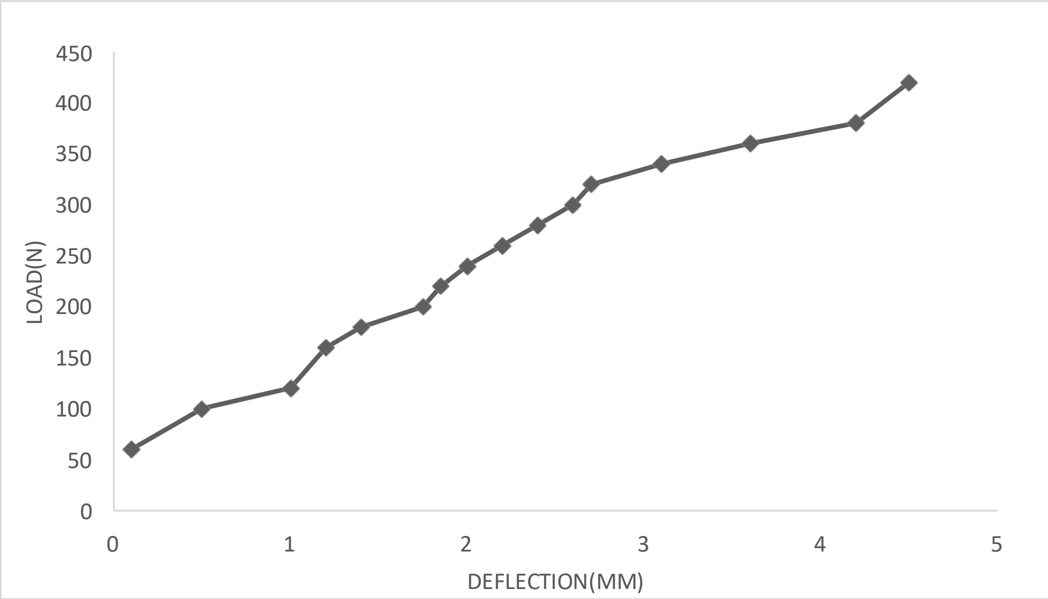

Fig. 4.1: When the overburden of the soil above the geo-grid 15 cm without surcharge (35cmx 35cm)

In this arrangement the depth of soil above the geo-grid is 15 cm and a dial gauge is fitted at front of the wall and load is increased with 20N increment continuously and the corresponding deformation is noted down with the help of dial gauge and after the load 420N the geo-grid come out of the box and failure occurs.

Pullout test can also be performed to obtain the value of coefficient of apparent friction (f).

In this test reinforcing strips are pulled out from the wall and curve is plotted between pulled out load vs deflection. From this plot maximum pulled out load is obtained.

Then coefficient of apparent friction is given

$f = T/2\sigma LW$

T=Maximum pulled-out load

σ=normal intensity at reinforcing strip level $= \Upsilon Z + q$

ϒ=unit weight of the soil

Z=depth of reinforcing strip below soil surface

q =intensity of uniformly distributed surcharge on the soil surface

L=length of reinforcing strip

W=width of reinforcing strip

$f = 420 \times 10^{-3} / (2x(22x0.15)\ x0.35x0.35) = 0.519$

Table 4.3: When the overburden of the soil above geogrid 15 cm and surcharge is applied (35cmx 35 cm)

LOAD(N)	DEFLECTION(mm)
220	0.1
260	0.2
300	0.3
340	0.6
380	0.9
420	1.1
460	1.5
500	1.9
540	2.2
580	2.8
640	3.8

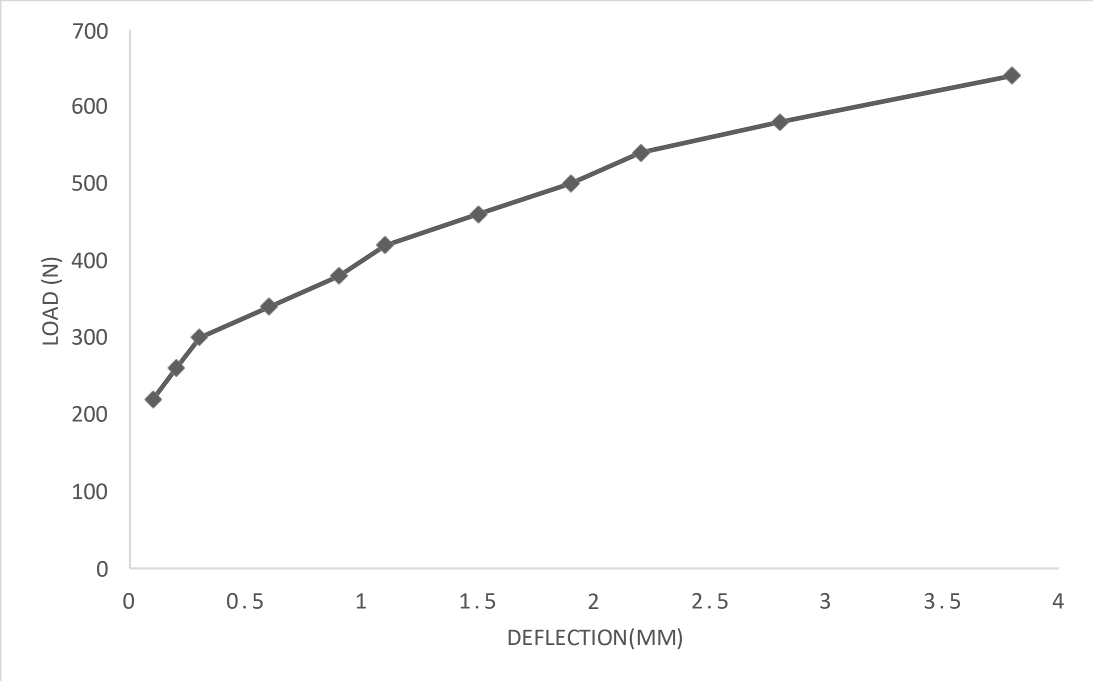

Fig 4.2: When the overburden of the soil above geogrid 15 cm and surcharge is applied (35cmx 35 cm)

When there is surcharge and height of the soil above the geo-grid is 15cm and load at which the failure take place is 640N, load is applied continuously with 40N increment until the failure take place.

The coefficient of friction is given by:

$f = T/2\ \sigma\ LW$

$= 640x10^{-3}/2x((22x0.15+1.07)\ x\ 0.35\ x\ 0.35) = 0.597$

Fig 4.3: surcharge and height of the soil above geo-grid 15 cm over (35 cm x 35 cm)

Table 4.4: When the overburden of the soil above the geo-grid 8 cm and no surcharge (35cm x35cm)

LOAD(N)	DEFLECTION(mm)
60	0.2
80	0.3
100	0.4
120	0.5
140	1
160	2
180	2.8
200	4
220	5
240	6

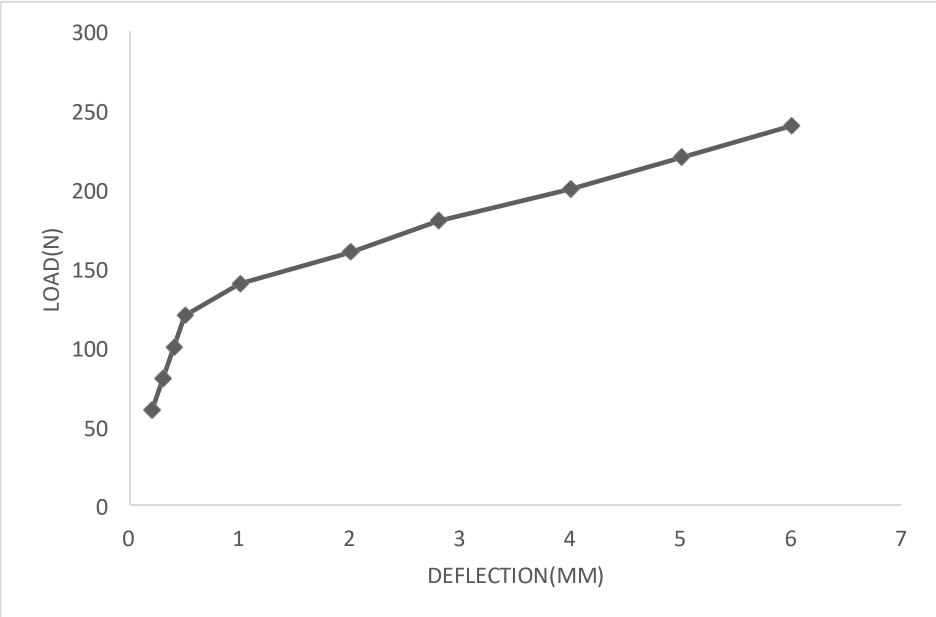

Fig. 4.4: When the overburden of the soil above the geo-grid 8 cm and no surcharge (35cm x35cm)

When there is no surcharge and height of the soil above the geogrid 8 cm, failure take place at the load of 240N, and the load in increased from 60 N to up to 240N successively until the failure take place

Coefficient of friction is given by:

$$f = T/2\sigma LW$$

$$= 240X10^{-3}/2x(22x0.08x0.35x0.35) = 0.556$$

Fig 4.5 : Height of the soil above the geo-grid 8cm and without surcharge

Table 4.5 : When the overburden of the soil above geogrid 8 cm and surcharge is applied(35cmx35cm)

LOAD(N)	DEFLECTION(mm)
100	0.2
120	0.3
140	0.4
160	0.5
180	0.9
200	1.1
220	1.3
240	1.7
280	2.1
300	3.7
340	4.2
380	4.8
420	6

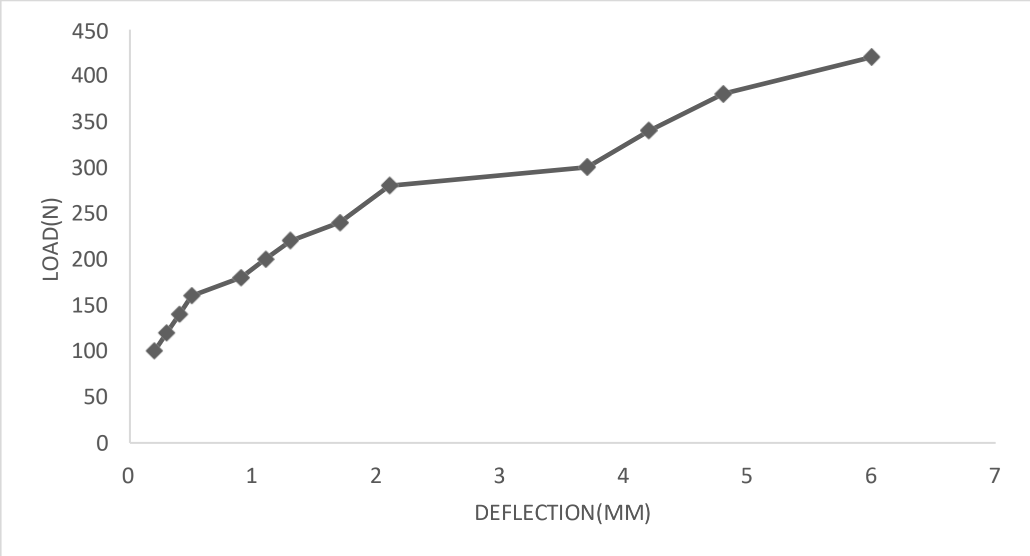

Fig. 4.6: When the overburden of the soil above geogrid 8 cm and surcharge is applied(35cmx35cm)

When the load is applied the failure take place at the load of 420 N successively load is applied with 20 N increment continuously.

When there is surcharge applied 1.07 kN/m2 and the height of the soil above the geogrid 8cm
Apparent coefficient of friction given by

$f = T/2\sigma LW$
$= 420\times10^{-3}/2\times((22\times0.08+1.07)\times 0.35\times0.35) = 0.605$

Fig 4.7: Failure when height of the soil above geo-grid 8 cm and surcharge is applied

Table 4.6 : Overburden of the soil above the geo-grid 15cm and no surcharge (35cmx40cm)

LOAD(N)	DEFLECTION(mm)
80	0.1
100	0.2
120	0.4
140	0.5
180	0.6
240	0.8
280	1
320	1.2
360	1.4
400	1.9
420	2.2
440	2.4
480	2.9
520	3.4
560	3.9
580	4.4

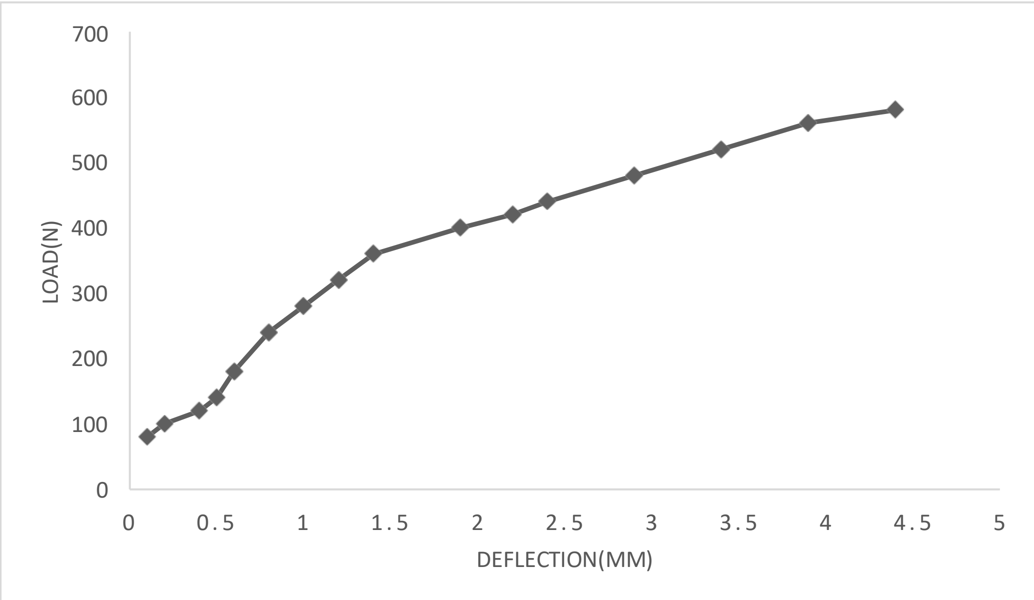

Fig. 4.8: Overburden of the soil above the geo-grid 15cm and no surcharge (35cmx40cm)

When there is no surcharge and the height of the soil above the geo-grid is 15 cm and the size of the geo-grid is 35cmx40 cm and the load is increased from 80N to 580N up to failure with 20 N increment then the coefficient of friction is given by:

$$f = T/2\sigma LW$$

$$= (580 \times 10^{-3}) / (2 \times 22 \times 15 \times 10^{-2} \times 35 \times 40 \times 10^{-4}) = 0.627$$

Table 4.7 : Overburden of the soil above geogrid 15 cm and surcharge is applied over (35cm x40 cm)

LOAD(N)	DEFLECTION (mm)
220	0.03
260	0.07
300	0.1
340	0.15
380	0.2
420	0.3
460	0.5
500	0.6
540	0.8
580	0.9
620	1.3
660	1.7
700	2
740	2.4
780	3.1
820	3.6
860	4.1

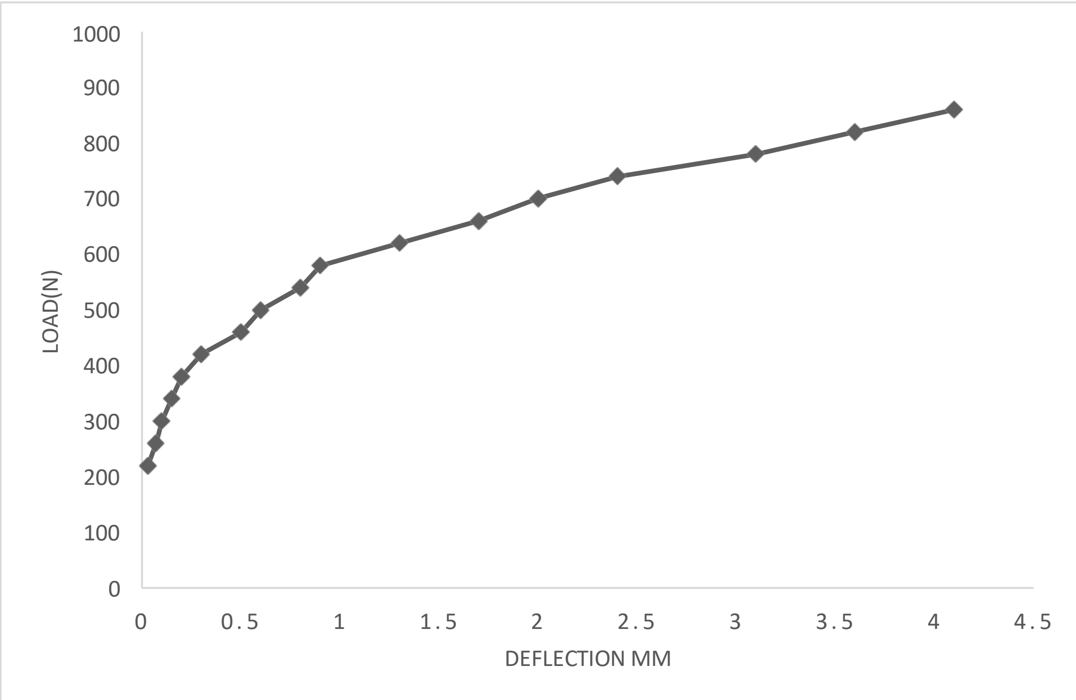

Fig. 4.9: Overburden of the soil above geogrid 15 cm and surcharge is applied over (35cm x40 cm)

When the load is increased from 220N to 860N and its increment with 40N continuously until the failure take place and the failure take place at the load of 860N then the coefficient of friction is given by:

$f = T/2\sigma LW$

$= 860 \times 10^{-3} / (2 \times (22 \times .15+1.07) \times 35 \times 40 \times 10^{-4}) = 0.702$

Table 4.8 : When the overburden of the soil above geo-grid 8 cm and no surcharge (35cmx40cm)

LOAD(N)	DEFLECTION (mm)
80	0.2
100	0.3
120	0.4
140	0.5
160	0.7
180	0.9
200	1
220	1.2
240	1.4
260	1.6
280	1.9
300	2.1
320	2.2
340	3.4
360	5.4
380	6.3

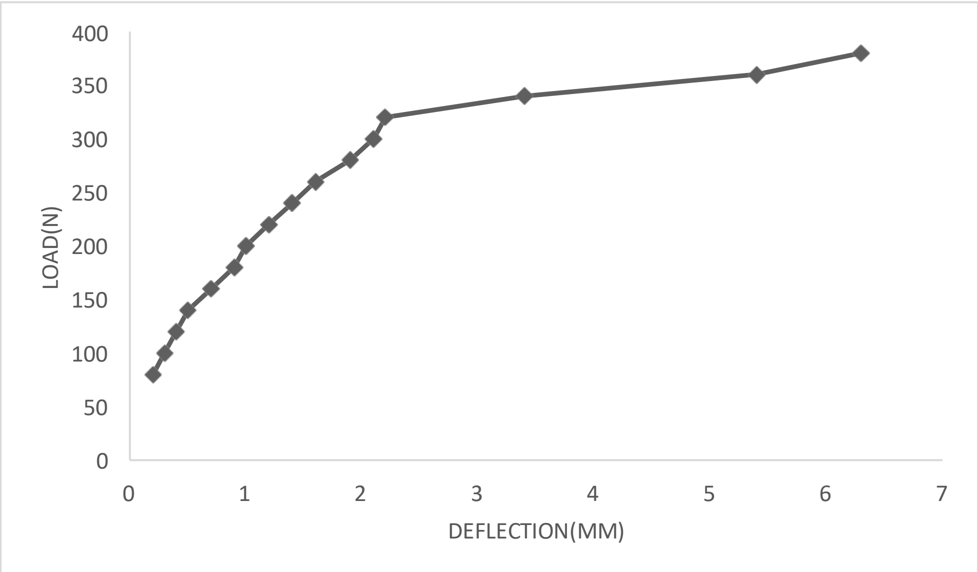

Fig. 4.10 When the overburden of the soil above geo-grid 8 cm and no surcharge (35cmx40cm)

When there is no surcharge and the height of the soil above the geogrid is 8 cm and the load is increased from 60N to 380Ncontinously until the failure take place until coefficient of friction is given by:

f =(380x10^-3)/(2x22x8x10^-2x35x40x10^-4) =.77

Table 4.9 : When overburden of the soil above geo-grid 8 cm and surcharge is applied (35cm x40cm)

LOAD(N)	DEFLECTION (mm)
140	0.1
180	0.2
220	0.3
260	0.35
300	0.4
340	0.5
380	0.8
420	1.2
460	1.8
500	2.4
540	3.4
580	5.5

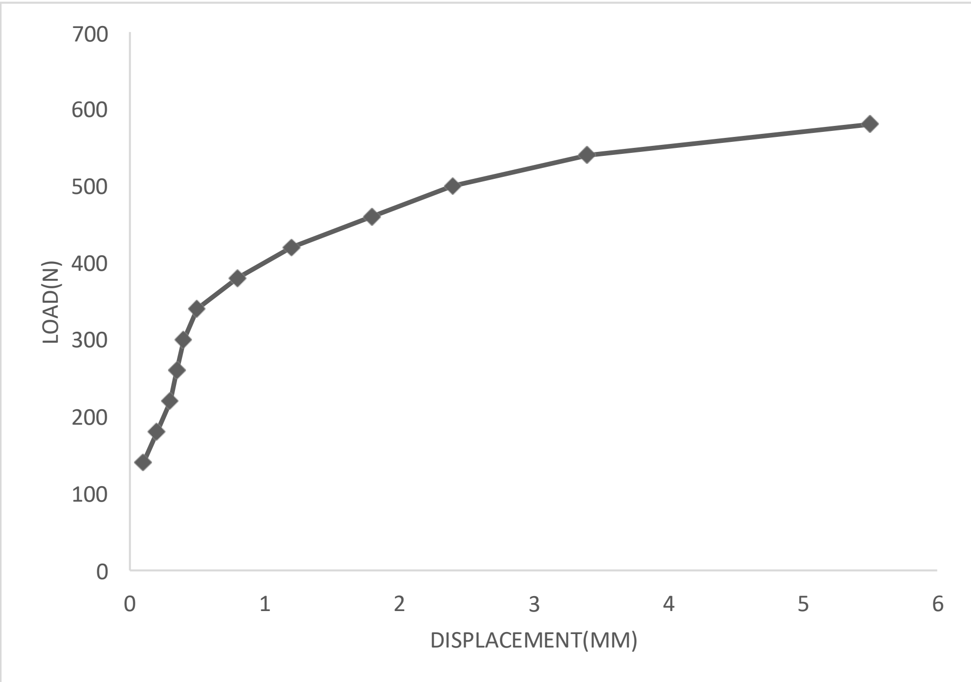

Fig. 4.11: When overburden of the soil above geo-grid 8 cm and surcharge is applied (35cm x40cm)

Fig. 4.12 : Top view when surcharge is applied

The load is increased continuously from 140N to 580N with 20N increment each until the failure take place.

Then the coefficient of friction is given by

f =T/ 2 σ L W

= $580x10^{-3}$/ (2 x (22 x .08 +1.07) x 35 x 40 $x10^{-4}$) = 0.73

It is cleared from the above figures, pull out load at which failure occurs and from formula for determining the apparent friction coefficient shows that as the height of the soil increases the value of apparent friction coefficient decreases. When the size of the geogrid 35cm x 35 cm for fig. 4.1 and fig.4.4 without surcharge (rigid plate) at top and fig. 4.2 and fig. 4.6 with surcharge (rigid plate) at the top for height 15 cm and 8 cm respectively shows the decreases value of apparent friction coefficient clearly.

It can also be seen, when the size of the geogrid 35cm x 40 cm for fig. 4.8 and fig. 4.10 without surcharge (rigid plate at top) and fig. 4.9 and fig. 4.11 with surcharge for the height 15 cm and 8 cm respectively shows the decreases value of apparent friction coefficient clearly.

For the fig. 4.1, fig.4.2, fig.4.4 and fig. 4.4, when the size of the geogrid 35 cm x 35 cm and for the fig. 4.8, fig 4.9.fig.4.10, fig.11 when the size of the geogrid 35 cm x

40 cm, it was by the formula that as the length of the geogrid increases value of apparent friction coefficient increases.

When the surcharge plate was used on the top of the soil for the height 15 cm and 8 cm in both the cases, when size of geogrid was 35 cm x 35 cm and 35 cm x 40 cm, it was found that value of apparent friction coefficient increases.

4.1.1 a. EFFECT OF LENGTH OF GEOGRID

Table 4.10 : Without surcharge15 cm overburden of the soil above geogrid (35cmx35cm) and (35cmx40cm)

LOAD(N)	DEFLECTION(mm)G1	DEFLECTIONG2(mm)
80	0.1	0.05
100	0.5	0.2
120	1	0.4
160	1.2	0.5
180	1.4	0.6
200	1.75	0.65
220	1.85	0.7
240	2	0.8
260	2.2	0.9
280	2.4	1
300	2.6	1.1
320	2.7	1.2
340	3.1	1.3
360	3.6	1.4
380	4.2	1.7
420	4.5	1.9
440		2.2
460		2.4
480		2.9
520		3.4
560		3.9
580		4.4

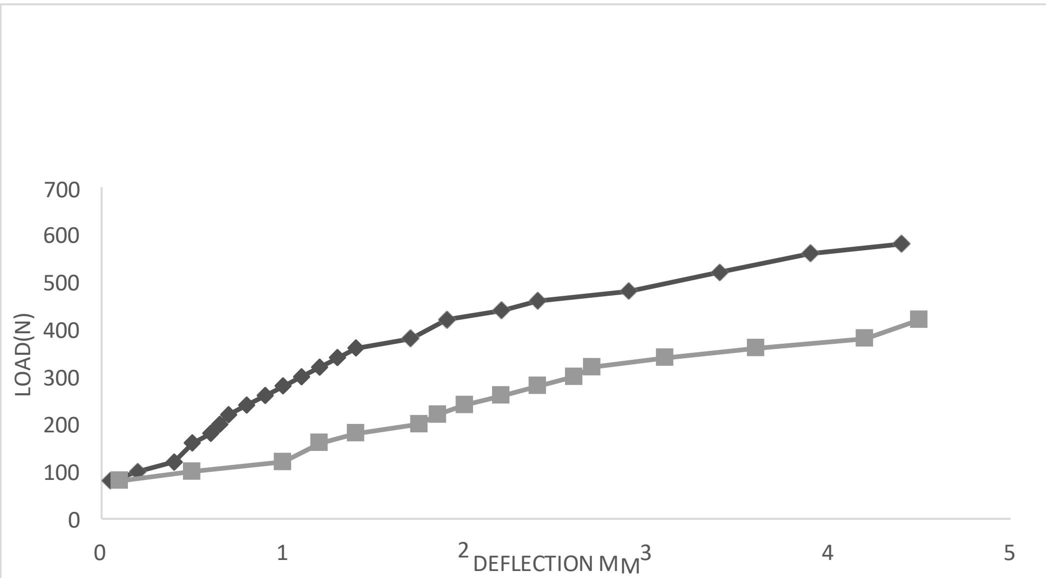

Fig. 4.13: Without surcharge15 cm overburden of the soil above geogrid (35cmx35cm) and (35cmx40cm

Table 4.11: Surcharge and 15 cm overburden of the soil above geo-grid over (35cmx35cm) and (35cmx40cm)

LOAD(N)	DEFLECTION (mm)G1	DEFLECTION (mm)G2
220	0.1	0.03
260	0.2	0.07
300	0.3	0.1
340	0.6	0.15
380	0.9	0.2
420	1.1	0.3
460	1.5	0.5
500	1.9	0.6
540	2.2	0.8
580	2.8	0.9
620	3.2	1.3
640	3.8	1.7
700		2
740		2.4
780		3.1
820		3.6
860		4.1

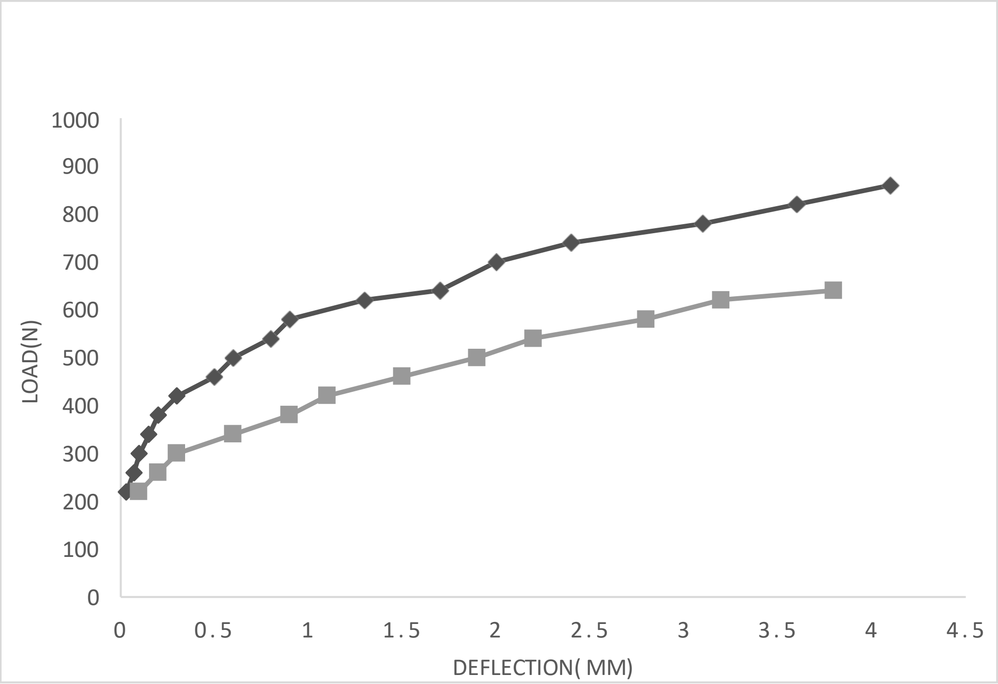

Fig. 4.14: Surcharge and 15 cm overburden of the soil above geo-grid over (35cmx35cm) and (35cmx40cm)

Table 4.12 : Without surcharge and overburden of the soil above geo-grid 8cm over (35x35cm) and (35cmx40cm)

LOAD(N)	DEFLECTION (mm)G1	DEFLECTION (mm)G2
60	0.2	0.1
80	0.3	0.2
100	0.5	0.3
120	1	0.4
140	2	0.8
160	2.8	1
180	4	1.2
220	5	1.4
240	6	1.6
260		1.9
280		2.1
300		2.2
320		3.4
340		5.4
360		6.3
380		

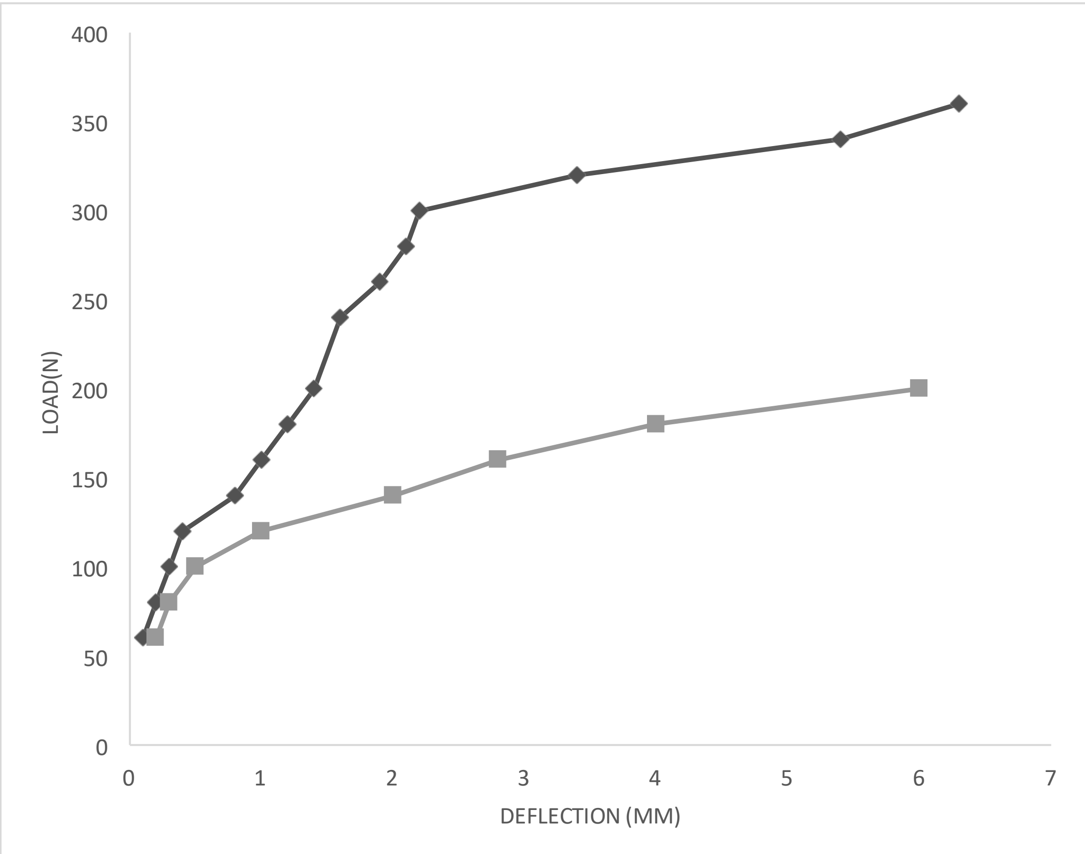

Fig. 4.15: Without surcharge and overburden of the soil above geo-grid 8cm over (35x35cm) and (35cmx40cm)

Table 4.13 : Surcharge and overburden of the soil above geo-grid 8cm over (35cmx35cm) and (35cmx40cm)

LOAD(N)	DEFLECTION (mm)G1	DEFLECTION (mm)G2
100	0.2	0
120	0.3	0
140	0.4	0.1
160	0.5	0.15
180	0.9	0.2
200	1.1	0.25
220	1.9	0.35
240	2.8	0.35
280	3.7	0.4
300	5.5	0.5
340		0.8
380		1.2
420		2.4
460		3.2

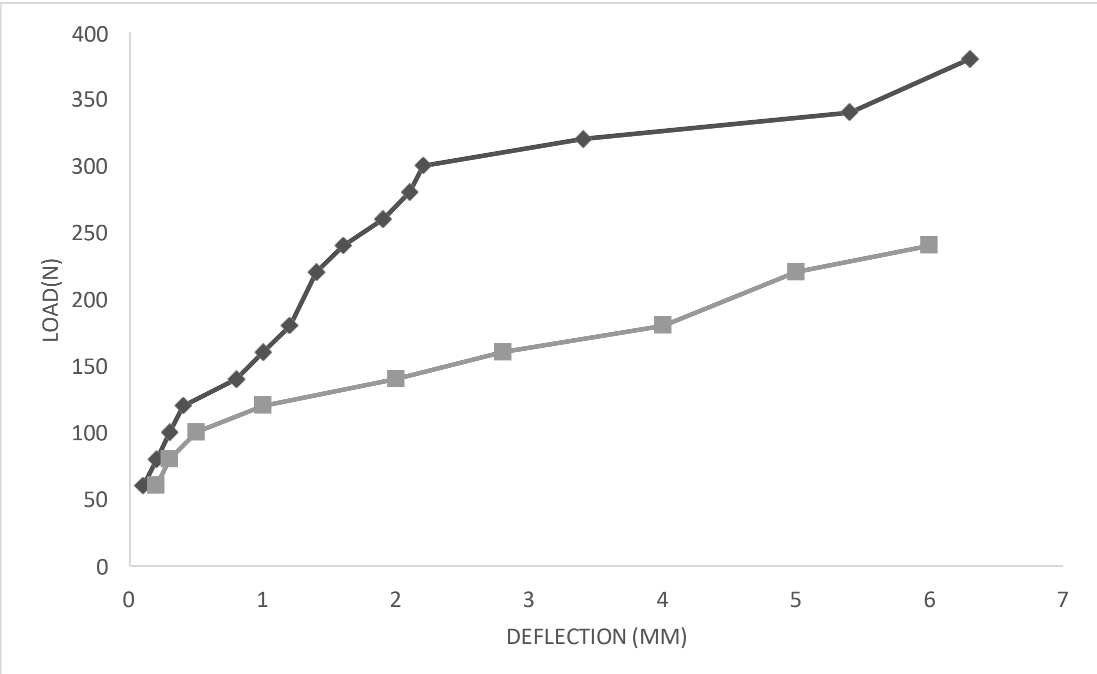

Fig. 4.16: Surcharge and overburden of the soil above geo-grid 8cm over (35cmx35cm) and (35cmx40cm)

From the fig.4.13 to fig. 4.16 we have considered the effect of increase the length of the geogrid for 15 cm overburden of soil with and without surcharge (rigid plate on plate) and 8 cm height of the geogrid with and without surcharge, in all the cases it was found that when the length of the geogrid increased, pull out strength of the soil is significantly increases for increased length of geogrid in all the figures 4.13 to 4.16.

4.1.1 b. EFFECT OF SURCHARGE ON LOAD VS DEFORMATION CURVES

Table 4.14 : Surcharge and without surcharge height 15 cm above geogrid (35cmx35cm)

LOAD(N)	DEFLECTION (mm)So	DEFLECTION (mm)S1
60	0.1	0
100	0.5	0
120	1	0
160	1.2	0
180	1.4	0
200	1.75	0
220	1.85	0.1
240	2	0.1
260	2.2	0.2
280	2.4	0.3
300	2.6	0.3
320	2.7	0.7
340	3.1	0.9
360	3.6	1.1
380	4.2	1.2
420	4.5	1.4
460		1.5
500		1.9
540		2.2
580		2.8
620		3.2
640		3.8

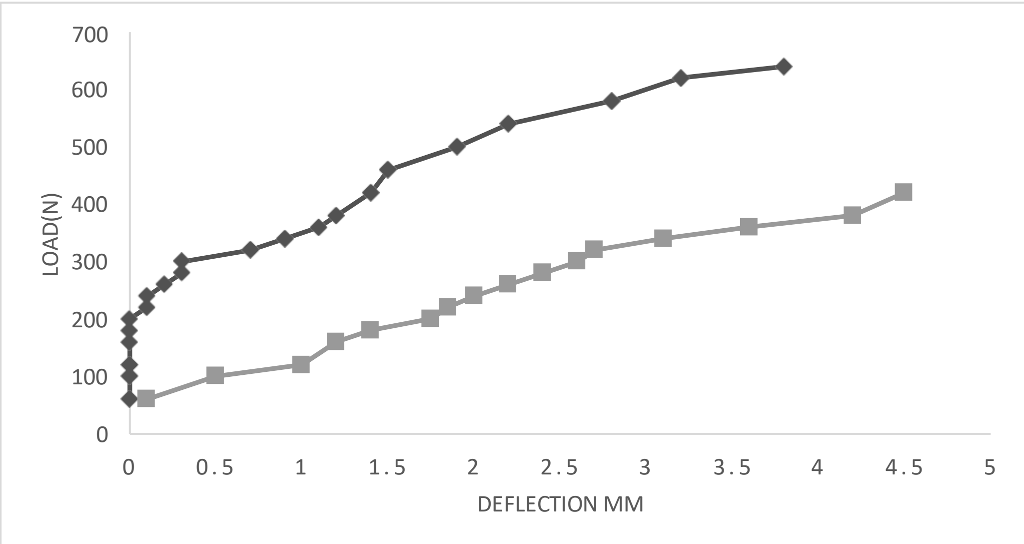

Fig. 4.17: Surcharge and without surcharge height 15 cm above geogrid (35cmx35cm)

Table 4.15 : Surcharge and without surcharge overburden of the soil above geo-grid 8cm and size (35cmx35cm)

LOAD(N)	DEFLECTON (mm)So	DEFFLECTION (mm)S1
60	0.2	0
80	0.3	0
100	0.5	0.2
120	1	0.3
140	2	0.4
160	2.8	0.5
180	4	0.9
220	6	1.1
240		1.9
280		2.8
300		3.7
340		4.2
380		4.8
420		6

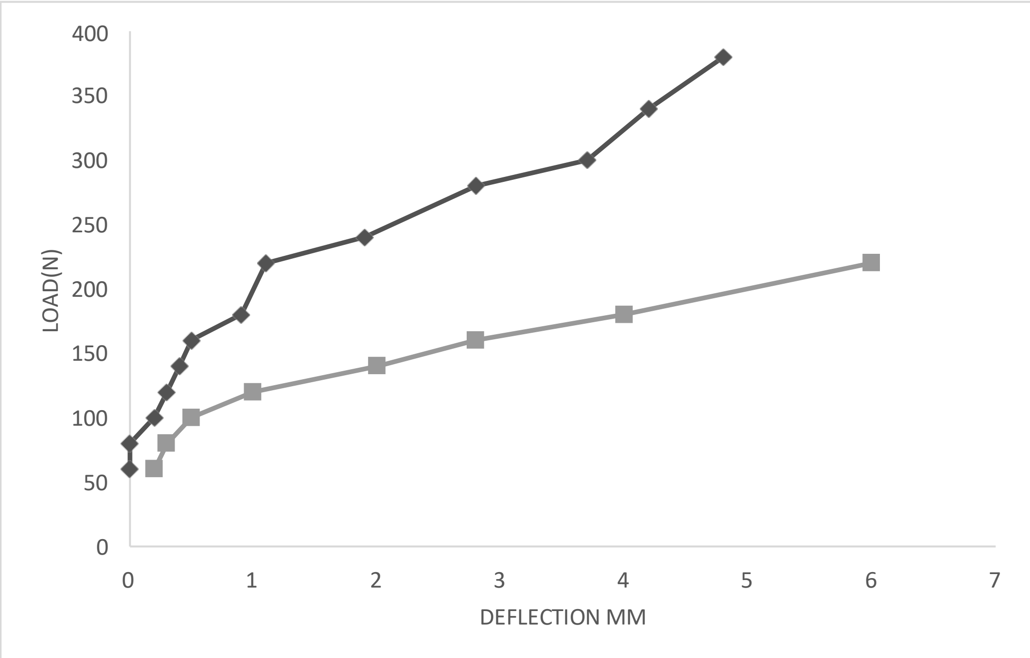

Fig.4.18: Surcharge and without surcharge overburden of the soil above geo-grid 8cm and size (35cmx35cm)

Table 4.16 : Surcharge and without surcharge, overburden of the soil 15 cm and size of geogrid (35cmx40cm)

LOAD(N)	DEFLECTION (mm)So	DEFLECTION (mm)S1
80	0.1	0
100	0.2	0
120	0.4	0
140	0.5	0
180	0.6	0
240	0.8	0
280	1	0.03
320	1.2	0.07
360	1.4	0.1
400	1.9	0.15
420	2.2	0.2
440	2.4	0.3
480	2.9	0.5
520	3.4	0.6
560	3.9	0.8
580	4.4	0.9
620		1.1
660		1.3
700		1.7
740		2
780		2.4
820		3.6
860		4.1

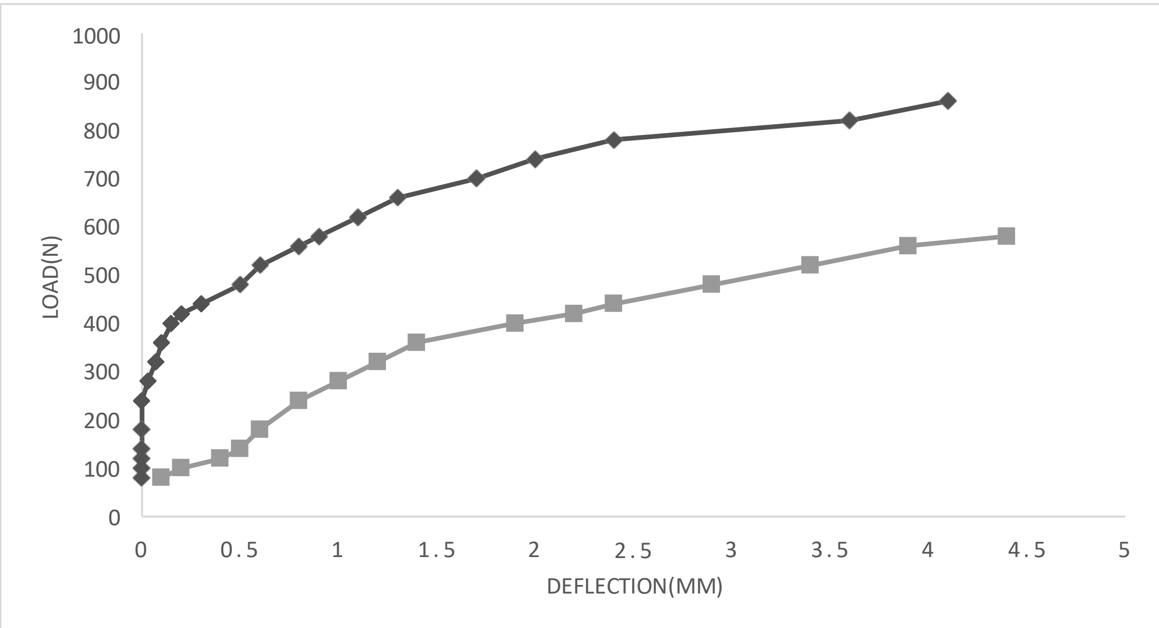

Fig. 4.19: Surcharge and without surcharge, overburden of the soil 15 cm and size of geogrid (35cmx40cm)

Table 4.17 : Surcharge and without surcharge and overburden of the soil above geogrid 8 cm and size of geogrid (35cmx40cm)

LOAD(N)	DEFLECTION (mm)So	DEFLECTION (mm)S1
80	0.2	0
100	0.3	0
120	0.4	0
140	0.5	0.1
160	0.7	0.15
180	0.9	0.2
200	1	0.25
220	1.2	0.3
240	1.4	0.35
260	1.6	0.4
280	1.9	0.45
300	2.1	0.5
320	2.2	0.55
340	3.4	0.6
360	5.4	0.8
380	6.3	0.9
420		1.2
460		1.8
500		2.4
540		3.4
580		5.5

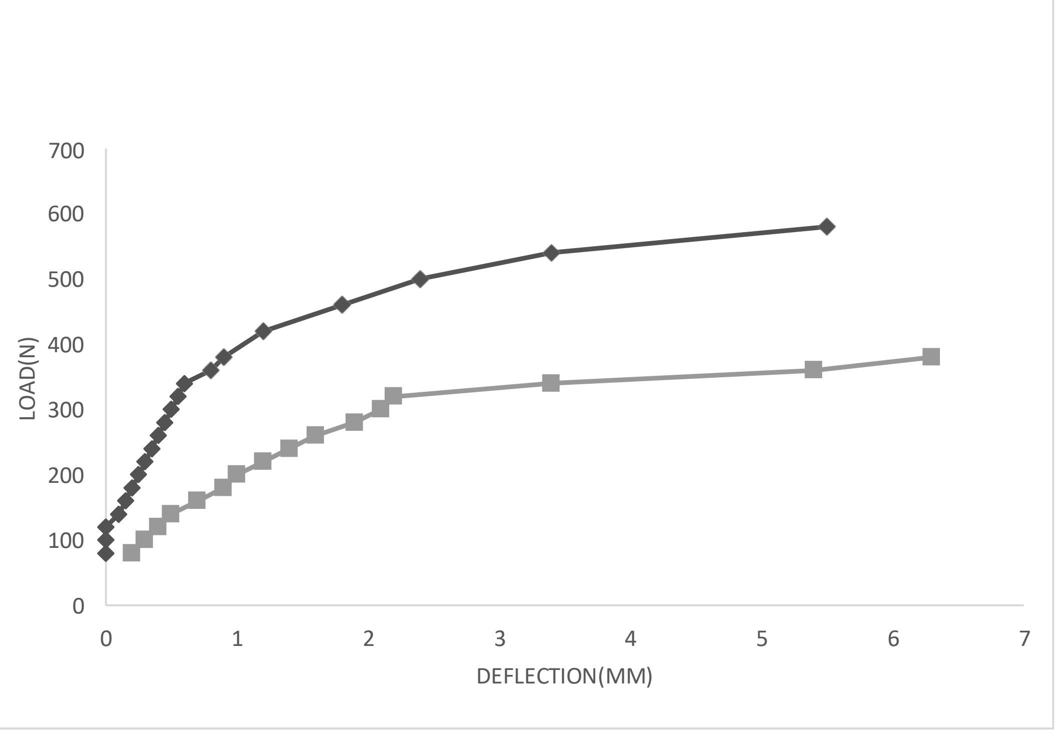

Fig.4.20: Surcharge and without surcharge and overburden of the soil above geogrid 8 cm and size of geogrid (35cmx40cm)

From the fig. 4.16 to fig. 4.20, we have considered the effect of surcharge (rigid plate on top of the soil) on 15 cm and 8 cm height of the soil on both the size of geogrid 35 cm x 35 cm and 35 cm x 40 cm. In all the cases we found that, when effect of surcharge is considered the pull-out strength of the soil significantly increases.

4.1.1 c. EFFECT OF HEIGHT OF SOILON GEOGRID ON LOAD VS DEFORMATION CURVES

Table 4.18 : without surcharge and overburden of the soil above geogrid 8 cm and 15 cm over size of geogrid (35cmx40cm)

LOAD(N)	DEFLECTION(mm)H8	DEFLECTION(mm)H15
60	0.2	0.05
80	0.3	0.1
100	0.4	0.2
120	0.5	0.4
140	1	0.6
160	2	1.2
180	2.8	1.4
200	4	1.75
220	5	1.85
240	6	2
260		2.2
280		2.4
300		2.6
320		2.7
340		3.1
360		3.6
380		4.2
400		4.5
420		

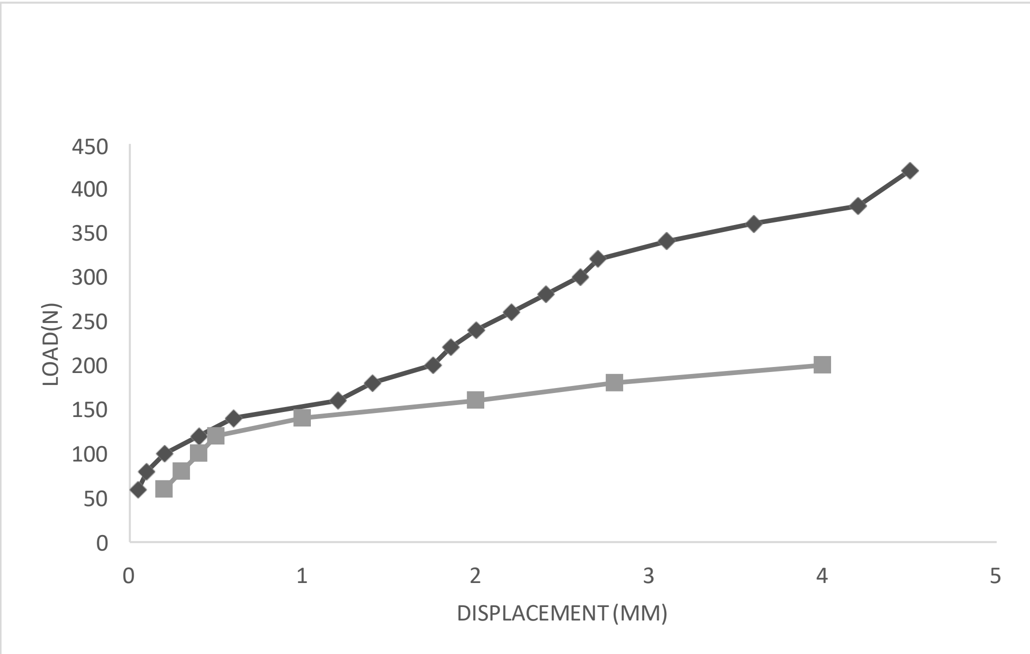

Fig. 4.21: without surcharge and overburden of the soil above geogrid 8 cm and 15 cm over size of geogrid (35cmx40cm)

Table 4.19 : Surcharge and overburden of the soil above geo-grid 8cm and 15cm above geo-grid (35cmx35cm)

Load(N)	DEFLECTION(mm) H8	DEFLECTIO N(mm)H15
100	0.2	0
120	0.3	0
140	0.4	0
160	0.5	0
180	0.9	0
200	1.1	0
220	1.3	0.1
260	1.9	0.2
300	3.7	0.3
340	4.2	0.6
380	4.8	0.9
420	6	1.1
460		1.5
500		1.9
540		2.2
580		2.8
640		3.8

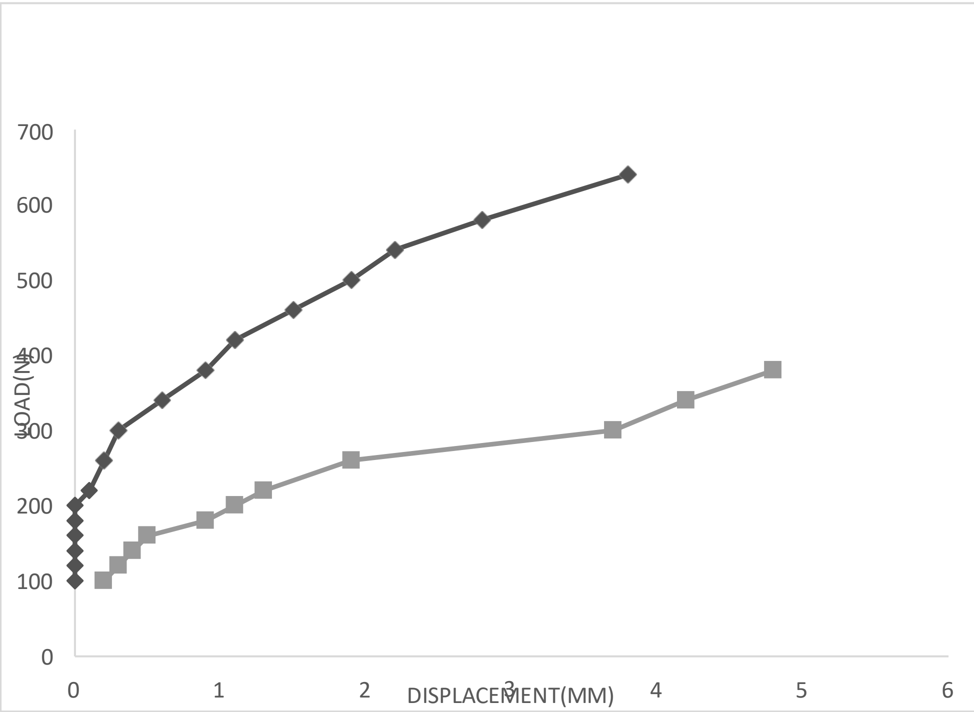

Fig. 4.22: Surcharge and overburden of the soil above geo-grid 8cm and 15cm above geo-grid (35cmx35cm)

Table 4.20 : No surcharge and overburden of the soil above geo-grid 8cm and 15 cm and the size of geo-grid (35cmx40cm)

LOAD(N)	DEFLECTION(mm)H8	DEFLECTION(mm)H15
80	0.2	0.1
100	0.3	0.2
120	0.4	0.3
140	0.5	0.35
160	0.7	0.4
180	0.9	0.6
200	1	0.65
220	1.2	0.7
240	1.4	0.8
260	1.6	0.85
280	1.9	0.9
300	2.1	1
320	2.2	1.2
340	3.4	1.3
360	5.4	1.4
400	6.3	1.9
420		2.2
440		2.4
480		2.9
520		3.4
560		3.9
580		4.4

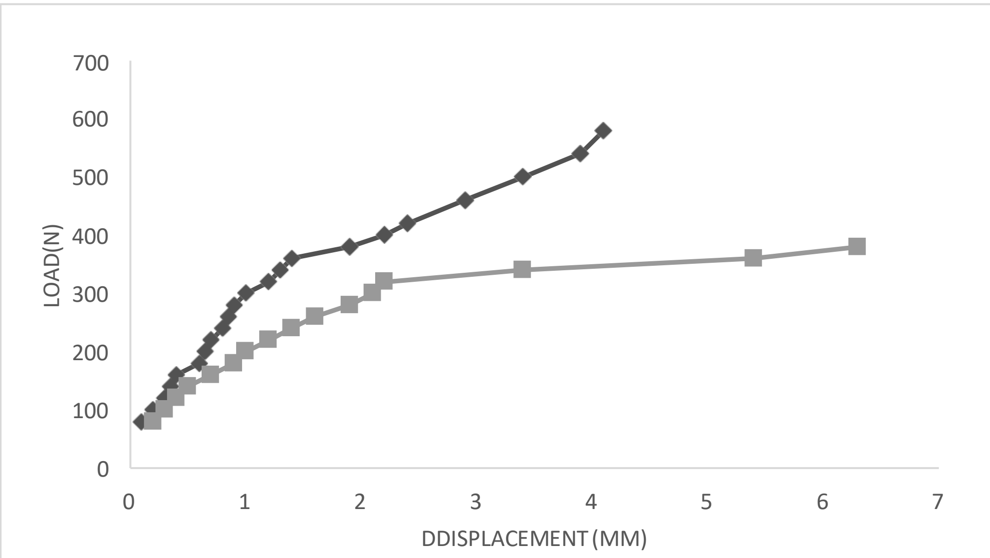

Fig4.23: No surcharge and overburden of the soil above geo-grid 8cm and 15 cm and the size of geo-grid (35cmx40cm)

Table 4.21 : Surcharge and overburden of the soil above geo-grid 8 cm and 15cm (35cmx40cm)

LOAD(N)	DEFLECTION (mm)H8	DEFLECTION (mm)H15
140	0.1	0
180	0.2	0
220	0.3	0.03
260	0.35	0.07
300	0.4	0.1
340	0.5	0.15
380	0.8	0.2
420	1.2	0.3
460	1.8	0.5
500	2.4	0.6
540	3.4	0.8
580	5.5	0.9
620		1.3
660		1.7
700		2
740		2.4
780		3.1
820		3.6
860		4.1

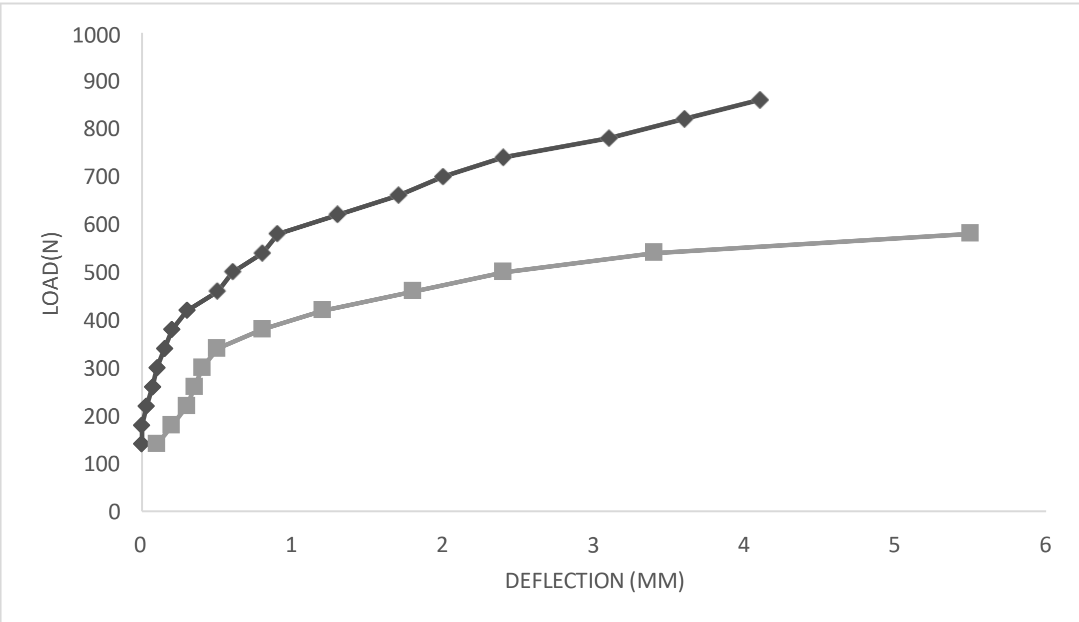

Fig 4.24: Surcharge and overburden of the soil above geo-grid 8 cm and 15cm (35cmx40cm)

From the fig. 4.20 to curve 4.20, we have considered the effect of height of soil above geogrid on pull-out strength 15 cm and 8 cm, with and without surcharge over both the sizes of geogrid 35 cm x 35 cm and 35 cm x 40 cm. it was found that when the height of the soil over the geogrid increases pull-out strength also increases and the values of coefficient of friction decreases for the increased overburden height of the soil which was calculated earlier.

4.2 Experiment carried out on dried soil

i. When the height of the soil above the geo-grid was 15 cm and no surcharge the failure load was 350N.
ii. When the surcharge is used at 15 cm above the geo-grid the failure load was 490N.
iii. When height of the soil above the geo-grid 8 cm without surcharge (rigid plate) failure load was 220 N.
iv. When we use height of the soil above 8cm and with surcharge the failure occurs at the load 320N.

In the dry soil failure was sudden, no continuous deformation was noted down at the front of the wall before failure. A small vertical deflection was observed before failure. It was found that with surcharge, the failure load increases. Here value of apparent friction is calculated at maximum load.

4.3 EFFECT OF MOISTURE CONTENT

By this analysis we found that in case of dry soil pull out strength is less compare to moist soil. In case of moist soil deformation is continuous, it is because of cohesion between the particles. In case of dry soil there is no cohesion between the particles and they are interlocked (fine sand and silt major part), when the load is increased after a particular limit interlocking breaks, that's why small vertical deformation takes place before failure which can be directly observed. In all the cases pull-out strength of the dry soil is less compare to moist soil.

CONCLUSION

On the basis of results obtained in this study, following conclusions can be drawn:

i. Deformation decreases as the length of the geo-grid increases for the particular value of pull-out load and the failure takes place at comparatively large load for increased length of the geo-grid.

ii. As the overburden (height)of the soil over the geo-grid increases, deformation decreases for a particular load and the failure takes place at large load for increased height.

iii. When rigid plate (effect of surcharge) is applied, its pull out strength increases. Here surcharge plate provides uniform pressure $1.07 kN/m^2$ and it increases the pull-out strength.

iv. When the dry soil is used, failure takes place suddenly, not give continuous deformation as in case of moist soil and before failure some vertical deformation can be observed directly in case of dry soil. Failure takes place at lower load compare to moist soil.

v. When the height of the soil above the geogrid increases, value of friction coefficient decreases.

vi. When the length of the geogrid increases, apparent friction coefficient value increases.

vii. When the surcharge plate is applied for a fixed height, value of apparent friction coefficient increases but it may decrease, when the soil height above geogrid is comparatively low.

viii. Value of friction coefficient is less than one, in case of soil. It means in actual field condition structure will fail due to dynamic load having value less than structural load over the soil

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