A MAJOR PROJECT REPORT

ON

INFLUENCE OF DEGREE OF COMPACTION AND SURCHARGE ON CBR VALUE OF GEOGRID REINFORCED CLAY AND SANDY SOILS

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BY

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2016

CERTIFICATE

This is to certify that majo project report entitled "INFLUENCE OF DEGREE OF COMPACTION AND SURCHARGE ON CBR VALUE OF GEOGRID REINFORCED CLAY AND SANDY SOILS" is a confide record of work carried out by PARVEEN KUMAR (2K14/GTE/12) under my guidance and supervision, during the session 2016 in partial fulfillment of the requirement of degree of Master of Technology (Geotechnical Engineering) from Delhi Technological University, Delhi.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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DECLARATION

I hereby declare that the work in this project report entitled “INFLUENCE OF DEGREE OF COMPACTION AND SURCHARGE ON CBR VALUE OF GEOGRID REINFORCED CLAY AND SANDY SOILS” is bonafiderecord of work carried out by me as a part of major project in partial fullfillment for the Master of Technology in Geotechnical Engineering.

I have not submitted the matter presented in this report for the award of any degree.

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NOTATIONS

SYMBOL	DESCRIPTION
C_C	Coefficient of curvature
C_U	Coefficient of uniformity
D_{10}	Effective size
D_{30}	Grain diameter corresponding to 30% finer
D_{60}	Grain diameter corresponding to 60% finer
G	Specific gravity
DST	Direct shear test
CBR	California bearing ratio
SEM	Scanning electron microscope
OMC	Optimum moisture content
MDD	Maximum dry density
LL	Liquid limit
PL	Plastic limit
PI	Plasticity index
γ_d	Dry density
ϕ	Angle of internal friction
µ	Micron
^{o}	Degree
H	Thickness of layer
SP	Poorly graded sand

ABSTRACT

As the many constructions activity are to be done in different fields under many government schemes. There is huge need arise to economize the construction cost and cost of material. The subgrade is that part of soil which supports the many types of footing and also carries the load from superstructure. As at every place good quality of subgrade is not available, so there is need to improve the quality of weak subgrade. Either we replace it completely and fill it with good quality of material or improve the engineering property of subgrade by using ad mixer or by using the polymer just like geogrid, geotextiles etc.

As the replacement of subgrade is not economical solution when the weak subgrade is presented up to a should have good bearing capacity and other engineering properties which may further economize the cost of construction.As the material chosen for the improvement of subgrade must have appropriate strength itself or in combination with the soil and it must be economical to use and easily available. In the present investigation CBR tests were carried out on sandy and clay soils. With these two types of soils we are also using the geogrid as reinforcement at different positions.Here we are also increasing the surcharge and degree of compaction. Effect on the CBR value is to be observed at increase in surcharge and degree of compaction on reinforced clay and sandy soils. It was reported that with increase in surcharge and degree of compaction CBR value of soil also increased. The optimum result comes out when we use increased surcharge, degree of compaction and geogrid in a single stage.

CHAPTER 1

INTRODUCTION

1.1 General Subgrade

It is that part of soil surface that takes the load of footing as well as of superstructure. A good quality of subgrade is not available everywhere the n either we replace it or by giving some chemical or mechanical treatment, the subgrade can be made suitable for foundation purpose or we can also geosynthetic material just like geotextile and geogrid. Here we are concentrating on the degree of compaction, increment of surcharge and use of geogrid.

1.2 California Bearing Ratio Test (CBR)

It was developed by California Division of Highway. This method is used as the classifying and evaluating the base course and subgrade soil material for the flexible pavements. This is an empirical test used to determine the material properties. It measures the strength of the soil subgrade. It consist of a standard piston of area 0.1962 m^2 (diameter is 50 mm) is penetrate in the soil at the standard rate of 1.25 mm/min. CBR value is equal to the ratio of load carried by the specimen at 2.5 mm or 5mm penetration to the load carried by the standard specimen. In most of the cases the CBR value decreased as we increased penetration. Generally CBR value at 2.5 mm is to be taken but if it comes out greater at 5mm than at 2.5mm then to conform it test is to be repeat again. CBR measures the resistance of material against the penetration of standard plunger in controlled moisture and density condition

CBR value is extensively to be used for field correlation of the flexible pavement thickness requirement.

Here we are find out the CBR value with varying factors are degree of compaction, increment of surcharge and use of geogrid.

Table 1. CBR values of soil with their rating.

Range of CBR values (%)	Rating
2 to 5	Very poor subgrade
5 to 8	Poor subgrade
8 to 20	Fair to good subgrade
20 to 30	Excellent subgrade
30 to 60	Good sub-base
60 to 80	Good base
80 to 100	Best base

1.3 Degree of compaction: Degree of compaction affects the void ratio, dry density and other soil parameters widely. As it is find out that there will be more degree of compaction or by applying more compactive efforts, then the air present in the void of soil is comes out from the pores of soil and soil will rearrange itself in a better compact structure .

As the airs from voids are pulled out then there is decrease in the void ratio and increase in the dry density. Now the soil can takes more load without going on excessive immediate settlements. Now the subgrade can be used in better way.

In the fields there are various types of method available by virtue of that we can makes the structure compact. For this purpose there are various types of rollers are available. The effectiveness of these can be increased by using thin layer of soil and more compactive efforts.

1.4 Surcharge**:** It is the load applied on the soil either permanently or temporary. Surcharge is also another factor that affects the behavior of soil in various conditions. Surcharge can be applied on the existing subgrade by placing a large mass of soil on it or by mechanically with the help of jacks. It can also be apply by lower down water table permanently. As the time passes the surcharge applied preexisting soil rearranges its self into a better structural form. After the removal of surcharge it is find out that load carrying capacity increases upto some points. Now the soil tends to retain the effect of stress changes that it has been taken place in there geological history in the form of their structure . Whenever we applied the load the stresses develop in the subgrade are less than the stresses that it ever experienced in the past history then the soil is said to be normally consolidated and it can takes the load very easily without going failure . If the stresses experienced are more than that it experienced in the past history then the soil is said to be over consolidated.

For normal consolidated soil OCR=1

For over consolidated soil OCR >1

1.5 Geogrid: These are just like a net having large opening made of polymers likes as high density polyethylene and polypropylene etc. These opening are to be called as apertures. These apertures allow the geogrid to makes better interlocking with the soil and boulders such that it works as reinforcement. Geogrid are generally provided at the base of subgrade. Sometimes it is provided at the surfaces in case of slopes and wall . they give adequate strength to the soil . This strength is due to the filled interlocks with geogrid . This effect of generation of strength can be analyze with the help by knowing the strength of geogrid , mesh size and by the base material which is to be used .

1.5.1 Types of geogrid : Generally there are two types of geogrid –

1. Single axial geogrid
2. Biaxial geogrid

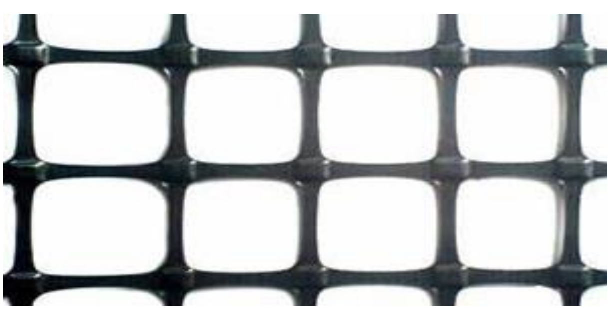

Fig 1. Biaxial geogrid

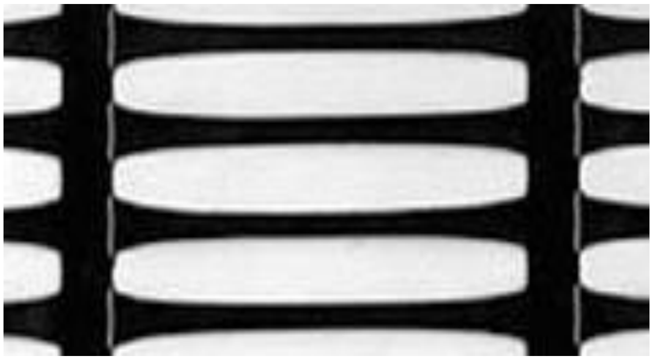

fig2. Single axial geogrid

1.5.2 Why it is to be used:

1 Geogrid made of polymer having stable structure.

2 Low deformation at large loading.

3 Good tensile strength.

4 Due to opening it can make better interlocking.

5 Easy to handle and transport.

6 It can control the differential settlements.

1.5.3 Installation:

First of all unfold the geogrid roll.

Geogrid may be overlaps either side by side or end to end.

For the very soft subgrade with CBR value less than 1, then three feet overlaps is to be provided.

For the soft subgrade with CBR value in between 1 to 2, then two feet overlaps is to be provided.

For the firm subgrade with CBR value greater than 2, then one feet overlaps is to be recommended.

Ties are to be used for 10 feet interval for good overlaps.

1.5.4 Application:

1 Geogrid can be used as the base reinforcement.

2 It can be used as asphalt reinforcement.

3 It can be used in the bridge and railway abutments.

4 It can be used to reinforce the steepened soil slopes.

5 It can be used as reinforced foundation over piles.

6 It can be used in retaining walls.

7 It can be used to reinforce embankment over soft foundation.

1.6 Objective:

1 To characterize the soil and geogrid.

2 To observe the effect of degree of compaction on CBR value of the soil.

3 To observe the effect of surcharge on CBR value of the soil at high degree of compaction.

4 To observe the effect of placement of geogrid on CBR value of soils with high degree of compaction and surcharge.

5 To analyze the result.

6 Conclusions

In order to achieve the objectives, literature has been reviewed which is reflected in the next chapter.

CHAPTER 2

LITERATURE REVIEW

The literature has been review specifically with respect to CBR value of the soil .The main focus is on the effect of various parameters on the CBR value of the soil.

Dr. Yousif Jawad [1] studied the effect of compaction on the gypseous soil. For this purpose they took the soil from Kirkuk city having the gypsum content of 37% and 56%. Various test are to be conducted such as XRD, CBR, compaction test and UCS etc. All these CBR tests are to be conducted for standard proctor test and modified proctor test. It is find out that swelling percentage is more in case of soil with gypsum content 56%. From shear test result it is to be finding out that for the two compactive effort and two types of gypseous soil, the cohesion increases. The soaked CBR values are to be find out increased as we increased compactive efforts.

K. Bandyopadhyar [2] studied the effect of different types of compaction i.e. Static and dynamic at different energy level at various moisture content from optimum moisture content. For this purpose fly ash from Farakha thermal power plant is to be taken. It is find out that CBR values at optimum moisture content at 32%, 36% and 45% with heavy and light compaction. It is observed that CBR values decrease as the increase in maximum dry density and optimum moisture content in the both cases dynamic and static compaction.

Zornberg and Gupta [3] determined how the geosynthetics material properties influence the performance of pavement system and its mechanism. They also develop the analytical, field and laboratory method to quantify the geoynthetic properties. For this purpose they use the finite element method (FEM) and discrete element method (DEM) .Several cyclic load are to be applied on the soil and geosynthetic system to simulate with the dynamic nature of traffic. It is find out that by using the geosynthetic performance of pavement can be increased. But the selection criteria of geosynthetic used in pavement is not established completely.

SZ. Fischer and F. Horvat [4] investigated the effect of geogrid layer under the railway blast. For this purpose they prepare the full scale model of railway track. They simulate the railway superstructure with the help of finite element method and discrete element in 2D and

3D . In FEM loading plate, sheet and blast are to be modeled as the different elements. A multiple shear test, field test and numerous geosynthetic types are to use for this purpose.

S. V. Krishna Rao [5] used the linen fiber material with the silty sand with aspects ratio of 50,100 and 150. UCS, CBR and direct shear test are to be conducted at these aspect ratios. They derived an equation between fiber content (FC) and aspect ratio (AS) as

$$CBR\ (\%) = 18.18 + 0.034\ AS + 15.131\ FC$$

It is find out the CBR values increased by 20.3%, 29.5% and 37.8% with aspect ratio of 50 , 100 and 150 respectively. Friction angle and cohesion increased by 11% and 22.6% respectively.

Nabil Al Joulani [6] find out the effect of stone powder, lime and degree of compaction on the CBR values of fine sand. He added various percentage of stone powder in 10% , 20% and 30% by weight at optimum moisture content .He also find out the CBR value at different number of blows ie. 10, 30 and 65 blows .It is find out that CBR value at 25 blows increased from 5.2% to 16% without additive and to 18% with addition of lime and stone powder by 30%. It is also find out that the pavement thickness is to be reduced by 47% and 55% with addition of 30% lime and stone powder .With addition 30% of stone powder and lime, the internal angle of friction will be increased by 50%. He also correlates his results with the recently studies literature.

Alemgena A. Araya [7] In the developing countries, pavement design are generally empirically in nature that depend on single input CBR values. But this value does not provide the resilient and deformation characteristics of road material .The develop a technique for characterization of the mechanical behavior based on the CBR test by using the repeated load cycle. Confining pressure is measured with the help of strain gauge in CBR stress state . Finite element analysis is also be done for repeated load and is to be derived an equivalent resilient modulus, this can be used as input for pavement design analysis.

Fatemeh Mousavi [8] investigated the effect of polymer on the swelling potential and CBR values of clayey soil collected from forest road near university of Tehran, Iran. CBR and free swell index test are to be conducted. The swelling potential decreased by 12.37% 33.03%

and 51.32% with addition of 0.019%, 0.041% and 0.06% of polymer and CBR value is increased by 31% and 23% for penetration of 2.5 mm and 5 mm respectively.

Charles Anum Adam [9] investigated the effect of geogrid on the CBR value of poor lateritic subgrade material in unsoaked and soaked condition. They placed the geogrid at the third layer with in the sample height and then CBR values are to be finding out. It is to be find out that CBR values increased for sandy silt soil for soaked and unsoaked condition by 11% and 112%.

SaAd F. Ibrahim [10] investigated the long term effect of drying and wetting on the subgrade soil with low cost stabilizer. They find out the CBR values for different numbers of blow i.e. 10, 25 and 56 for the four day soaking period. It is found out that CBR value for modified proctor test increased by 48%, 66%, 36%, and 38% for 2.5 % $CaCl_2$, 5% lime, 6% RHA and 6% Kaolin respectively. The soaking period is taken as 4, 7, 14 and 28 days. It is also find out that the long term soaking will decreases the CBR values.

AKO Lade, AS and Olayniya [11] investigated the effect of geogrid on the engineering properties of subgrade in soaked condition. For this purpose they collect three samples and placed the geogrid in three independent layer and soaking is to be done for 18 hr. It is find out that geogrid placed at 3/5 distance show higher value of CBR the other place by 15%, 14 % and 12.21%.

V.K. Chakravarthi and B. Jyotsha [12] determined the efficiency of geosynthetic separator and finer on the CBR value of the soft subgrade. It is find out that percentage finer and plasticity index influence the CBR value which is increased by 12% with finer and 11.72% with plasticity index. CBR value with geogrid is 50% higher than the oil without geogrid.

Prof. Mayara .M Yeole [13] used the geogrid as the reinforced and find out the effect on the bearing capacity. They placed the geogrid at the various level and CBR values is to be find out . With the two layer of geogrid are placed at 25mm and 75mm from the top then CBR value increased by 38.21% and when we placed the geogrid at the 25mm from top in one layer then the CBR value increased by 29.55%. When two layer placed at 50mm and 75 mm from top the CBR values increased by 22.99%.

Naveen B. Shirur [14] established a relation between the physical properties of soil and the CBR values. For this purpose they take the soil sample having the liquid limit in between 20 to 70. The various relation between CBR values and the index properties with the help of simple and multiple linear regression analysis and an appropriate equation is develop for estimation of CBR from index properties. From the simple linear regression analysis (SLRA). It is find out that CBR values decreased as there is increment in the plasticity index and it decrease as moisture content increases. He gives a relationship as

Y (CBR %) = - 0.2443 OMC + 7.5264

Y (CBR %) = 4.99 MDD - 5.711

These are derived from SLRA to predict CBR from optimum moisture content and maximum dry density.

The CBR value predicted are mostly for highly compressible clay soil (CH).

Charles A. Adams [15] investigated the effect of triaxial geogrid reinforcement on CBR of natural soil used for road pavement. They use the two kinds of geogrid T_x 160 and T_X 170. The geogrid are to be placed above the third layer. The CBR values with T_x 170 increased more than the T_x 160. CBR values increased by 25% under soaked condition.

Archana Muraleedhara [16] analyzed the behavior of geogrid on the silty sandy soil. For this purpose geogrid is placed in single, double, triple layer and four layers in both condition soaked and unsoaked condition. It is find out that the CBR value for the three layer system is much more than the single and double layer system. But the CBR value comes out in the four layer system is completely different. In the four layer system CBR value comes out less than the all three system. It is also find out that with inclusion of geogrid there is improvement in the drainage characteristics of the soil also.

Sadok Benmebarek [17] studied the effect of geosynthetics on the performance of road embankment. For this purpose they take the soil from the road embankment which is at 11km on **Sabkha** soil of **chott EI Hodna** in Algeria. They find out that **Sabkha** surface have very poor bearing capacity and water table is also at the surface. They use the geosynthetics layer to improve the performance of the embankment. It is find out that geosynthetic increase the bearing capacity of soil. They use the biaxial geogrid over the first lift of embankment. They also perform numerical simulation with the help of software PLAXIS. It also shows that with the geosynthetics improves the bearing capacity of stabilized soil. There is increase of 85% in the bearing capacity. Due to flood CBR values is less than 1%.

Taozhary [18] used the ligin based industrial material for silt stabilization and study the engineering problem and micro structural characteristics of stabilized foundation. Liginis kind of polymer compound which can be used as the soil stabilizer for cohesive as well as for non cohesive. This material generally derived from the by product of timber and paper industries .It is find out that unconfined compressive strength of soil stabilized with ligin increases up to ligin percentage of 12% after further increase in ligin percentage , it slightly decreases . The similar trends also find out in the CBR test results.

Robert Nini [19] studied the CBR values for soaked condition with the placement of sandy layer. The main purpose is that to increase the CBR value of clay instead of using the geogrid or any other geosynthetic material but by drainage. The drainage can be obtained by using the sand layer. The six different type of soil are to be taken and placing the sandy layer at different position. CBR value is to be finding out and compare with or without the sand layer. It is find out that CBR value is increased for soil with the sand layer.

CHAPTER 3

MATERIALS AND METHODS

In order to fulfill the objectives of the present project on CBR on clay and sandy soils with geogrid is to be done. The materials and methodology are explained in the following paragraphs.

3.1 Materials used for the Investigation:

In the present study sand and clay soil with geogrid are to be used.

Sand: Sand is a generally composed of finely grouped rock and minerals particles. The soil particles which may pass through 4.75mm sieve and retained on 75micron sieve is termed sand. For the classification of sand types we take the help of sieves analysis.

Clay: Clay has very fine size particles which are much smaller than silt particles i.e. the soil which may pass through the 2 micron size is known as clay. The characterization clay is to be done with A line chart.

Geogrid: These are just like a net having large opening made of polymers likes as high density polyethylene and polypropylene etc. These opening are to be called as apertures. These apertures allow the geogrid to makes better interlocking with the soil and boulders such that it works as reinforcement.

Water: Normally tap water is used which is available in Geotechnical laboratory.

3.2 Methodology for the Investigation:

In the present project after finding out the index properties of the soil and methodology of them is describe as

1. To find out the general properties of subgrade soil (i.e. clay and sandy soil) and Geogrid.
2. Find MDD by Standard Proctor test.
3. Find out CBR value for soaked and unsoaked sample at different surcharge load i.e. 5kg, 7.5kg and 10kg.

4. Find out CBR value Geogrid reinforced sample at different location at different surcharge.
5. Variable quantities are-

-Surcharge

-Methods of compaction.

-Position of geogrid (At 0.50H and 0.67H from the top of mould).

-Soil (sandy and clay)

Draw the different curve for CBR and analyses them.

3.3 Test to be conducted is:

3.3.1 Specific Gravity (IS-2720-Part-3-1980):

Specific gravity is defined as the ratio of unit weight of solid to the unit weight of water. Specific gravity is used for determination of many engineering properties of soil indirectly or directly by many derived equations. Specific gravity can be finding out by Pycnometer.

3.3.2 Liquid Limit (IS- 2720-Part-5-1985):

Water is added to the soil put it into the Cassagrande's apparatus and a groove of 2mm is to be cut and blows are given to the apparatus over the rubber pad. Numbers of blows are to be counted to close the groove. The water content at which 25 blows required to closethe groove is taken as liquid limit.

3.3.3 Plastic Limit (IS- 2720-Part-5-1985):

Plastic limit of the soil is that at which a soil when we rolled into a thread of 3mm diameter start to crumble. The minimum water content at which soil is in plastic stage is called plastic limit water content.

3.3.4 Proctor Compaction Test (IS-Part-7-1974):

Proctor compaction test is used to determine the relationship between the water content and the dry density of the soil at a specified compactive effort. From this we find out optimum moisture content corresponding to maximum dry density.

3.3.5 Direct Shear Test (IS-2720: Part-13-1986):

Direct shear test is used to the determination of the shear strength parameter i.e. cohesion and internal angle of friction. A standard size 60mmx60mm box was used to perform direct shear test. Minimum three tests are to be conducted to find out the shear strength parameters. Here we conducting the test on different three normal stresses i.e. 50, 100, 150KPa and the shear strength parameter are to be finding out by plotting a straight line from the graph of shear stress v/s normal stresses.

3.3.6 CBR Test:

CBR apparatus is consisting of a mould 150 mm diameter having a base plate and collar, loading frame and dial gauge to measure the penetration. In case of soaking, mould is placed in water for 4 days then swelling and water absorption is to be noted. It consist of a standard piston of area 0.1962cm^2 (diameter is 50 mm) is penetrate in the soil at the standard rate of 1.25 mm/min. CBR value is equal to the ratio of load carried by the specimen at 2.5 mm or 5mm penetration to the load carried by the standard specimen . In most of cases CBR value at 2.5 mm is more than at 5mm. The standard loads of crushed stones are 1370kg (7000KN/m^2) and 2055kg (10500KN/m^2) at 2.5mm and 5mm penetration respectively.

CBR value as percentage of actual load cause penetration of 2.5mm or 5mm to the standard load is shown below as

$$CBR = \frac{Load\ carried\ by\ the\ specimen}{Load\ carried\ by\ standard\ specimen} * 100$$

Here two value of CBR is to be obtained .When it comes out higher at 2.5mm than at 5mm penetration then we will adopt the former one. If its vice versa is comes out than repeats the test for rechecking.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Results of the tests carried out-

The geotechnical properties of soil determined as per IS Code 2720 (part 1-40) which are reflected in the following section.

4.1.1 Specific Gravity:

Table2: Determination of specific gravity

Pycnometer	**A**	B	C
Mass of Empty bottle, M1 (g)	222.50	167.90	221.60
Mass of bottle + dry soil, M2 (g)	280.90	223.80	278.90
Mass of bottle + soil + water, Mass of bottle filled with water M_3 (g)	543.20	502.00	543.80
M4 (g)	504.70	465.50	507.60
Specific gravity, G	2.57	2.60	2.70
Average specific gravity, G	2.63		

4.1.2 Sieves Analysis:

Table3 Sieves analysis of clay soil:

Sieve sizes (mm)	**Mass of Soil Retained(gm.)**	**Percent Retained (%)**	**Cumulative Percent Retained (%)**	**Cumulative Percent Finer (%)**
4.75	5.70	1.33	1.13	98.87
2.36	10.50	2.10	3.43	96.57
1.15	40.20	8.10	11.53	88.47
0.425	60.67	12.1	23.63	73.37
0.300	40.20	8.12	31.75	68.25
0.212	30.70	5.99	37.74	62.26
0.150	23.10	5.10	41.84	58.16
0.075	40.00	8.00	49.20	50.80
Pan	250.90	50.80	100.00	0

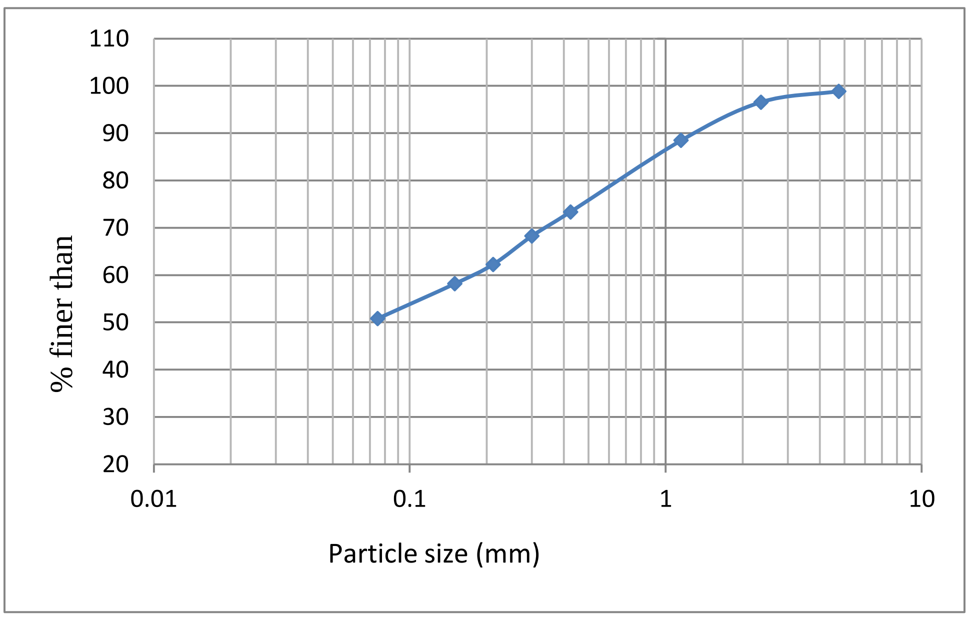

Fig.3 Particle size distribution of clay

Table 4 Sieve analysis of sand

Sieve sizes (mm)	Mass of Soil Retained(gm.)	Percent Retained (%)	Cumulative Percent Retained (%)	Cumulative Percent Finer (%)
4.75	50.32	5.03	5.03	94.17
2.36	67.91	6.79	11.82	88.17
1.15	157.00	15.60	27.63	72.37
0.6	103.32	10.33	37.80	61.98
0.300	138.11	13.81	51.71	48.18
0.150	251.40	25.14	76.86	23.14
0.075	187.31	18.73	95.50	4.41
Pan	44.05	4.40	100.00	0

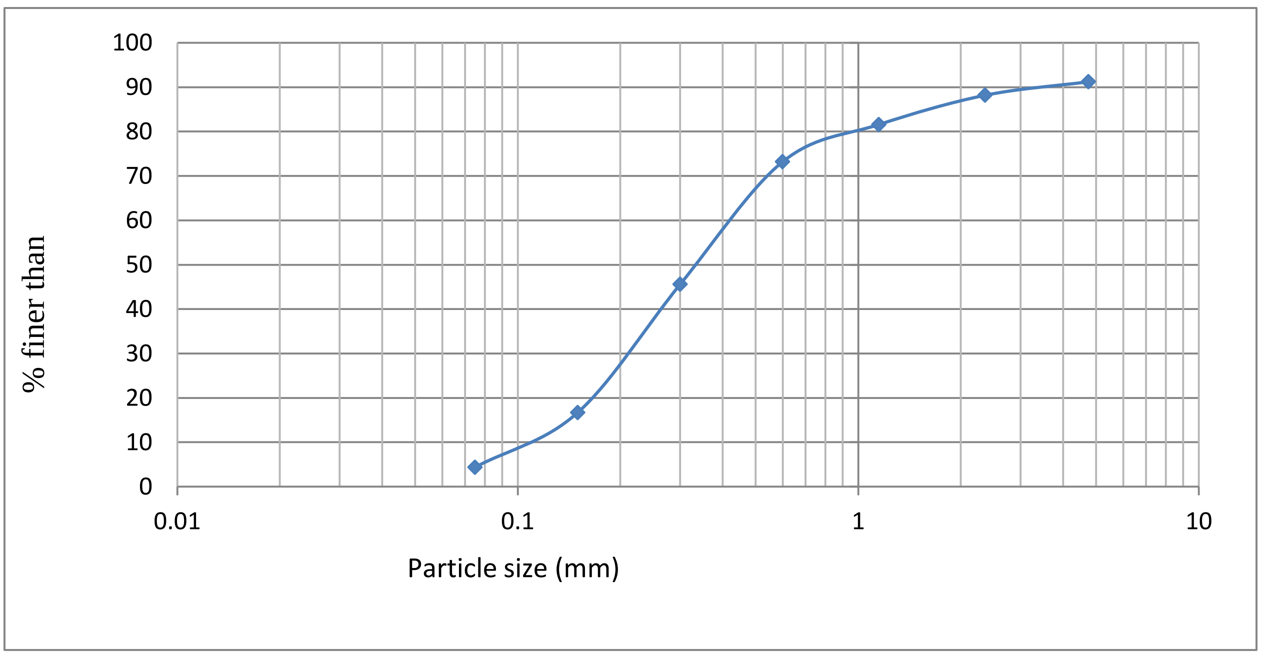

Fig.4 Particle size distribution of sand

4.1.3 Proctor Compaction Test :

Table 5 Modified Proctor test for clay

Water content (%)	Dry density(KN/m^3)
12.00	17.80
14.00	18.10
16.00	18.20
18.00	17.90
19.00	17.80

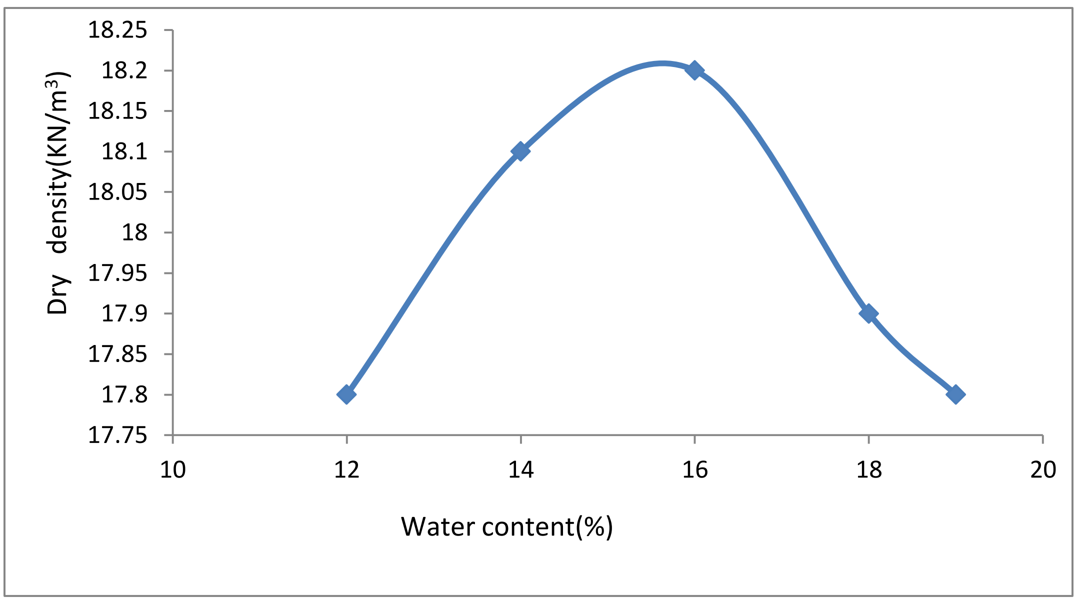

Fig.5 Compaction curve of clay

Table 6- Modified Proctor test for sand

Water content (%)	Dry density (KN/m^3)
5.00	17.00
7.00	17.30
10.00	17.74
12.00	17.67
15.00	17.35
17.00	17.12

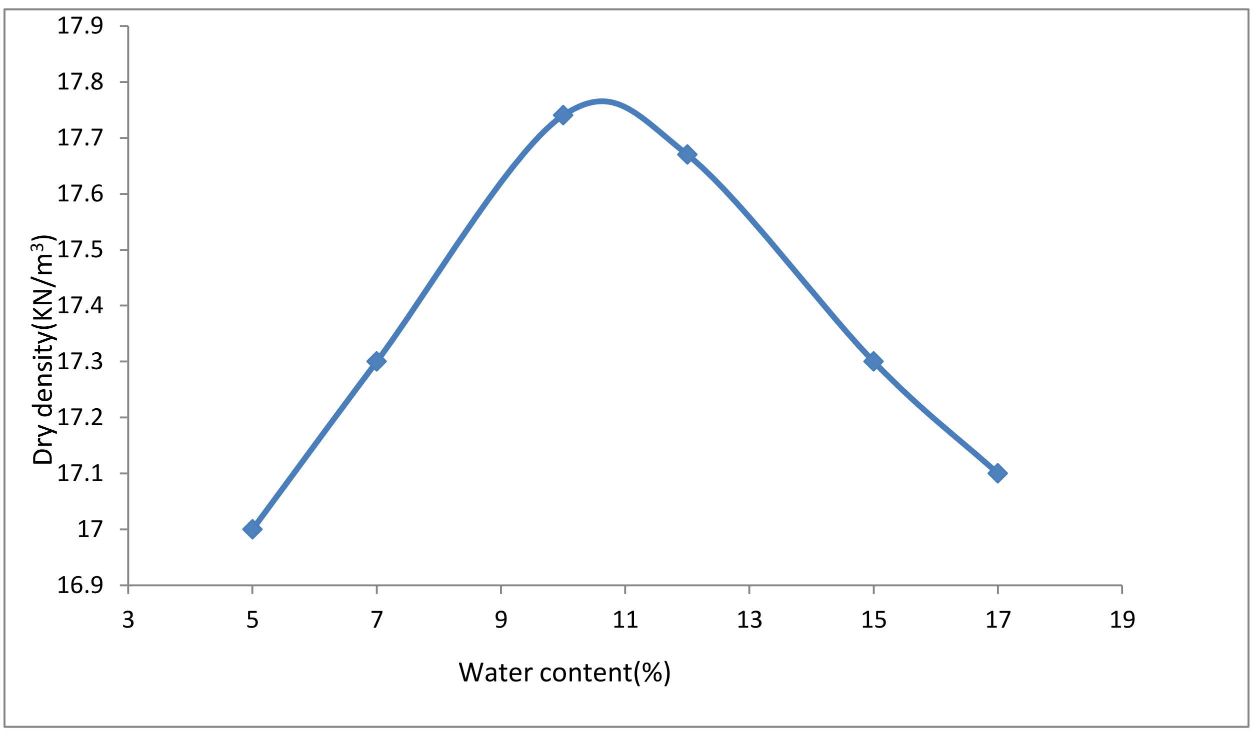

Fig.6 Compaction curve of sand

Table7- Properties of clay soil

Properties	Value
Maximum dry density (KN/m^3)	18.20
Optimum moisture content (%)	16.00
Liquid limit (%)	48.00
Plastic limit (%)	26.00
Plasticity index (%)	22.00
Specific gravity	2.63
Classification of soil	CI

Table8 Properties of sand soil

Properties	Value
Maximum dry density (KN/m^3)	17.74
Optimum moisture content (%)	9.74
Liquid limit (%)	NA
Plastic limit (%)	NA
Plasticity index (%)	NA
Specific gravity	2.67
Coefficient of uniformity (C_u)	3.34
Coefficient of curvature (C_c)	1.25
Classification of soil	SP

4.1.4 Geogrid properties:

Table 9 Properties of Geogrid

Properties	Value
Weight/Area (N/m^2)	3.05
Aperture length(m)	0.04
Aperture width(m)	0.31
Aperture thickness(m)	0.01
Thickness at junction(m)	0.004
Tensile strength @ 2% strain(KN/m)	6.00
Tensile strength @ 5% strain(KN/m)	11.80
Ultimate tensile strength(KN/m)	19.10
Flexural stiffness(KN/m^2)	0.75
Colour of geogrid	Black

These geogrid properties are provided by courtesy Garware Wall Ropes Limited Kirti Nagar, New Delhi.

4.1.5 Scanning Electron Microscope (SEM) Results:

SEM is performed at three scales (5 µm, 10 µm, 20 µm) and at two scales (200 µm, 500 µm) for clay and sand. From the figures it is observed that soil particles are angular in nature and have some silica in case of sand and in case of clay soil particles are plate like structure and having more surface area.

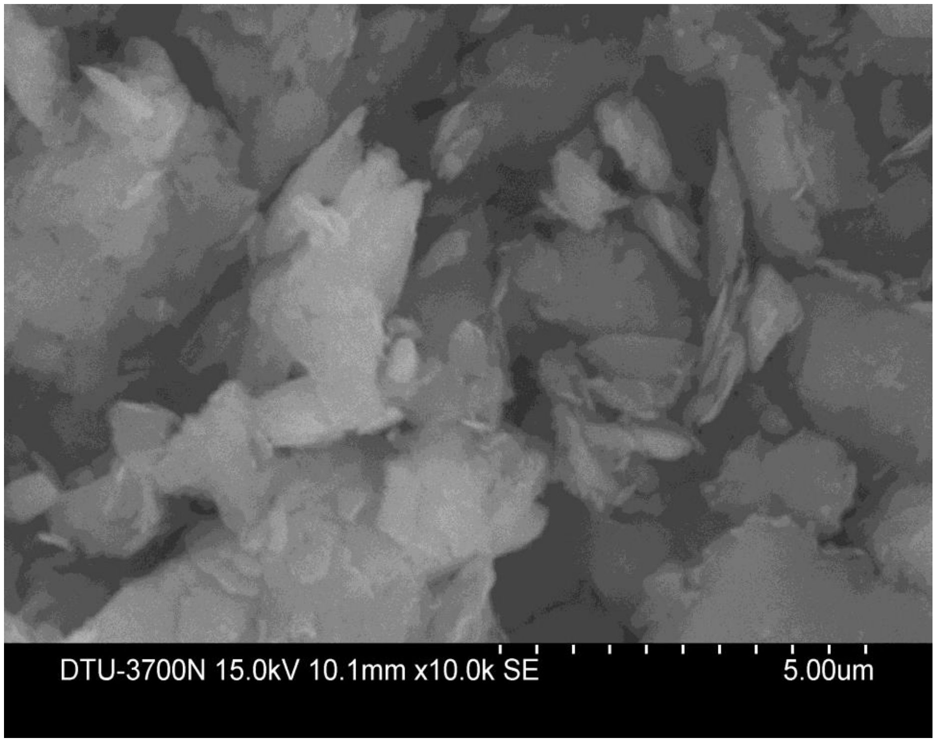

Fig.7 SEM of clay at 5µm

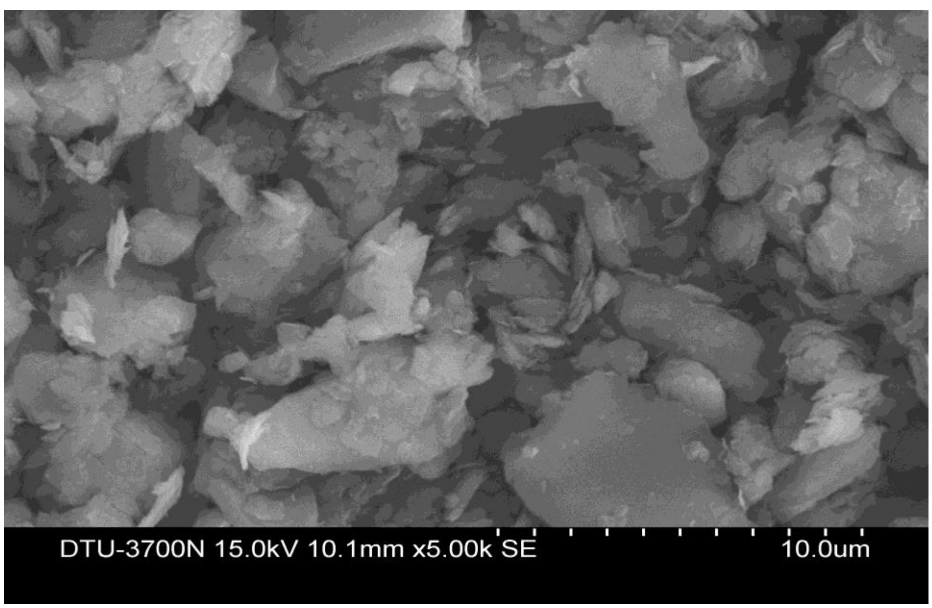

Fig.8 SEM of clay at 10µm

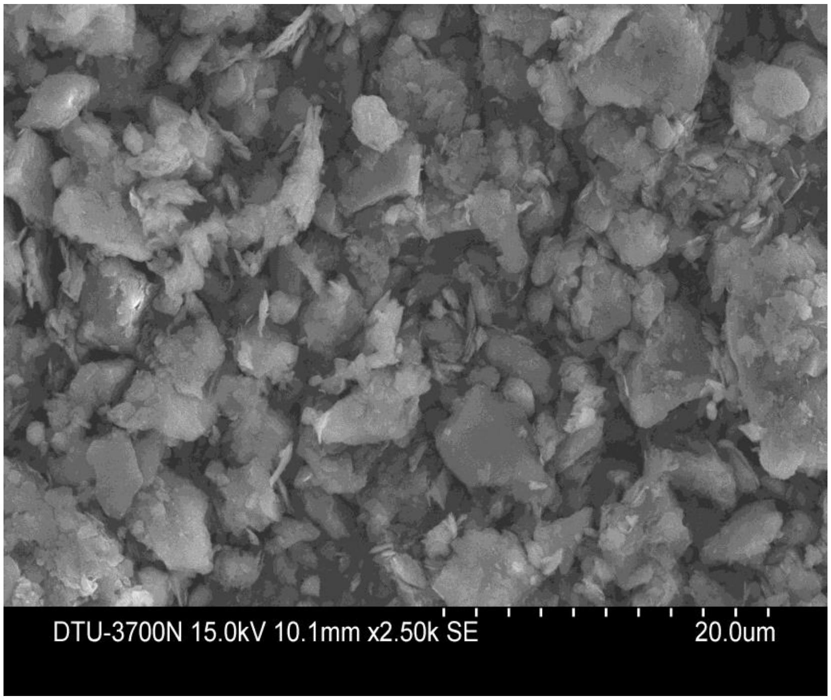

Fig9. SEM of clay at 20μm

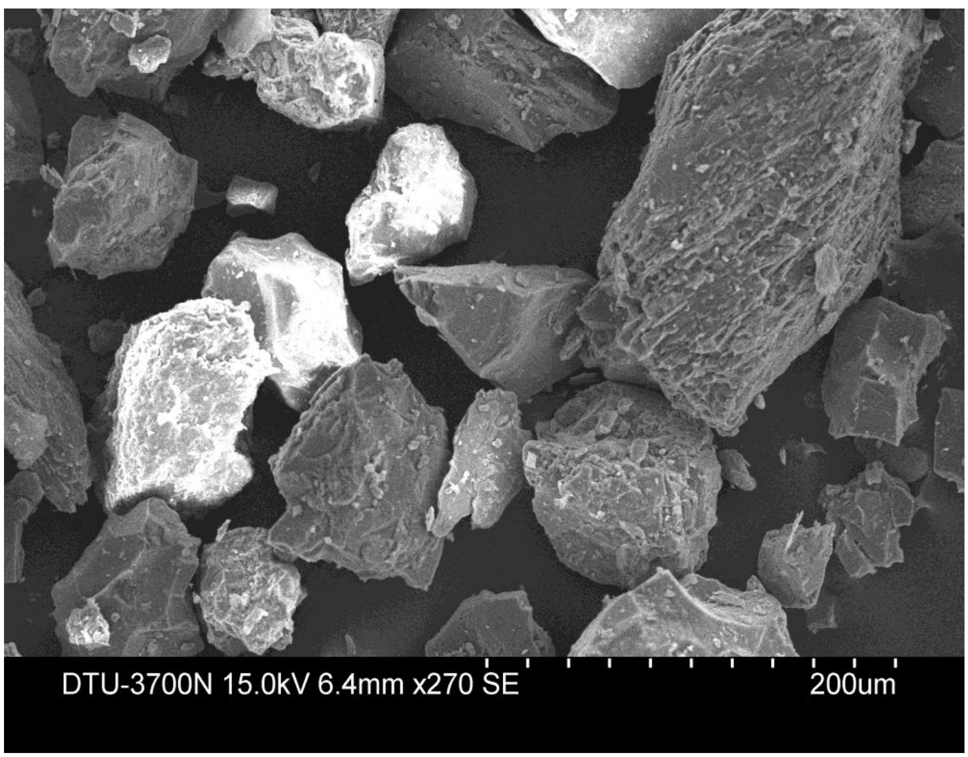

Fig.10 SEM of sand at 200μm

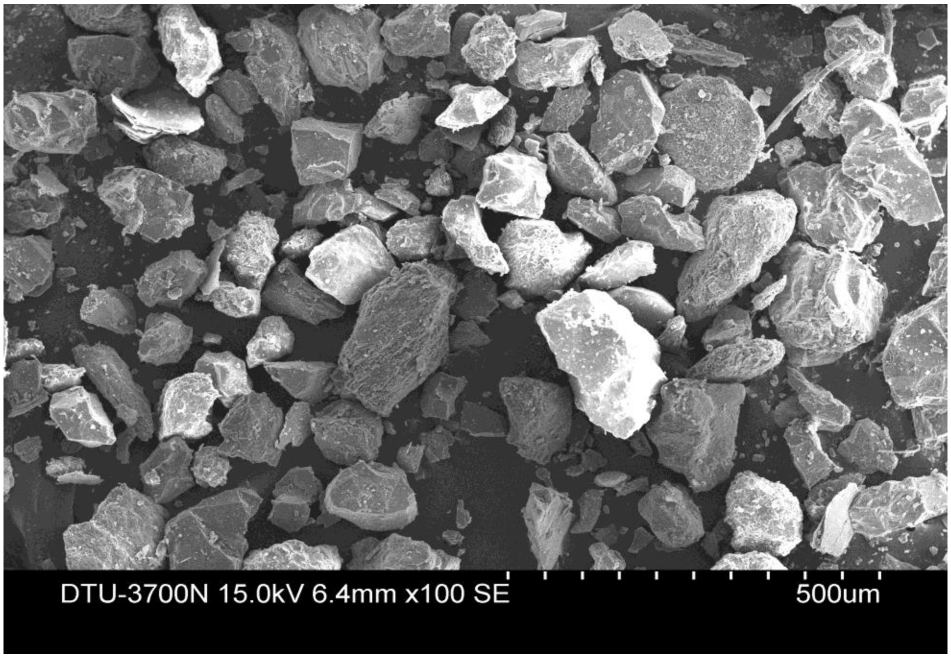

Fig.11 SEM of sand at 500µm

4.1.6 Direct shear test:

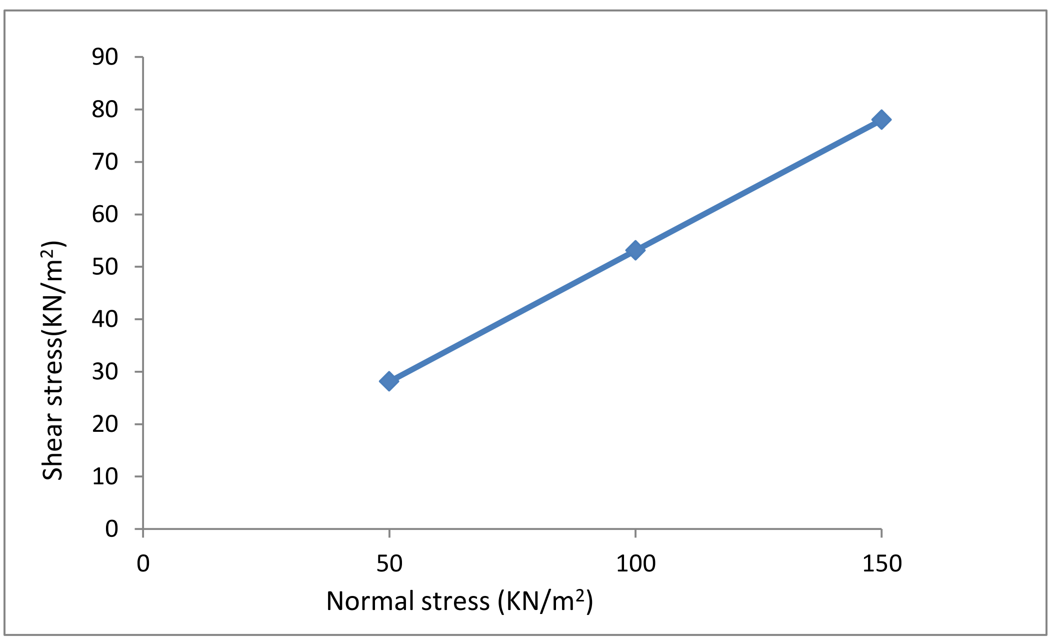

Fig.12 Variation of shear stress v/s normal stress in direct shear test on sand

The angle of internal friction and cohesion for sandy soil are 28.25^0 and zero.

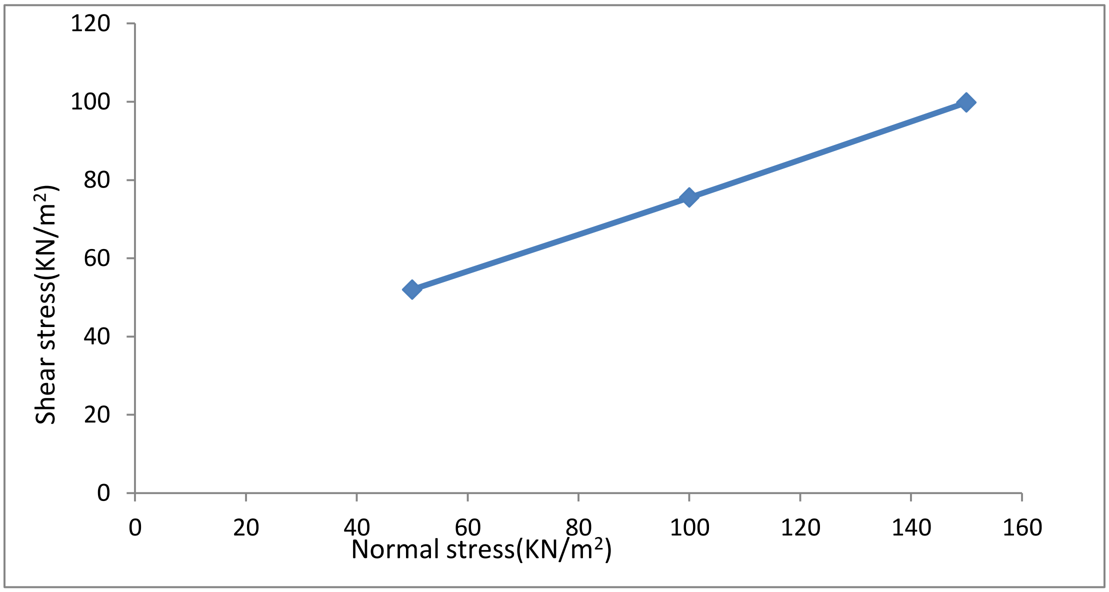

Fig.13 Variation of shear stress v/s normal stress in direct shear test on clay

The angle of internal friction and cohesion for sandy soil are 23^0 and $30KN/m^2$

4.2 Results of CBR Test:

Fig.14 Photograph of CBR apparatus with specimen.

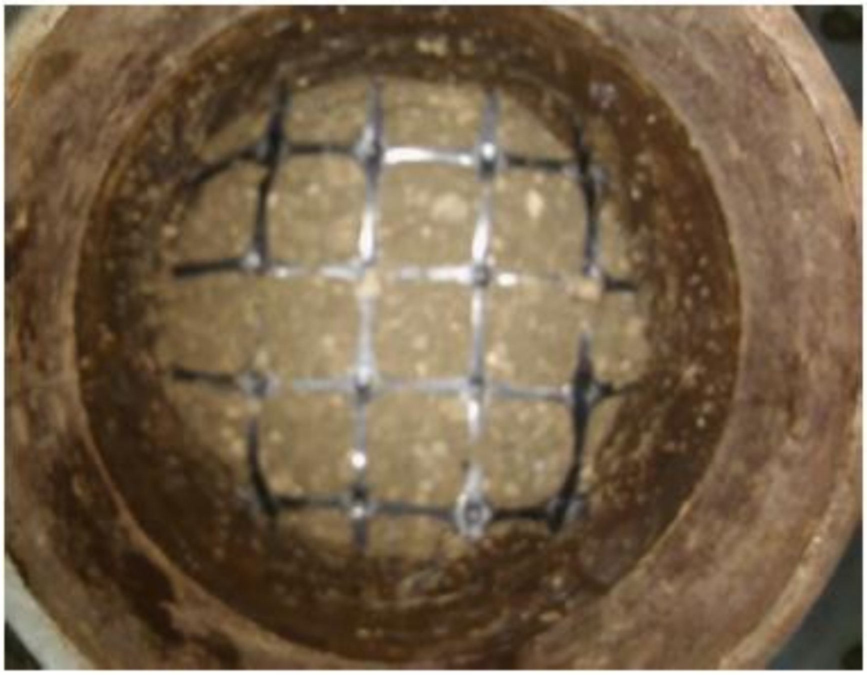

Fig.15 Photograph of CBR mould with geogrid.

Fig.16 Photograph of CBR mould for soaking condition.

4.2.1 Clay with 5kg surcharge (Heavy compaction):

Table 10 Load v/s penetration values of Clay and clay with geogrid at 5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with1 layer of geogrid	Load on soil with 2 layer of geogrid
	0	0	0
0.50	7.00	11.50	17.10
1.00	22.00	29.40	36.20
1.50	35.00	41.20	48.20
2.00	44.00	52.10	58.00
2.50	53.50	60.10	67.30
3.00	60.00	65.30	72.10
4.00	66.20	71.60	78.40
4.50	72.00	77.80	82.00
5.00	77.00	85.20	89.20
7.00	96.00	101.00	105.00
7.50	103.00	107.00	111.00
8.00	110.00	113.00	118.50
9.00	115.00	118.00	126.00
10.00	118.00	123.40	128.00
12.50	126.00	133.00	139.60

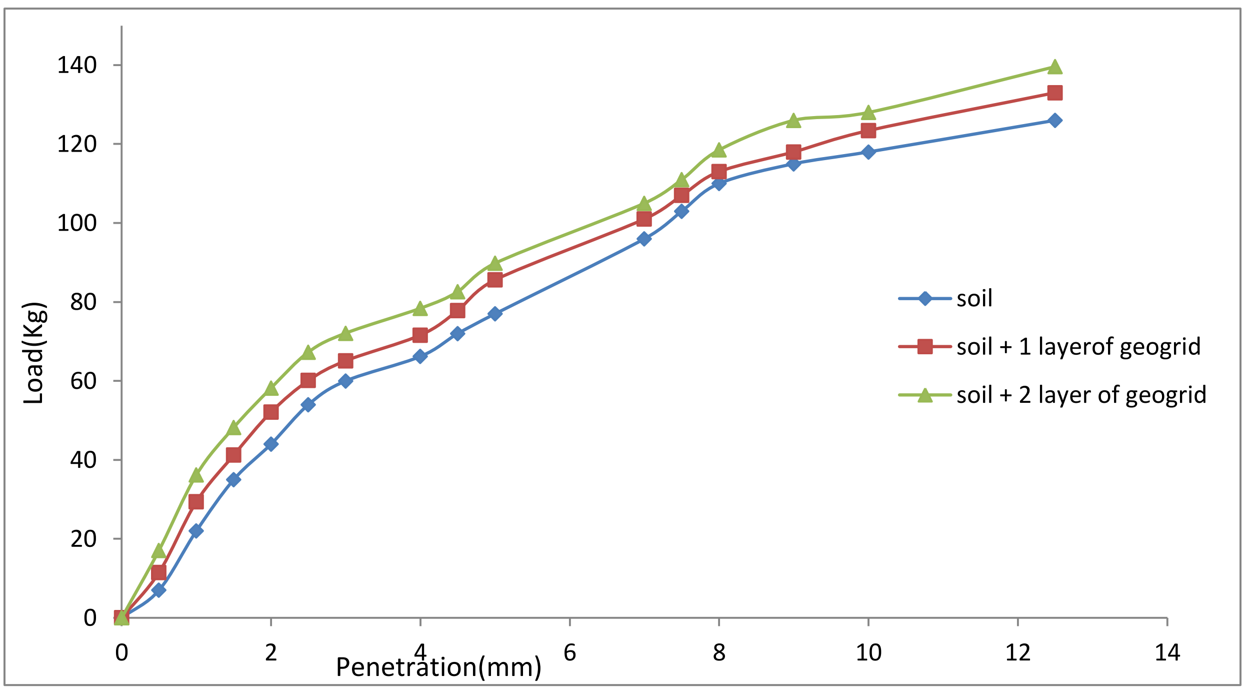

Fig.17 Load v/s penetration of Clay with 5kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 3.9%, 4.4% and 4.9%.

<u>4.2.2 Clay with 7.5kg surcharge (Heavy compaction):</u>

Table 11 Load v/s penetration values of Clay and clay with geogrid at 7.5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	12.70	18.80	26.40
1.00	28.60	23.40	39.40
1.50	38.22	45.30	51.10
2.00	47.10	54.10	62.20
2.50	57.10	62.20	70.60
3.00	61.00	68.10	76.30
4.00	68.70	73.30	82.20
4.50	73.40	79.40	87.40
5.00	80.00	86.00	94.40
7.00	99.70	103.20	109.60
7.50	105.20	108.60	113.80
8.00	110.60	116.00	120.70
9.00	120.50	124.00	131.00
10.00	127.00	131.20	139.00
12.50	140.60	148.80	159.00

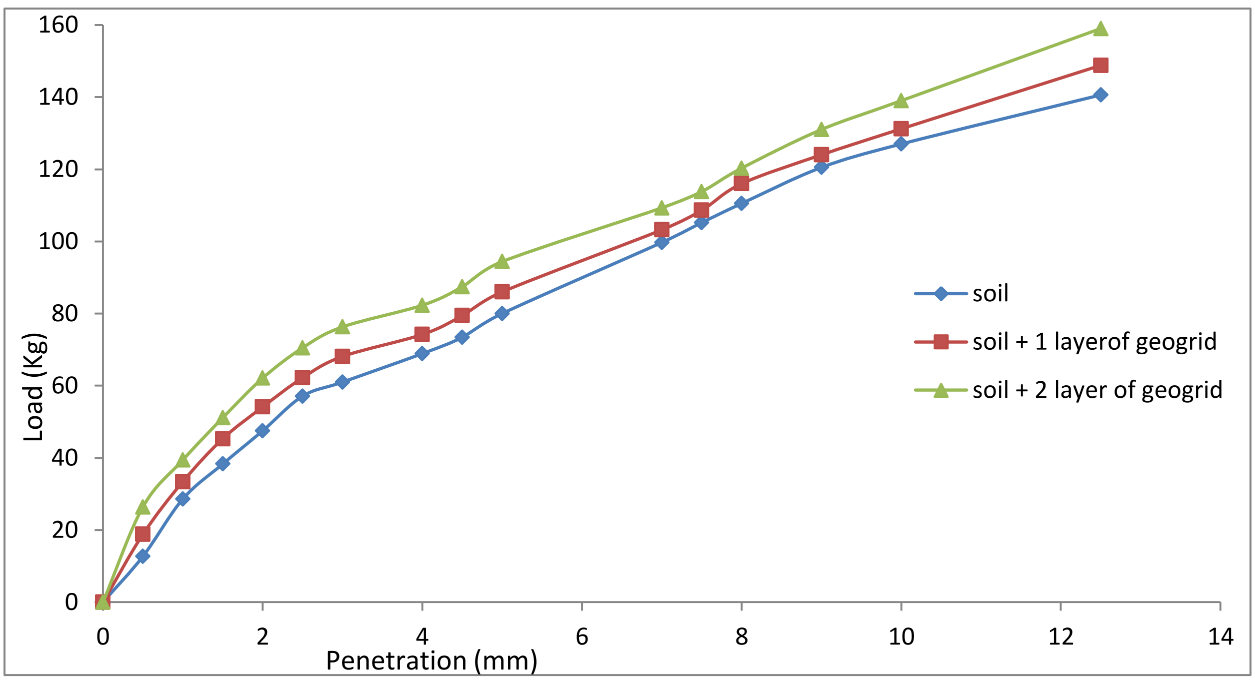

Fig.18 Load v/s penetration of Clay with 7.5kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 4.2%, 4.6% and 5.1%.

4.2.3 Clay with 10 kg surcharge (Heavy compaction):

Table12 Load v/s penetration values of Clay and clay with geogrid at 10 kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	16.30	21.30	30.10
1.00	32.10	36.50	43.10
1.50	43.70	49.10	54.20
2.00	53.10	57.89	65.40
2.50	60.50	65.50	74.40
3.00	66.70	73.30	79.40
4.00	72.40	78.10	86.70
4.50	77.30	83.40	92.00
5.00	84.00	90.00	97.60
7.00	100.80	104.20	113.30
7.50	106.80	109.50	120.0
8.00	113.40	121.70	125.40
9.00	124.30	131.50	136.00
10.00	131.80	138.00	145.10
12.50	148.00	155.00	167.7.00

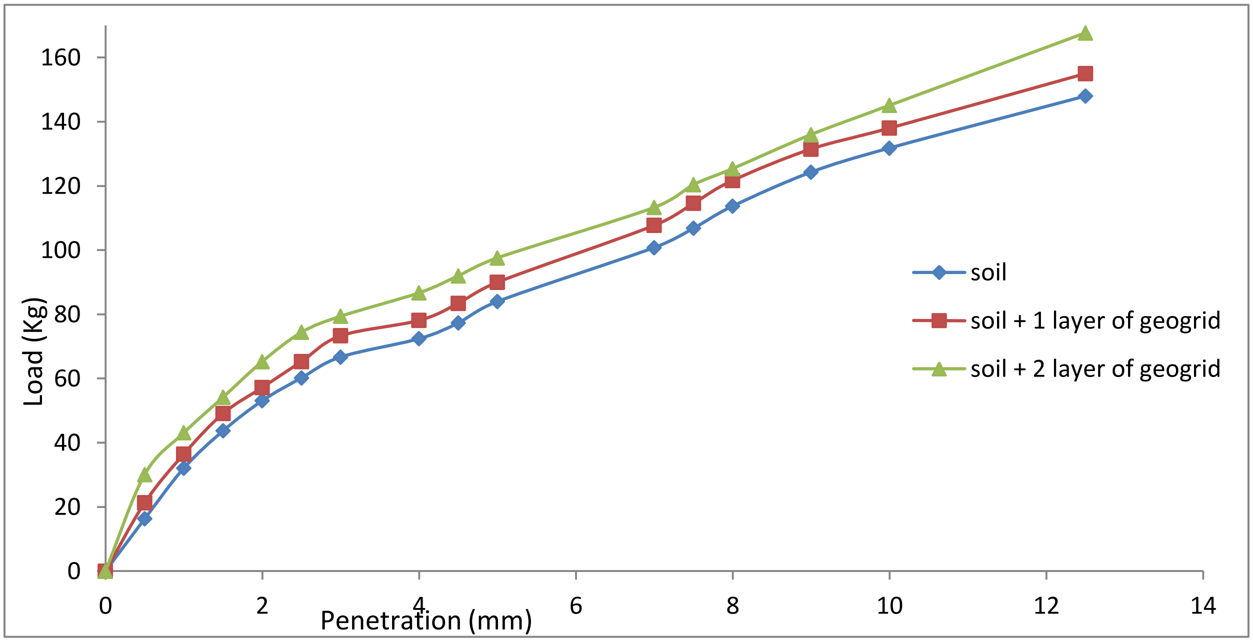

Fig19 Load v/s penetration of Clay with 10kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 4.5%, 4.8% and 5.4%.

4.2.4 Clay with 5kg surcharge (Light compaction):

Table 13 Load v/s penetration values Clay and clay with geogrid at 5kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	6.20	9.20	15.50
1.00	16.30	22.20	29.60
1.50	29.10	33.50	38.20
2.00	35.50	41.30	48.20
2.50	42.70	48.60	54.70
3.00	49.80	53.60	61.80
4.00	55.30	61.00	68.80
4.50	58.90	66.20	73.40
5.00	64.00	72.40	78.50
7.00	81.00	88.00	94.40
7.50	87.30	92.70	100.10
8.00	92.20	98.20	106.70
9.00	109.80	110.90	115.00
10.00	115.60	119.10	124.00
12.50	128.50	135.00	140.60

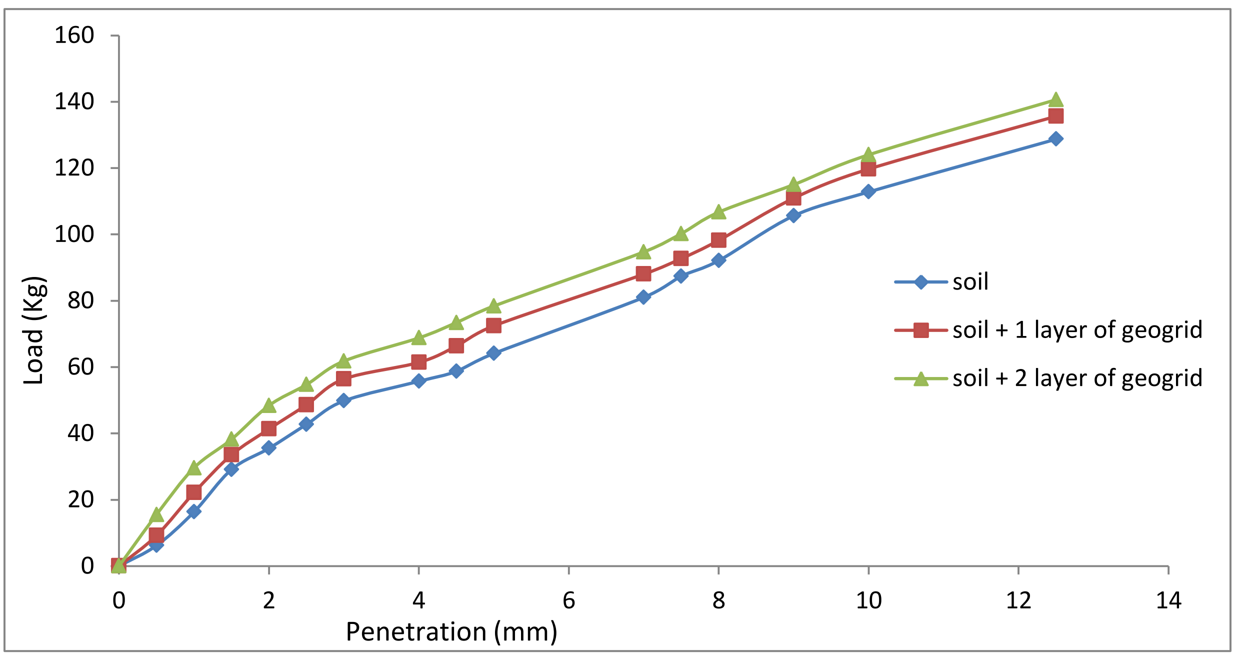

Fig. 20 Load v/s penetration of Clay with 5kg surcharge (Light compaction)

CBR value of soil and soil with geogrid are 3.1%, 3.5% and 4.0%.

4.2.5 Clay with 7.5kg surcharge (Light compaction):

Table 14 Load v/s penetration values of Clay and clay with geogrid at 7.5kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	9.20	13.40	17.30
1.00	20.20	27.50	33.40
1.50	31.40	38.60	42.70
2.00	40.60	45.50	52.50
2.50	47.20	53.90	58.40
3.00	53.10	60.00	65.70
4.00	58.14	65.00	72.10
4.50	62.34	69.40	78.10
5.00	68.89	74.40	87.60
7.00	87.60	95.40	106.00
7.50	93.40	103.00	110.40
8.00	101.20	110.00	116.40
9.00	112.10	118.90	126.80
10.00	120.10	126.00	136.00
12.50	128.21	137.00	147.60

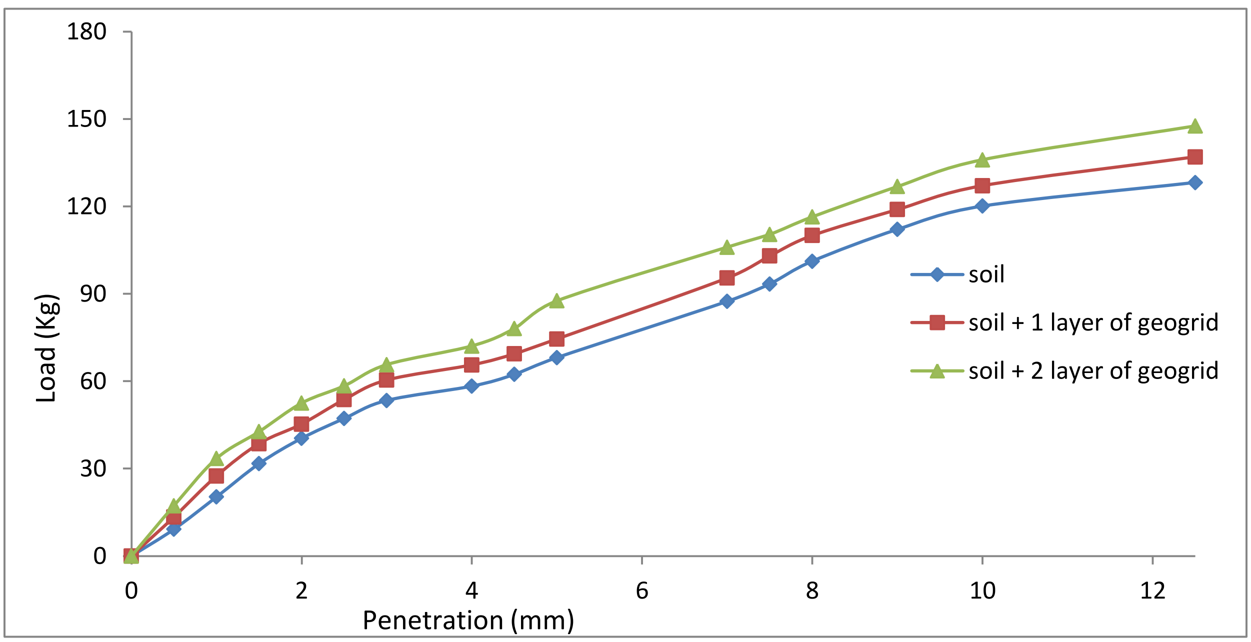

Fig21. Load v/s penetration of Clay with 7.5kg surcharge (Light compaction)

CBR value of soil and soil with geogrid are 3.4%, 3.9% and 4.2%.

4.2.6 Clay with 10kg surcharge (Light compaction):

Table 15 Load v/s penetration values Clay and clay with geogrid at 10kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	12.30	15.60	20.60
1.00	24.40	31.50	38.50
1.50	37.60	42.70	48.60
2.00	45.70	49.80	56.60
2.50	53.50	57.70	64.80
3.00	58.10	65.30	70.50
4.00	65.30	74.00	81.40
4.50	70.50	81.00	90.00
5.00	76.44	86.00	95.00
7.00	93.50	106.00	113.00
7.50	98.50	114.00	121.00
8.00	105.80	118.00	128.00
9.00	117.20	126.00	137.00
10.00	123.40	131.00	142.00
12.50	137.30	145.00	156.70

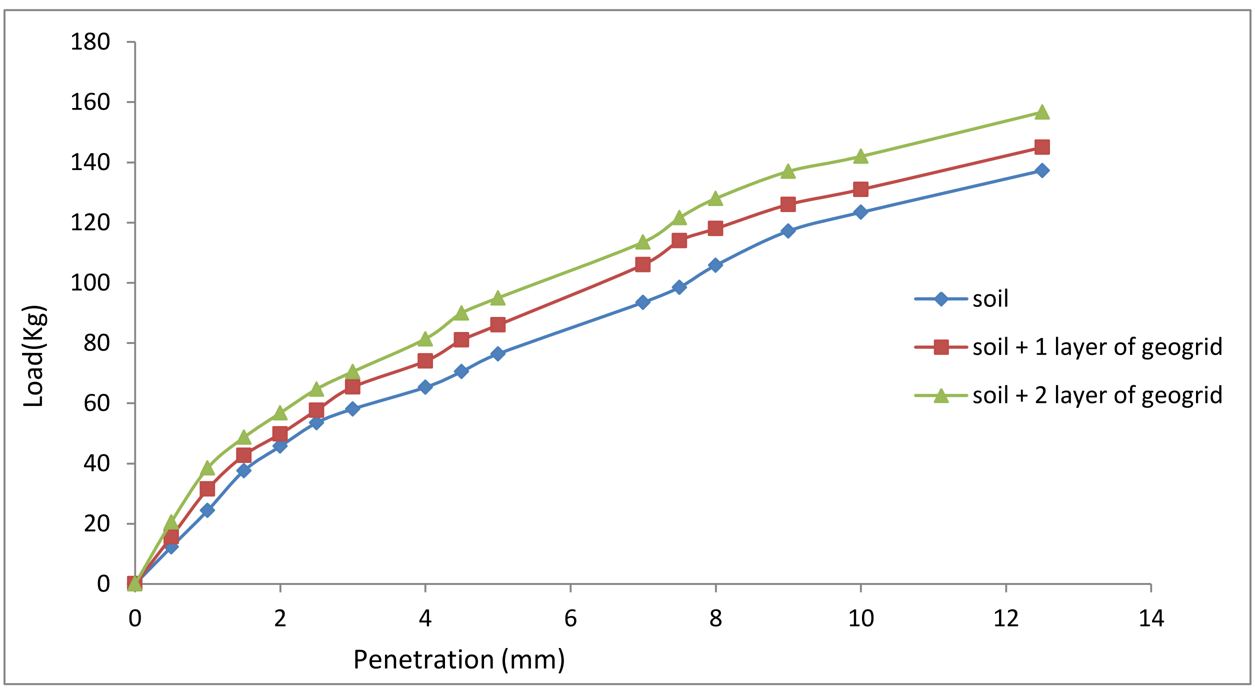

Fig22. Load v/s penetration of Clay with 10 kg surcharge (Light compaction)

CBR value of soil and soil with geogrid are 3.9%, 4.2% and 4.7%.

<u>4.2.7 Sand with 5kg surcharge (Heavy compaction):</u>

Table16 Load v/s penetration values sand and sand with geogrid at 5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	50.00	65.00	85.00
1.00	80.60	98.70	120.76
1.50	127.00	145.00	163.00
2.00	170.00	185.00	198.00
2.50	195.00	210.00	224.00
3.00	225.00	245.00	265.00
4.00	250.00	290.00	310.00
4.50	280.00	315.00	335.00
5.00	295.30	340.00	357.00
7.00	340.00	375.00	397.00
7.50	350.00	390.00	420.00
8.00	365.20	415.60	445.00
9.00	387.40	445.80	470.00
10.00	410.00	470.00	505.20
12.50	475.00	520.00	541.60

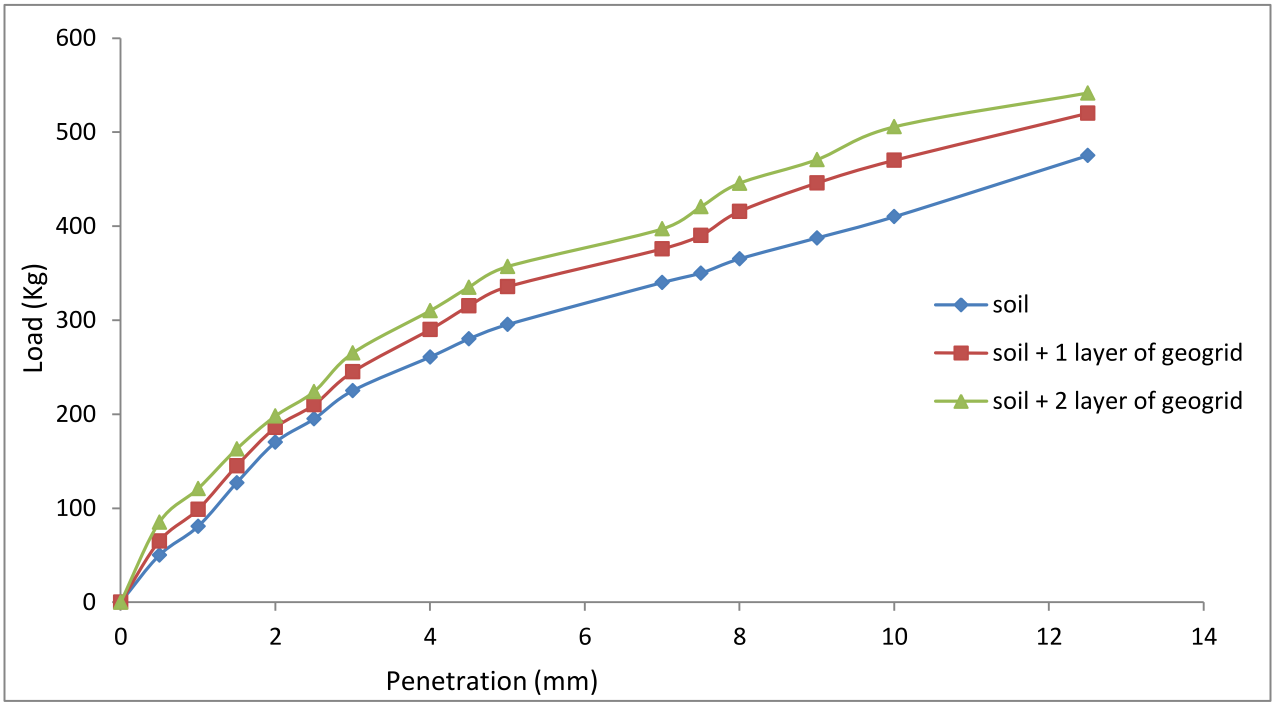

Fig23. Load v/s penetration of sand with 5kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 14.3%, 15.32% and 16.35%.

<u>4.2.8 Sand with 7.5 kg surcharge (Heavy compaction):</u>

Table 17 Load v/s penetration values of sand and sand with geogrid at 7.5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	59.20	72.40	92.40
1.00	90.70	107.70	127.00
1.50	139.00	153.00	173.40
2.00	190.00	199.00	210.60
2.50	210.00	230.00	245.50
3.00	235.80	256.80	275.40
4.00	268.30	298.60	325.60
4.50	289.70	321.80	358.00
5.00	315.20	340.70	380.00
7.00	350.10	390.40	430.00
7.50	370.50	411.30	450.60
8.00	397.80	432.00	475.40
9.00	414.10	460.00	515.00
10.0	430.00	490.00	550.10
12.50	485.50	535.90	591.00

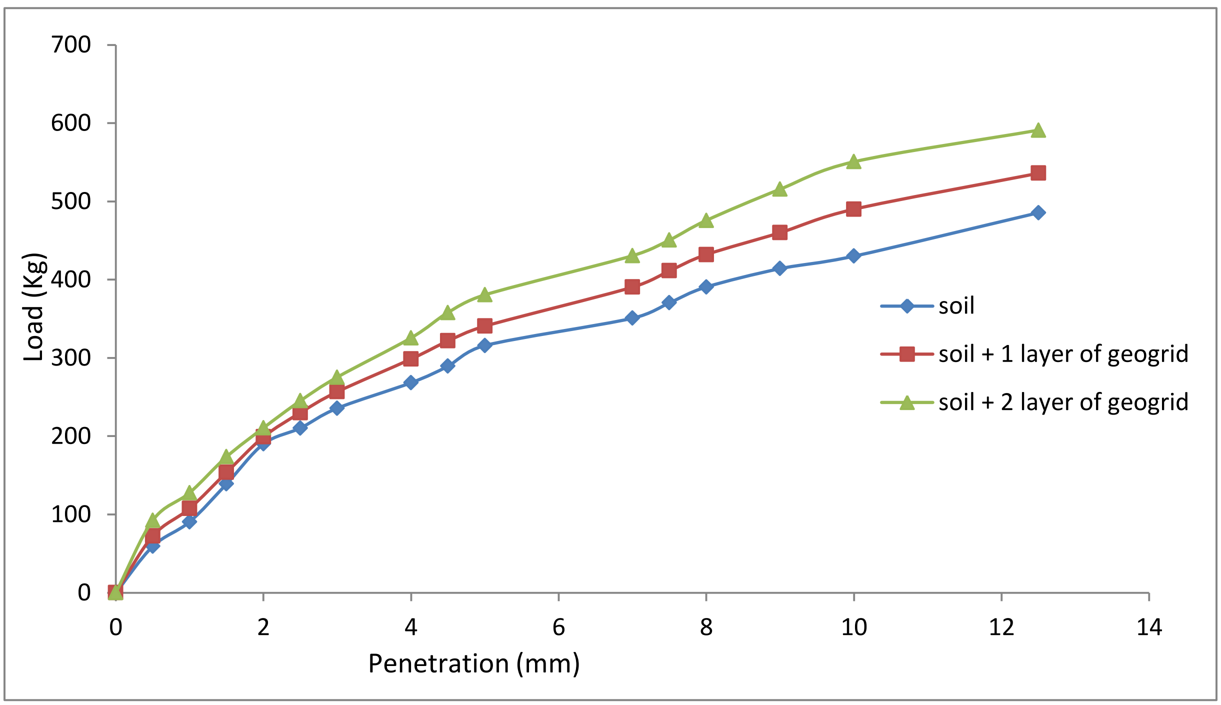

Fig24. Load v/s penetration of sand with 7.5kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 15.3%, 16.7% and 17.9%.

4.2.9 Sand with 10 kg surcharge (Heavy compaction):

Table18 Load v/s penetration values of sand and sand with geogrid at 10 kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	62.50	75.60	98.00
1.00	103.80	120.30	138.60
1.50	153.60	173.10	190.20
2.00	182.30	210.50	225.70
2.50	225.50	241.70	273.80
3.00	245.12	261.30	290.90
4.00	277.30	304.00	345.30
4.50	298.10	330.60	370.40
5.00	325.10	358.30	403.10
7.00	360.90	400.80	456.60
7.50	385.80	420.50	490.50
8.00	400.20	441.60	507.50
9.00	425.60	468.70	540.60
10.00	450.60	497.40	575.10
12.50	498.30	545.60	603.60

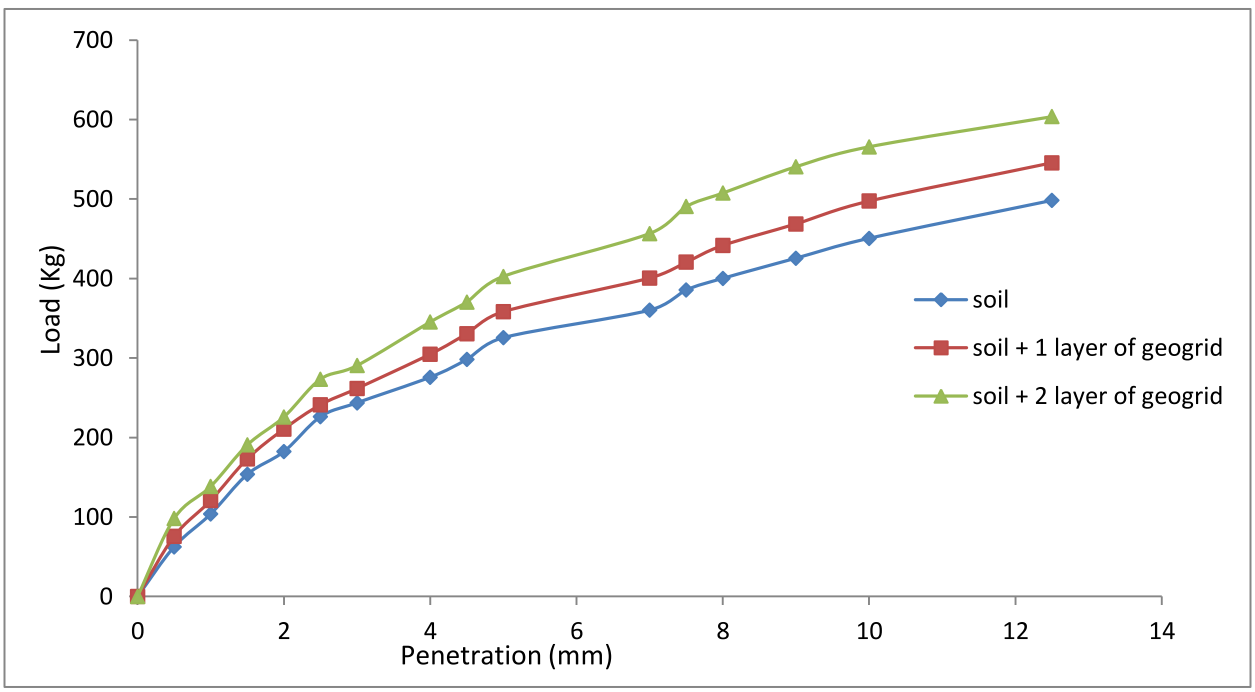

Fig25. Load v/s penetration of sand with 10 kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 16.5%, 17.6% and 20.1%.

4.2.10 Sand with 5kg surcharge (Light compaction):

Table 19 Load v/s penetration values of sand and sand with geogrid at 5kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	41.20	52.60	60.20
1.00	75.60	88.70	98.20
1.50	120.00	128.60	136.50
2.00	160.00	168.50	181.40
2.50	184.20	191.20	201.20
3.00	200.00	208.30	221.60
4.00	222.50	234.00	242.00
4.50	231.40	241.20	251.60
5.00	246.70	251.00	264.80
7.00	290.20	298.00	319.00
7.50	310.40	325.00	339.00
8.00	325.10	342.20	365.00
9.00	350.10	368.20	389.40
10.00	374.20	388.10	420.60
12.50	415.10	429.30	450.20

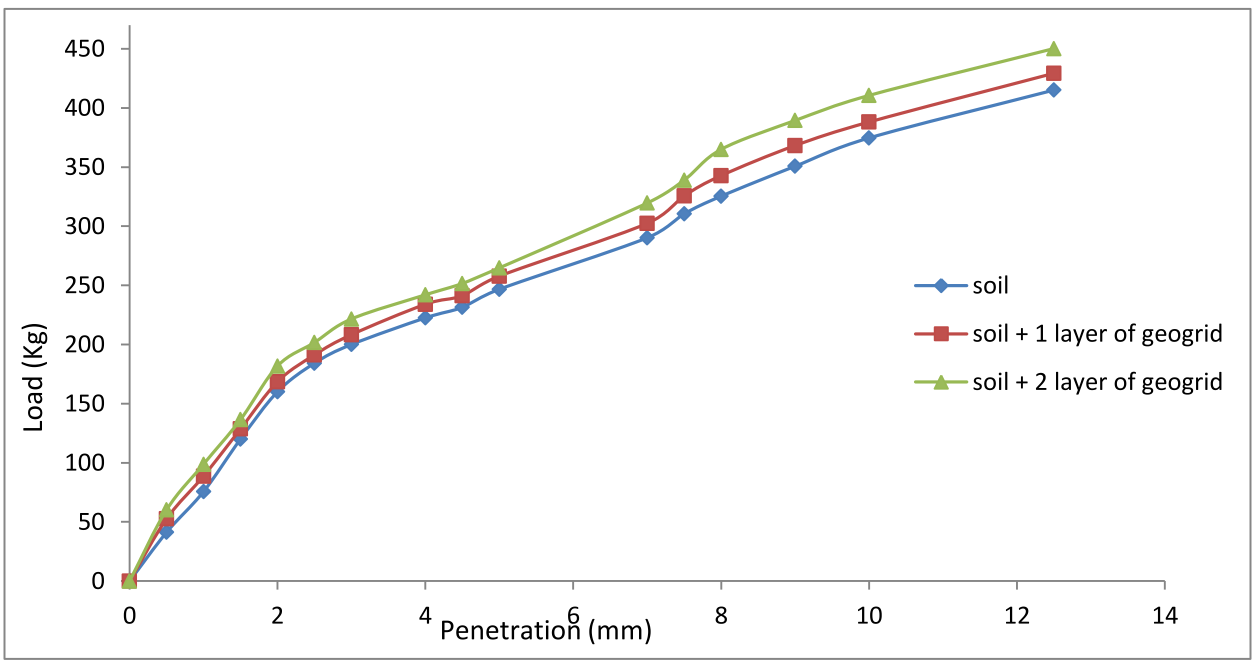

Fig26. Load v/s penetration of sand with 5kg surcharge (Light compaction)

CBR value of soil and soil with geogrid are 13.44%, 13.9% and 14.5%.

<u>4.2.11 Sand with 7.5kg surcharge (Light compaction):</u>

Table-20 Load v/s penetration values of sand and sand with geogrid at 7.5kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	50.60	58.70	67.50
1.00	88.00	98.00	107.80
1.50	128.00	139.50	153.00
2.00	167.00	178.00	189.00
2.50	187.40	199.00	214.00
3.00	205.40	216.00	229.00
4.00	228.20	239.00	253.00
4.50	237.60	251.00	268.00
5.00	260.00	269.00	284.00
7.00	302.30	315.00	335.00
7.50	327.00	339.00	355.00
8.00	340.40	357.00	378.40
9.00	369.20	379.00	395.60
10.00	395.00	406.00	420.10
12.50	425.10	447.00	460.00

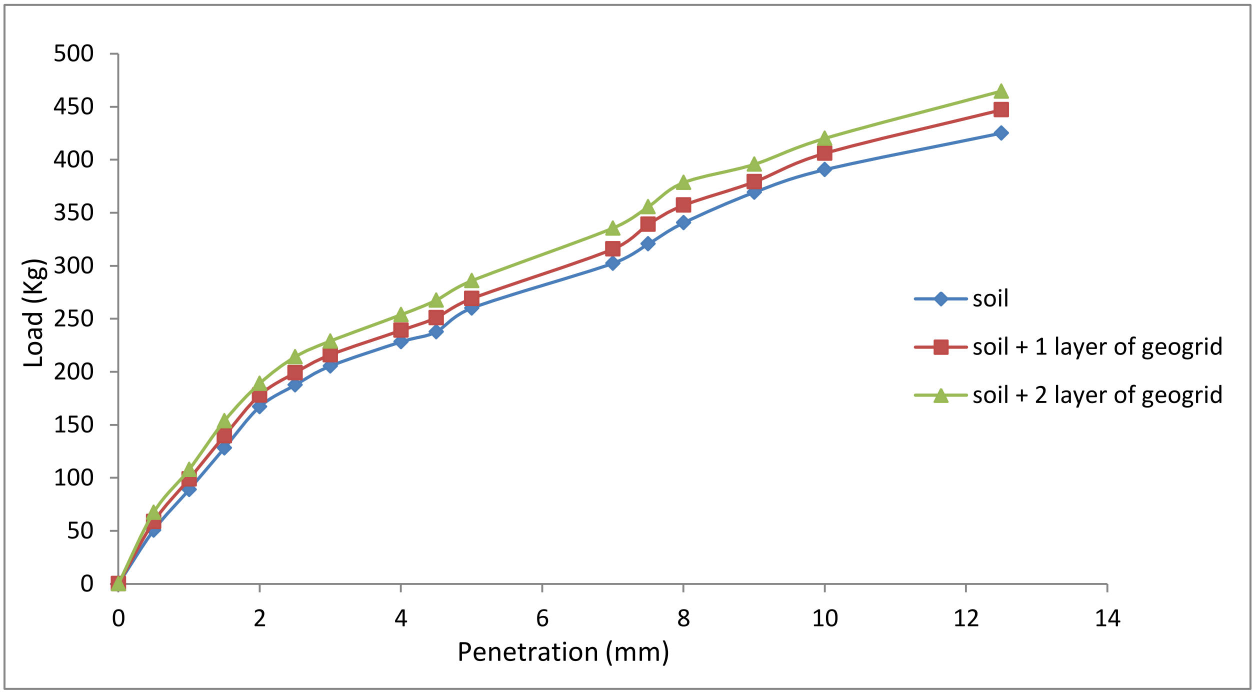

Fig27. Load v/s penetration of sand with 7.5kg surcharge (Heavy compaction)

CBR value of soil and soil with geogrid are 13.67%, 14.5% and 15.6%.

4.2.12 Sand with 10kg surcharge (Light compaction):

Table21 Load v/s penetration values of sand and sand with geogrid at 10kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	59.80	71.00	78.70
1.00	93.80	107.80	119.70
1.50	132.20	141.30	164.00
2.00	171.10	185.40	197.70
2.50	195.40	207.70	221.00
3.00	213.30	221.00	238.00
4.00	237.40	246.00	260.00
4.50	249.10	268.00	279.00
5.00	271.10	281.00	298.00
7.00	317.20	334.00	356.00
7.50	338.40	358.00	366.00
8.00	356.40	370.00	388.00
9.00	371.10	387.00	403.00
10.00	403.30	434.00	445.80
12.50	433.50	461.00	471.00

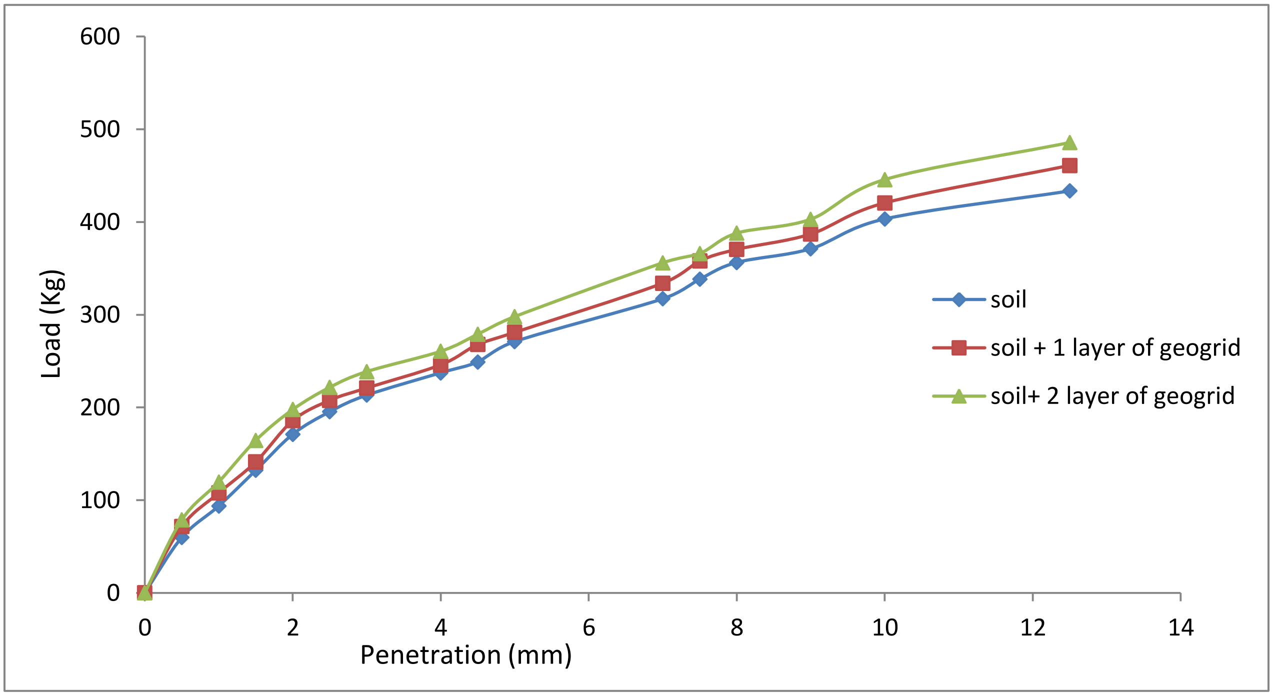

Fig28. Load v/s penetration of sand with 10 kg surcharge (Light compaction)

CBR value of soil and soil with geogrid are 14.26%, 15.1% and 16.2%.

4.2.13 Clay with 5kg surcharge at soaked condition (Light compaction):

Table22 Load v/s penetration values of clay and clay with geogrid at soaked condition with 5kg surcharge (Light compaction)

Penetration	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	5.37	8.80	11.30
1.00	10.30	15.65	18.60
1.50	17.46	22.60	25.50
2.00	23.45	26.40	29.40
2.50	25.12	28.40	34.50
3.00	28.67	31.60	36.50
4.00	32.12	34.80	39.50
4.50	34.41	38.40	43.60
5.00	36.12	41.50	46.20
7.00	43.00	47.60	51.50
7.50	45.00	49.70	55.20
8.00	48.30	52.20	56.70
9.00	52.20	56.30	61.10
10.00	55.40	59.10	65.30
12.50	70.00	75.00	79.00

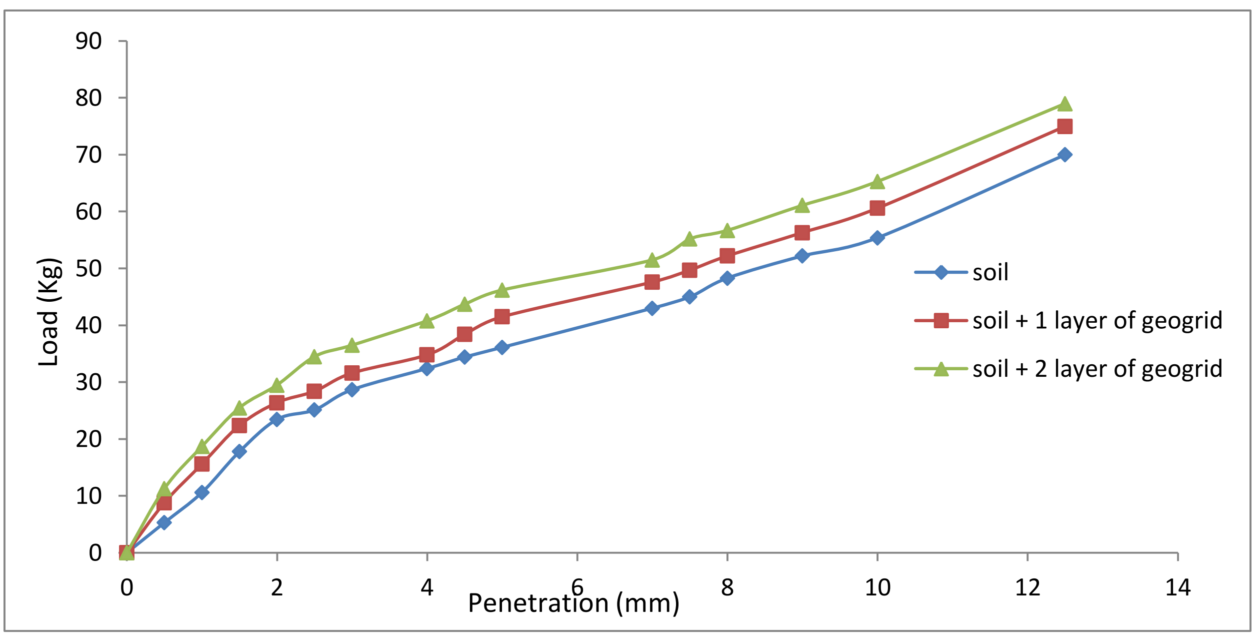

Fig29. Load v/s penetration of Clay with 5kg surcharge at soaked condition (Light compaction)

CBR value of soil and soil with geogrid are 1.3%, 2% and 2.5%.

4.2.14 Clay with 5kg surcharge at soaked condition (heavy compaction):

Table23 Load v/s penetration values of clay and clay with geogrid at soaked condition with 5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	8.21	11.10	15.50
1.00	16.80	19.50	22.40
1.50	23.56	27.70	30.70
2.00	27.48	32.50	35.40
2.50	31.21	35.60	41.20
3.00	33.60	38.10	44.50
4.00	36.10	43.20	47.60
4.50	39.90	45.50	50.10
5.00	42.10	49.60	53.00
7.00	53.10	58.10	64.00
7.50	56.20	62.30	68.50
8.00	61.10	66.40	72.00
9.00	66.40	71.50	77.10
10.00	71.50	74.60	85.60
12.50	80.10	85.00	99.00

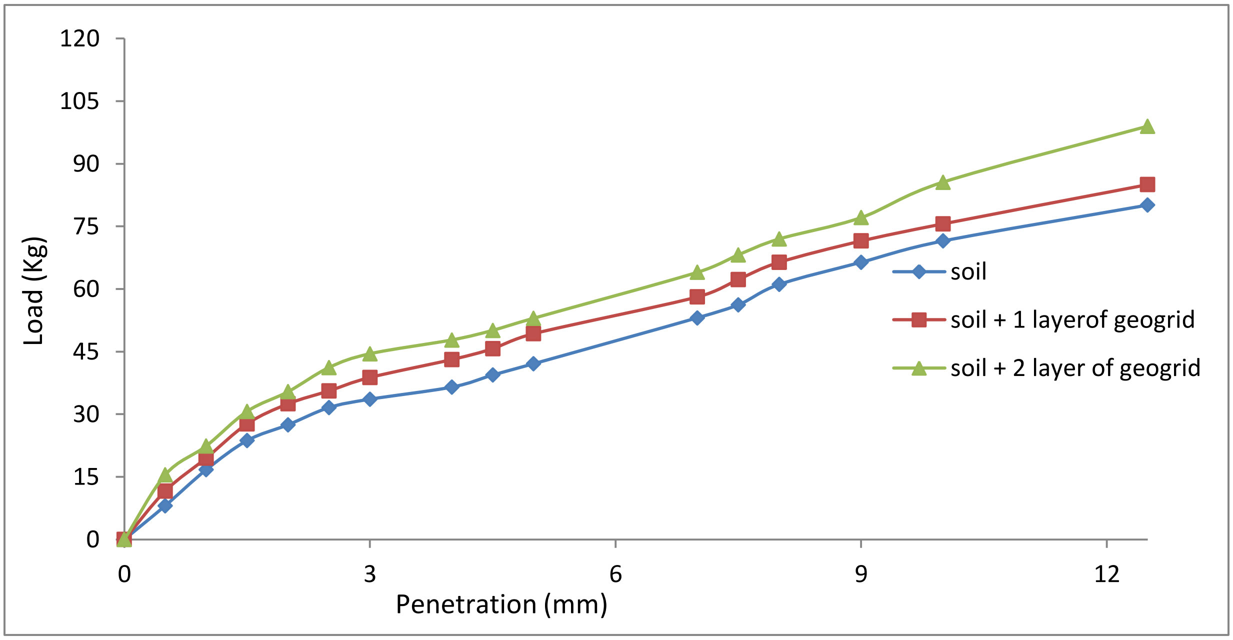

Fig.30 Load v/s penetration of Clay with 5kg surcharge at soaked condition (Heavy compaction)

CBR value of soil and soil with geogrid are 2.3%, 2.5% and 3%.

4.2.15 Sand with 5kg surcharge in soaked condition (heavy compaction):

Table24 Load v/s penetration values of sand and sand with geogrid at soaked condition with 5kg surcharge (Heavy compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	31.64	37.26	43.20
1.00	48.25	54.34	59.30
1.50	67.89	72.23	79.60
2.00	78.14	83.20	90.30
2.50	90.65	98.62	106.40
3.00	96.20	103.30	113.60
4.00	111.50	116.00	122.50
4.50	117.00	123.00	129.00
5.00	123.00	128.00	137.20
7.00	140.00	146.20	155.00
7.50	145.00	150.50	161.40
8.00	157.40	157.50	166.20
9.00	161.00	165.20	175.70
10.00	169.40	175.60	183.20
12.50	190.00	198.0	208.00

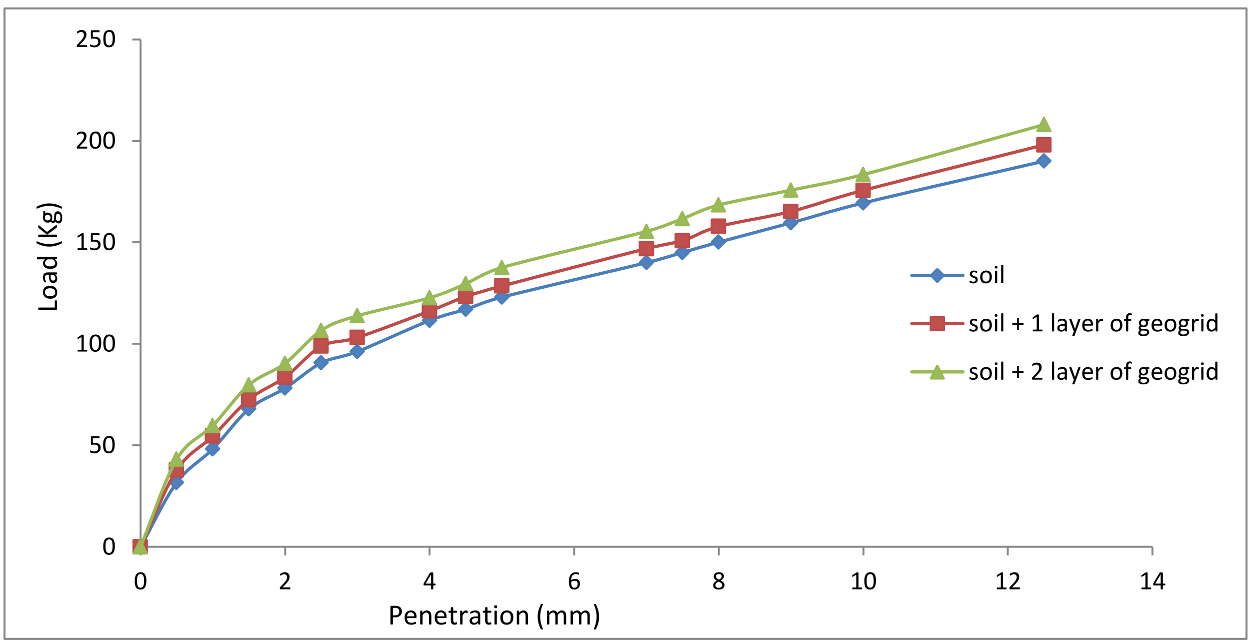

Fig31. Load v/s penetration of sand with 5kg surcharge at soaked condition (Heavy compaction)

CBR value of soil and soil with geogrid are 6.67%, 7.2% and 7.7%.

4.2.16 Sand with 5kg surcharge in soaked condition (Light compaction):

Table 25 Load v/s penetration values of sand and sand with geogrid at soaked condition with 5kg surcharge (Light compaction)

Penetration (mm)	Load on soil	Load on soil with 1 layer of geogrid	Load on soil with 2 layer of geogrid
0	0	0	0
0.50	27.42	31.20	38.00
1.00	45.12	49.50	57.00
1.50	62.12	66.70	71.00
2.00	73.42	78.20	85.60
2.50	89.21	94.50	98.00
3.00	95.12	99.20	105.00
4.00	108.10	112.50	119.00
4.50	112.30	118.90	126.00
5.00	119.90	129.00	134.00
7.00	137.80	145.60	151.20
7.50	143.20	151.40	158.70
8.00	149.30	158.40	164.80
9.00	154.10	165.00	172.10
10.00	161.50	178.00	180.50
12.50	186.00	192.00	200.40

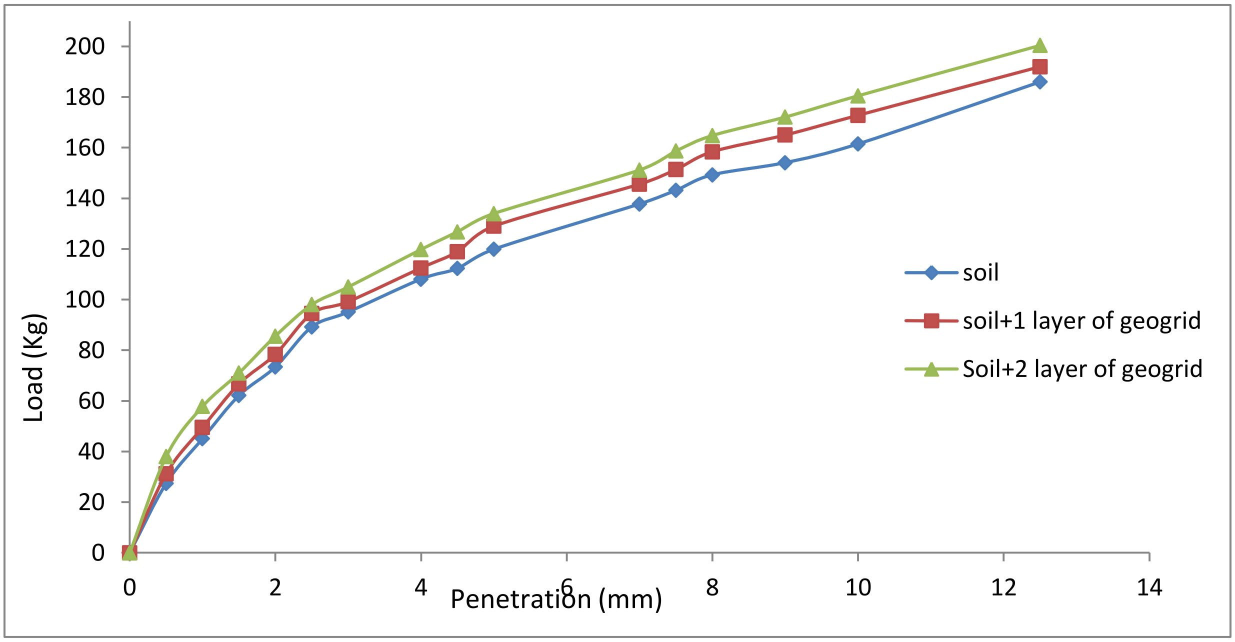

Fig 32 CBR of sand and sand with geogrid at soaked condition with 5kg surcharge (Light compaction.

CBR value of soil and soil with geogrid are 6.51%, 6.89% and 7.15%.

4.3 Discussion

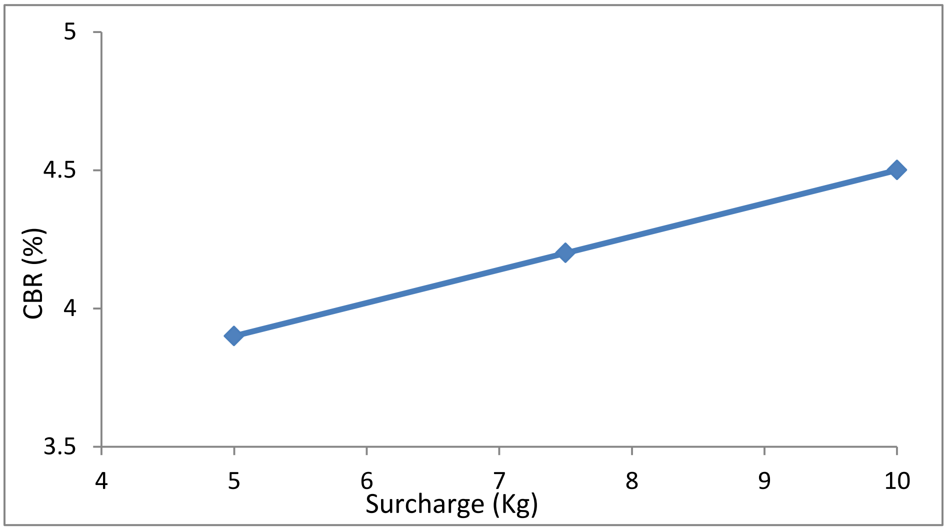

Fig 33 Variation of CBR of clay with increasing surcharge.

With increase in the surcharge up to 10 kg at heavy compaction in clay results 15.4% increase in the CBR value.

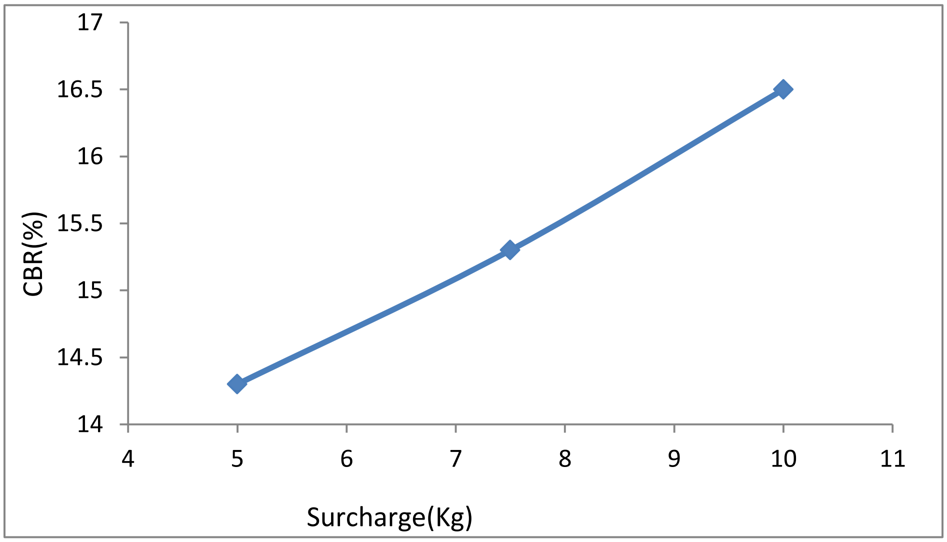

Fig 34 Variation of CBR of sand with increasing surcharge

With increase in the surcharge up to 10 kg at heavy compaction in clay results 15.3% increase in the CBR value.

With increase in the surcharge CBR value going to increase it may be due to as increase in the surcharge the air void in the soil will decreases that results in increase in the density of soil i.e. more will be the compact soil more will be the CBR value.

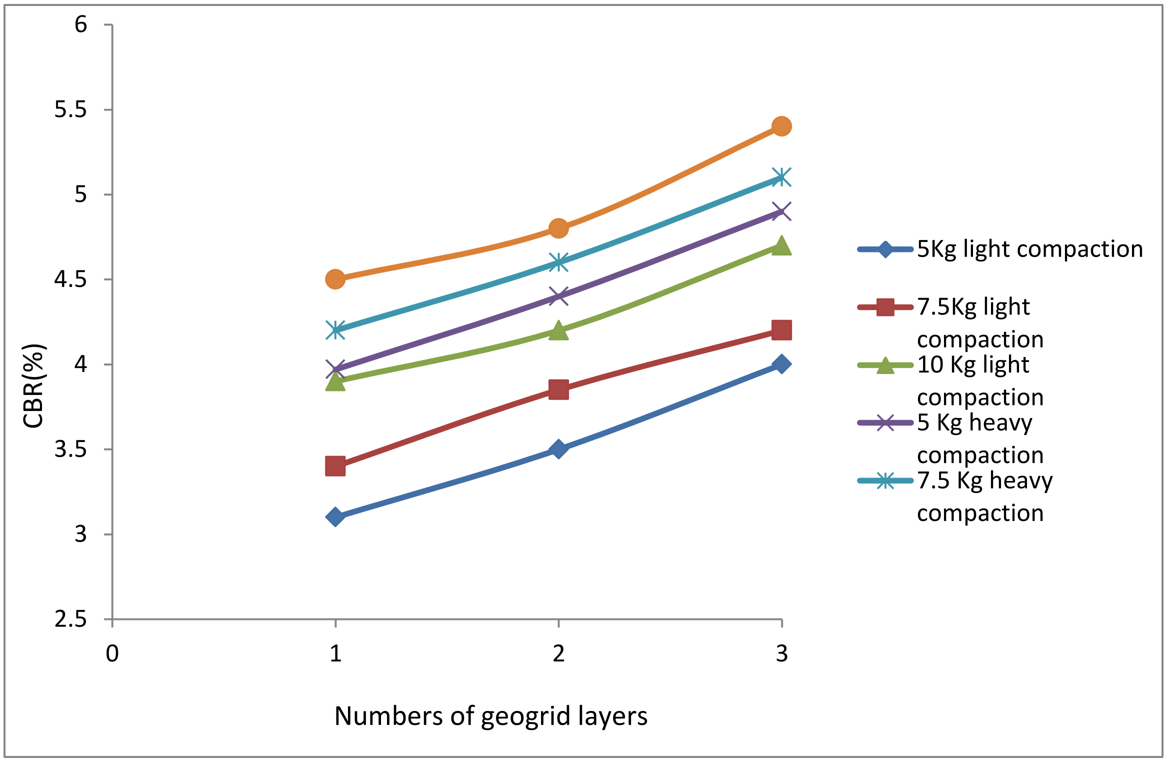

Fig.35 Effect of placement of geogrid on CBR value of clay with high degree of compaction and surcharge.

- In case of clay in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 12.9%, 29.1% and 12.8%, 25.6%.
- In case of clay at surcharge 7.5 kg in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 14.7%, 23.5% and 10.0%, 21.4%.
- In case of clay at surcharge10 kg in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 8%, 20.5% and 7%, 20%.
- With the application of geogrid, better will be the interlocking and it avoid shear failure. Generally soil fails in the shear, As the shear strength increases CBR value also increase.

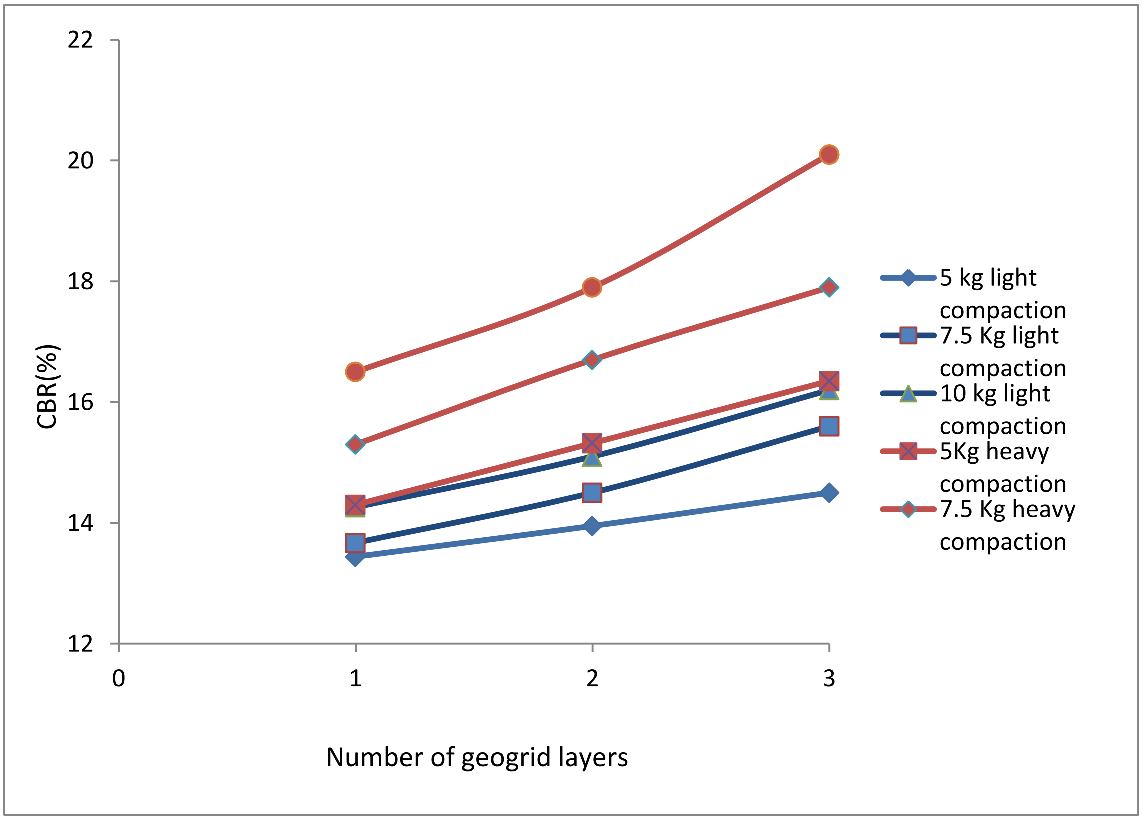

Fig.36 Effect of placement of geogrid on CBR value of sand with high degree of compaction and surcharge.

- In case of sand in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 3.77%, 7.8% and 7.31%, 14.33%.
- In case of sand at surcharge7.5 kg in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 6.07%, 14.1 % and 9.2 %, 14.33 %.
- In case of sand at surcharge10 kg in light and heavy compaction with one and two layer of geogrid the CBR values are increased by 2.3%, 7.5% and 6.7%, 21.82%.
- With increase in degree of compaction CBR values for clay and sand increase by 25.8% and 6.4 %. As we apply more compactive effort then air comes out from the void that results in increase in the density of soil. i.e. more will be the compact soil more will be the CBR value.

CHAPTER 5

CONCLUSION

On the basis of experiments on CBR test on sand and clay soil under different conditions viz. with surcharge, degree of compaction and placement of geogrid, the following conclusion may draw.

The CBR value of clayey soil increase in degree of compaction and surcharge. With these conditions the placement of geogrid in two layers, an enhancement of CBR value as observed further. The similar kinds of results were obtained in case of sandy soil also but there is more improvement as compare to that of clay soil in similar condition.

Scope for further study

Recommendation for the future work

After the complete experimental study on CBR test on reinforced soils is scope for the future study may be as follow:

1. The similar study can be carried out on different types of soils with increasing in number of geogrid layer.

2. The similar study can be carried out on different types of soils with increasing degree of compaction and surcharge..

3. The same test can be repeated for different moisture content.

REFERENCES

1. **Yousif Jawad(2006),** “Effect of Compaction on the Behavior of Kirkuk Gypseous Soil”, Journal of Eng. Sciences 97-104
2. **K.Bandyopadhyar(2009),** “Laboratory CBR Value of Fly Ash under different Condition”, GEOTIDE
3. **Zornberg and Gupta(2010) ,**“Geosynthetics in Pavements: North American Contributions”,International Conference of Geosynthetic,Brazil.
4. **SZ. Fisher and F.Horvat(2011),** “ Investigation of the Reinforcement and Stabilization Effect of Geogrid Layers under Railway Blast”, Slovak Journal of Civil Engineering 3-22-30.
5. **S.V. Krishna Rao(2012),** “Laboratory Study on the Relative Performance of Silty –Sand Soil Reinforced with Linen Fiber”, Springer-011-9449-2.
6. **Nabil Al Joulani (2012),** “Effect of Powder and Lime on Strength, Compaction and CBR Properties of Fine Soils”, Jordan Journals of Civil Engineering.
7. **Alemgena A .Araya, (2012),** “Investigation of the Resilient Behavior of Granular Base Material with Simple Test Apparatus”, Springer -011-9790-1.
8. **Fatemeh Mousavi, (2013)** “Effect of Polymer Stabilization on Swelling Potential and CBR of Forest Road Material”, KSCE Journal of Civil Engineering -014-0137-7.
9. **Charles Anum Adam, (2014)** “Effect of Geogrid Reinforced Subgrade on Layer Thickness, Design of Low Volume Bituminous Sealed Road Pavements”, International Refereed Journal of Engineering and Science-59-67.
10. **Saad F. Ibrahim,(2014)** “Long Term Dry and Wet Effects on the Engineering Behavior of Subgrade Soil with High Amount of Soluble Salts using Low Cost Stabilizers”, Journal of Civil Engineering and Urbanization Science Line Publication-492-500.
11. **AKO Lade, AS and Olaniya,(2014)** “Application of Geogrids on the Geotechnical Properties of Subgrade material under Soaked Condition”, Civil and Environmental Research -224-5790.

12. **V.K. Chakravarthi and Jyotsha,(2014)** "Efficiency of Overflying Coarse aggregate and Geosynthetic Separator on CBR value for Soft Subgrade of varying Plasticity- A lab Study" International journal Research in Engineering and Technology-2321-7308.
13. **Prof. Mayara. M yeole,(2014)** "Geotextile can be worth their Cost in Pavements" IOSR Journal of Engineering.
14. **Naveen B Shirur,(2014)** "Establishing Relationship between CBR value and Physical Properties of Soil" IOSR Journal of Mechanical and Civil Engineering-26-30.
15. **Charles A. Adams,(2015)** "Effect of Triaxial Reinforcement on CBR value of Soil used for Pavement", International Refereed Journal of Engineering and Science-79-68.
16. **Archana Muraleedhara,(2016)** "Behavior of Geogrid Reinforced Silty Sand", Techno Journal of Engineering and Research(TJER).
17. **Sadok Benmebarek,(2016)** "Effect of Geosynthetics on the Performance of Road Embankment over Sabkha Soil in Algeria: A Case Study" Int. J. of Geosynthetic and Ground Engg.-015-0040-04.
18. **Tao Zhang,(2016)** "Engineering Properties and Microstructural Characteristics of Foundation Silt Stabilized by Lignin based Industrial by Product",KSCE Journal of Civil Engineering-1-12.
19. **Robert Nini,(2016)** "CBR of Soaked Clay Drained by Sandy Layer", World Congress on Civil, Structural and Environmental Engineering-166-1002.

Bibliography

[1] IS: 2720 (Part 2), "Determination of water content," 1973.

[2] IS: 2720 (Part III/ Sec 1), "Reaffirmed 2002, methods of test for soils: Part-3, determination of specific gravity, fine grained soils, Bureau of Indian Standards," 1980.

[3] IS: 2720(Part 4), "Reaffirmed 2006, methods of test for soils: Part-2, determination of grain size analysis, Bureau of Indian Standards," 1985.

[4] IS: 2720 (Part VII), "Reaffirmed 2003, methods of test for soils: Part-7, determination of water content dry density relation using light compaction, Bureau of Indian Standards," 1980.

[5] IS: 2720 (Part 13), "Direct shear test," 1986.

[6] IS: 1498, "Classification and identification of soils for general engineering purposes," 1970.