LOAD SETTLEMENT BEHAVIOUR OF CIRCULAR FOOTING ON SAND REINFORCED WITH COIR GEOCELL

A DISSERTATION

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

OF

MASTER OF TECHNOLOGY

In

GEOTECHNICAL ENGINEERING

Submitted By

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CANDIDATE'S DECLARATION

I do hereby certify that the work presented is the report entitled "Load Settlement Behavior Of Circular Footing On Sand Reinforced With Coir Geocell" in the partial fulfillment of the requirement for the award of the degree of "Master of Technology" in Geotechnical Engineering submitted in the Department of Civil Engineering, Delhi Technological University, Delhi is an authentic record of my own work carried out under the supervision of Prof. A.K. Sahu, Department of Civil Engineering. The work is original and not copied from any other source without proper citation. The 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 "Load Settlement Behavior Of Circular Footing On Sand Reinforced With Coir Geocell" which is submitted by Ekansh Agarwal, 2K16/GTE/07, 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 the project work carried out 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.

Place: Delhi
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ABSTRACT

Coir geotextile is a natural form of geotextile which has been manufactured from the coir fibers and it has emerged as a very feasible and better alternative to the geosynthetics which were used earlier for the reinforcement practices and applications. This is due to its excellent properties, longevity and economical prospect. It is available at low prices in many developing countries and hence is used in low cost applications. This research work presents the results of plate load test carried out on a circular footing resting on sand reinforced with coir geotextile in its planar and geocell form. This work also aims at exploring the benefits and the outcomes of using coir geotextile as a reinforcement material for shallow foundations and thereby increasing the capacity of the sand. Geocells were made from the coir geotextile so that an extra confinement can be provided to the soil. The amount and characteristics of geotextile and geocells were kept same and a comparison has been drawn between them according to their performance. The placement depth, number of layers, etc. were varied and the results indicated that the bearing characteristics depend upon the type of reinforcement provided. For the equal amount of both the materials, geocells proved to be a way better than its planar form of reinforcement. The improvement factor for geocell reinforcement came to be 2.95 compared to 1.99 in the case of planar reinforcement.

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LIST OF ABBREVIATIONS

SYMBOL	TITLE
kN	Kilo Newton
Mm	Millimeter
Kg	Kilogram
Ø	Angle of internal friction
C	Cohesion
Cu	Coefficient of uniformity
Cc	Coefficient of curvature
D60	Diameter corresponding to 60% finer in the gradation analysis
D10	Diameter corresponding to 10% finer in the gradation analysis
D30	Diameter corresponding to 30% finer in the gradation analysis
OMC	Optimum Moisture Content
MDD	Maximum Dry Density
G	Specific gravity
u	Placement depth of coir geotextile
D	Diameter of the footing
S	Settlement of the footing
IF	Improvement Factor

CHAPTER 1

INTRODUCTION

Soil reinforcement technique has been used from ancient times and it is also practiced in our animal kingdom. Like Beavers build dams for them of mud which are reinforced with grasses, stones and trunk of tress so that a greater depth is ensured in shallow streams which prevents them from completely freezing during the winters. Some of the monuments in our history also give us the proof that soil reinforcement is being used over centuries. But there was no systematic study of this topic until Henri Vidal, a French engineer publish on soil reinforcement, his research in 1966. He began to use the term **Reinforced Earth**.

He proved the usefulness of this research by using it in the construction of the retaining wall. Till then, many civil engineers have followed him and started the use of reinforcement in the soil which is working satisfactorily till now. It has aroused so much awareness in the engineers that no other technique could do. Its cost and time effectiveness has made it a great success with engineers and many research workers.

To practice it in field, many reinforcement materials are available for the strengthening of the soil, popular nowadays are the GEOSYNTHETICS and especially the Geocells.

Geocells or the Cellular confinement systems are mainly used in the erosion control, channel protection, soil stabilization and earth retention structures. They have evolved from being made of HDPE or NPA to coir geocells. This evolvement has been so much beneficial that many research works have been done to explore the benefits and use of the naturally obtained coir geotextile and coir geocells (fabricated from coir geotextile). In this research work, the effect of the coir geotextile on bearing capacity of the soil has been investigated and a comparison between planar and geocell form of the coir has been made.

Some of the major types of Geosynthetics have been stated below:

1.1 Types Of Geosynthetics:

These are the materials which are used to make the terrain stable. They are the products made of polymer which are very helpful in solving various civil engineering problems. These are mainly of eight types which are :

1.1.1 Geotextiles:

These textiles consist of artificial fibers rather than the natural. Hence, they are less prone to bio-degradation. They are converted to flexible and porous fabrics by various machines or they are matted in a non-woven mannerism together. They are generally porous and allow the liquid to flow through them and there are many applications of them. Till date at least 100 areas are there which are served by the geotextiles.

1.1.2 Geogrids:

They are the geosynthetics which are rapidly growing now a days. They are neither woven nor knitted but they have a grid like configuration. They have large apertures in between them in both longitudinal and transverse directions.

i) They can be stretched into one, two or three directions for the enhanced physical properties.

ii) They can be manufactured by the standard textile manufacturing methods.

iii) They can be made by laser or bonding rods together ultrasonically.

1.1.3 Geomembranes:

Geomembranes speak to the next biggest gathering of geosynthetics, and in dollar volume their deals are more noteworthy than that of geotextiles. Their development in the United States and Germany was invigorated by administrative directions initially established in the mid 1980s for the coating of strong waste landfills. The materials themselves are generally thin, impenetrable sheets of polymeric material utilized fundamentally for linings and fronts of fluids or strong storerooms. This incorporates a wide range of landfills, surface impoundments, channels, and other facilities. In this manner the essential capacity is dependably regulation as a fluid or vapor boundary or both. The scope of utilizations, be that as it may, is extraordinary, and notwithstanding the ecological territory, applications are quickly developing in geotechnical, transportation, water powered, and private improvement building.

1.1.4 Geonets or Geospacers:

They are an another segment within the area of the geosynthetics. They are shaped by a constant expulsion of parallel arrangements of polymeric ribs at intense edges to each other. Relatively large apertures are formed when the ribs are opened. They are mainly of two types i.e. biplanar or triplanar. They are consisted of 3D network of stiff fibers of polymers in different styles and small pipes for drainage within geotextiles. Their outline work is totally inside the seepage zone where they are utilized to pass on fluids or gases of various types.

1.1.5 Geofoam:

Geofoam is the product which is made by the expansion of polystyrene which results in the creation of gas filled cells. The walls are unexpanded and hence are skeletal. They are light in weight but large in size and can be used in various applications.

1.1.6 Geosynthetic clay liners:

They are the bundles of factory made thin layers of bentonite clay which has been sandwiched between two geotextiles or are attached to a geomembrane. They are made compact and an integrity is obtained by the stitching process of needle punching or by excessive bonding. They find their applications in various places like private developments, transportation, etc.

1.1.7 Geoells:

These are also known as cellular confinement systems. They are 3D honeycombed structures which form a compacted base when soil is filled in them. When they are filled with soil, they form a new compacted and firm base and an identity due to interaction with the soil. They have many advantages like they reduce the lateral movement of the soil by confining it. It forms a matrix which is so stiff that it distributes load over a wider area and reinforces the soil. They are used mainly in slope protection and earth retention and nowadays they are being used in the road and rail load supporting structures. They are also used in the protection of walls and bunkers.

1.1.8 Geocomposites :

As suggested by the name, these are the combination of geo grids, textiles, and geo membranes in factory made unit. One or more of the above stated items may be absent. Also, these can be mixed with any other material made of synthetic. This is the best material which can be used for the reinforcement. They have wide areas of their application which are constantly increasing with time.

1.2 Functions:

There are mainly four functions which are:

1. Separation which is the process of placing of a geosynthetic material like a geotextile or geogrid between two materials which are not similar so that there is a barrier between the two and the functioning remains unchanged and may be improved. There are many applications of this function of the geosynthetics.

2. Reinforcement refers to the improvement and enhancement in the strength of the system when a geosynthetic material (can be any) is introduced between the soil layers. They all are good in tension but soil in poor in tension and hence they improve the properties of the soil. They are useful in slope protection and earth retaining wall structures.

3. Filtration is the unique property of geotextiles which helps the liquid to seep through them without the loss of the soil. They find applications in drainage system in highways, leachate collection system, retaining wall, etc.

4. Containment is the property exhibited by certain geotextiles and geo composites which function as liquid or gas barriers and don’t allow them to pass through them. eg, Landfill liners, covers, etc.

1.3 Advantages:

1. The manufacturing of geosynthetic materials is done in a good factory environment which is controlled and is far better than rock construction in the outdoors. All the companies manufacturing these materials are ISO certified and have a good reputation.
2. They have a low thickness which is an advantage.
3. They can be installed easily as they are light weight which eliminates the use of heavy and large earthmoving equipments.
4. Design methods for these geosynthetics are easily and readily available and there are many universities which teach its use and the advantages.
5. They are economical and cost effective. Moreover, it is sustainable(Low CO_2 footprints).

1.4 Disadvantages:

1. Certain additives like antioxidants, fillers, etc. have to be used to ensure the long term performance of these materials.
2. They are sometimes clogged or bio-clogged which is a problem and a challenging design for certain soil types such as loess soils, cohesionless silts, etc.

1.5 Need and Scope of the Project :

This study evaluates the effect and influence of coir geotextile and coir geocells on the bearing capacity of coarse sand as well as its settlement characteristics. Load settlement behavior of the coarse sand in reinforced and unreinforced condition would be checked.

Following is the scope of this study:

1. To manufacture a Mild Steel box of height 500mm and thickness 30mm and a circular plate of diameter 120mm.
2. To determine the geotechnical properties of the sand like its grain size distribution, various parameters, compaction features, etc.

3. To draw the load settlement curve of coarse sand to compare the bearing capacities of the soil in reinforced and unreinforced conditions.
4. To study the influence of the coir geocells on the settlement characteristics and the bearing capacity of the sand.
5. To perform the small scale plate load test on the sand filled in the box of diameter 600mm and height 500mm.
6. To conclude the results obtained.

1.6 Arrangement Of Chapters :

The main and the very basic motive of this study is to investigate the influence of the coir geocells on the bearing capacity of the sand and to calculate the difference in settlements of sand in reinforced and unreinforced conditions. Moreover, to compare the results an improvement factor is also calculated.

Chapter 1 includes a brief introduction of the project, its need and scope.

Chapter 2 includes a thorough literature review of various studies done with time on the geosynthetics, their uses and the role played by them specially coir geocells in the improvement of bearing capacity of sand and to reduce its settlement.

Chapter 3 takes us through various materials and equipments that have been used for the completion of this project. Moreover, the properties of the materials which we have used and the various experiments performed are discussed in detail in this chapter.

Chapter 4 is the thorough discussion of the plate load test that has been done on the modeled circular footing. Also, a comparison is drawn between the results of the reinforced and unreinforced sand and an improvement factor is calculated.

Chapter 5 includes conclusions obtained from experiments performed, limitations and the future recommendations of the project.

CHAPTER 2

LITERATURE REVIEW

In this chapter, various researches done by different researchers on the more or less same topic has been written. A very important criterion for the foundation is that it's design should fulfill both serviceability and strength criteria. Moreover, the soil beneath the super structure should be strong enough and should have enough bearing capacity to withstand the load of the superstructure and not fail in shear.

D.I. Bush et al.(1990) : In this study, it has been shown that how a geocell and its unique features can be used to increase the bearing capacity of the soft soil. At last, geocell proves to be economical and good reinforcement solution to the soft soil.

Sujit Kumar Dash et al. (2001) : In this research, tests on a strip footing resting on sand and reinforced with geocells have been done.Various parameters were varied in the tests like geocell position, its height, width, positioning from the top, pocket size and their tensile stiffness. From the tests, an observation that there was no failure even when the settlement was 50% of the footing width and load was 8 times the ultimate bearing capacity of unreinforced sand was made. From the tests, the depth of the placement of the geocells and their dimensions needed to mobilize the maximum bearing capacity improvement have been determined. Main factors which have to be taken into account while testing are aperture size and orientation of ribs.

Amalendu Ghosh et al.(2004) : In the present investigation, the use of pond ash has been emphasized. Now a days, pond ash is being used to stabilize the low lying areas for constructing industrial and residential sites over them. The improve the bearing capacity of pond ash, the reinforcement with jute geotextiles has been done. The effect of different parameters such as depth of the first layer of the geocell, no. of layers of the geocell, width of the geocell, geotextile sheet length, etc. has been observed.

P. Vinod et al.(2009) : In this research work, the braided coir rope is used as a reinforcement and its effectiveness is observed in the strength improvement and reduction in settlement by doing plate load tests on footing in the laboratory. Moreover, the influence of various parameters such as length of reinforcement, depth, no. of layers and no. of piles of braided coir rope has been investigated. The results have shown that there is a six times improvement in strength and 90 percent of reduction in settlement by using this kind of reinforcement in soil. The optimum value of the depth of embedment of the reinforcement was also calculated and it was 0.4 times the width of the footing. If there is an increase in the number of layers within the appropriate depth, then strength improvement ratio is improved to a great extent and the optimal settlement reduction is observed when 3 layers of coir rope are used.

N. Ameta, D. Purohit, A. Wayal(2009) : According to them, the effect of reinforcing the dune sand(which has low shear strength, low permeability) with nylon fibers has been observed. Nylon fibers have been mixed in different ratios and different percentage by weight of the sand and then the effect on the bearing capacity of dune sand has been noted. Various parameters have been varied like the depth of the nylon fibers below the foundation level. The interpretation of the settlement results has been done and it has been found out that the bearing capacity increases with the increasing nylon content.

P. Vinod and Ajitha B. Bhaskar(2010) : In this paper, experiments are done on model square footing reinforced with coir geocells which are woven. Three folds improvement occurs when only one layer of geocell is placed in the soil has been deduced. Hence, coir geocells are an appropriate material for the improvement of the soil. Moreover, it was found out that improvement in the properties of the soil by reinforcing it depends upon the reinforcement type and and is unique for each ine of them. An equation is also produced for calculating the improvement in the strength of the footings rested on soil reinforced with coir geocells. If its durability is increased, then the coir geocell could prove to be a preferred material for soil reinforcement in many countries as it is available there at no or very little cost.

Murad Abu Farsakh et al.(2013) : In the present research, tests have been done on geosynthetically reinforced sand. Various parameters like tensile modulus, spacing between different layers, depth from the foundation level, embedment depth, shape of the footing, etc. have been varied. Strain distribution along the reinforcement has also been calculated. It has been stated that the settlement can be reduced to a good amount if thickness of the geotextile is increased in each layer and it performed better than geogrid alone. Also, a comparison between the studies of various authors has been carried out and it has been found out that the results are more or less same.

Manash Chakraborty and Jayant Kumar(2014) : In this survey, the ultimate bearing capacity of cohesive soil which has been placed over circular sheets of reinforcement has been calculated by the upper bound theorem of limit analysis and linear optimization.

Elif Cicek et al.(2015) : In this analysis, tests are done on a strip footing in reinforced and unreinforced condition to check the effect of reinforcement length. Reinforcement number and type have been varied to check the effect of reinforcement length. The strip footing was kept on geotextiles and geosynthetics and the effect in bearing capacity has been observed and the length of the footing required for optimum improvement with different reinforcement types and positions has been calculated.

Dharmesh Lal et al.(2017) : Geocell has excellent engineering properties and has great longevity. In this study, it has been recognized as an alternative to geosynthetics for application in reinforcements. Moreover, it is good for developing countries as it is easily available and cheaper than other materials. In this consideration, a plate load test has been done on square model footing which rests on a sand bed that is reinforced with coir geocell. Performance of the geocells and planar form was compared in this test. The tests state that coir geocells provide better results than its planar forms.

Kiran and Nagraj Bacha(2015): In this investigation they studied the conduct of sand which is being reinforced for improving the bearing ability and reducing the settlement when square footing and circular footing are used. They used lateritic soil as layer in sand bed and geo-grid as reinforcement. They performed plate load test for various conditions on model footings of square and circular footings of size 10.5cm and 9.2 cm diameter. They compare the results of bearing capacity of reinforced and unreinforced condition under both footings. From the test results they observed that by providing a perfect setup of the reinforcing geo-grid, the bearing capacity of sand can be improved as compared to the unreinforced sand & settlement can be reduced. They also conclude that reinforced sand have 30% more load carrying capacity than unreinforced sand under square footing and 10% more in circular footing. When compared to the behavior of square and circular footing under reinforced and unreinforced condition the square footing performs good and have high load carrying capacity than circular footing.

Mohamed and Vanapalli(2016): They have determined the bearing capacity of sandy soils using plate load tests , cone penetration tests and standard penetration tests.

Alawaji(2001): In his study he evaluate the benefits of geo-grid-reinforced sand over collapsible soil to constrain settlement. He used a circular plate of 100mm and Tensor SS2 geogrids to perform Model Plate load test. The width to depth ratio of the geo-grid was changed to find their consequences on the settlement, young's modulus and bearing capability ratios. From his tests results obtained it was observed that the performance of the sand geo-grid system increased with increasing geo-grid width and reducing geo-grid depth. He also observed that by this method the bearing ability of sand over collapsible soil can be increased and the settlement can be reduced.

Dixit and Patil (2007): They study the consequence of shape, width and depth of footing on soil's bearing capacity. They also evaluate the effect of water table. They analyzed the results obtained by methods given by Terzaghi and IS code. They observe the variation in bearing ability obtained from different methods for different shapes. They observed that the bearing ability of strip footing was least as compared with square, circular and rectangular shaped footings by local shear failure or Terzaghi's method. And in IS code method, the ultimate bearing capacity was observed to be found for circular footing and minimum for strip footing. In general shear failure case by Terzaghi's method, bearing capacity was maximum for strip and minimum for circular. And in case of IS code method max for square and min for circular. They concluded that the important parameters which affect the bearing ability of soil are, breadth of the foundation, unit weight, cohesion and depth of the foundation, and friction angle.

Araújo and Costa (2015): They evaluate the effect of size of Footing of shallow foundations in sand. They performed three plate load tests on a sand backfill using plates with diameters of 0.30, 0.5 and 0.80 m. The stress-settlement curves obtained with the tests did not show a clear failure pattern, therefore, conventional failure criteria were used to find the bearing capacity. They conclude that for a same applied stress the settlement values increases as the plate dimensions increases, but this increasing is nonlinear. The values of allowable stress obtained by the three-plate method of Housel decreased with the increasing of plate size. The same was observed for Leonards' criterion.

After reading the literature reviews and making a proper understanding of the topic, the materials required for the fulfillment of the research work were collected and all of them have been stated in the upcoming chapter.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials and the equipment used

As we all know a project cannot be completed without the use of materials and equipments. Hence, various materials and equipment used to complete this project are as follows:

3.1.1 Sand

Sand has been taken from the playground of DTU and its sieve analysis has been performed.

Fig. 3.1 Coarse Sand

3.1.2 Coir Geotextiles

The coir geotextiles used for manufacturing geocells were taken from K.K. Envirotech, Kolkata.Various researches have discussed the properties and tensile load-strain characteristics of the coir geocell in their papers. Geocells are made by cutting the geotextiles to the length and height required from the full their full rolls and then they are stitched together to form yarns to form a honey comb structure. Bodkin joints are not inserted. The pocket size (d) of the geocells used for this experiment was 11cm x 11cm. Height of the cell taken is 7cm. The tensile properties of the coir geotextiles have been determined as per ASTM D 4595(1994). Mass of the geotextile(g/m^3) is 723, failure strain in % is 17.3, Aperture size of the geotextile is 6mm X 10mm and thickness is 6.27mm.

Fig3.2 Knitted Coir Planar Geotextiles

3.1.3 Cylindrical Steel Tank

It was manufactured by the steel workshop. The size of Box was modeled on basis of the previous researches and papers. As per IS 1888:1982, the width of the box used should be at least five times the width of the plate which has been used as the footing to minimize the confinement effect due to the side walls of the container. Following this IS code's criteria, the diameter of the box was adopted as 600mm for a plate of diameter 120mm. The tests were performed in the college laboratories.

Fig 3.3 Cylindrical Steel box

3.1.4 M.S. Plate

Plate of mild steel was manufactured by the steel workshop. The size of circular plate used is of 120mm thickness.

Fig. 3.4 M.S. Plate

3.1.5 Hydraulic Jack

The hydraulic jack used in the test is taken from the concrete lab of Delhi Technological University and is of 50kN capacity. The base diameter of the jack is 8.5cm. It was placed between the reaction frame and the footing for the test.

Fig. 3.5 Hydraulic Jack

3.1.6 Dial Gauge

A dial gauge measuring settlement of range of 0.001mm was used to record the value of settlement of footing plate. The dial gauge was placed over the footing and was fixed to the reaction frame through its stand.

Fig. 3.6 Dial Gauge

3.1.7 Test Setup

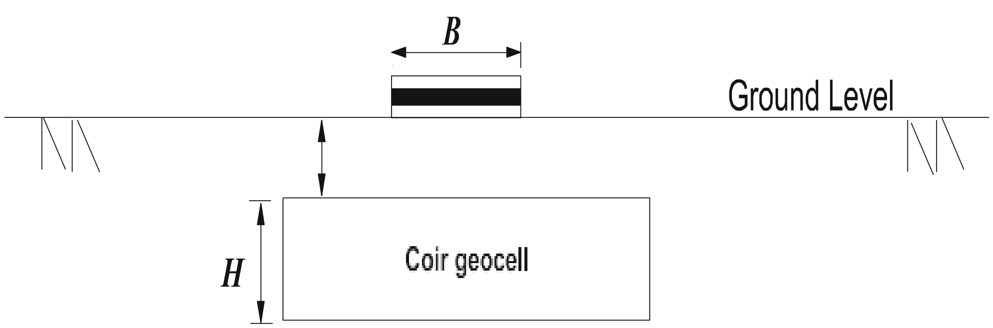

Fig. 3.7 Test Setup Diagram

Fig. 3.8 Test Setup

3.1.8 Reaction Frame

Reaction frame has been chosen as a truss kept at DTU which could be used for plate load test in field. The reverse action of hydraulic jack has been utilized for applying load on the footing kept above the soil in the tank.

Fig. 3.9 Reaction Frame

3.2 Experiments Performed In The Project

3.2.1. Characterization of Coarse Sand

Various tests have been performed to estimate the basic properties of sand which are:

3.2.1.1 Particle Size Distribution

This test is done as per IS2720 part 4 using the Sieve analysis. The soil was oven dries and then passed through 4.75mm sieve for fine sieve analysis.

Sieving of the soil is then done by placing the prescribed sieves in the IS code one over the other including a pan at the bottom for the collection of the sieved soil and a cover at the top so that soil does not come out while shaking. This assembly of sieves is then placed in a sieve shaker and the sieving is done for 10min. After this, the quantity of soil retained on each sieve is noted and percentage finer is calculated. Also, a graph of particle size vs percentage finer is plotted on semi log graph.

3.2.1.2 Specific Gravity

It is determined by pycnometer method as per IS 2720 part 3.

Oven dried sample of the soil is taken and put in the pycnometer flask. The weight of soil and flask together is M_2. Flask is then filled up to the top with water while constant stirring. Now, total weight of the flask along with water is M_3. Flask is now emptied, washed and filled up to the top with water again and the combined weight of flask and water is measured and taken as M_4. Weight of the flask when empty is M_1.

Now, Specific Gravity(G) = $(M_2 - M_1)/\{(M_2-M_1) - (M_3 - M_4)\}$

Fig. 3.9 Pycnometer

3.2.1.3 Compaction Characteristics

These are found out by the Standard Proctor test as per IS code 2720 part 7-1980. This test is performed to calculate the optimum moisture content(OMC) and the maximum dry density(MDD) of the soil. For this known weight of the oven dried soil is taken and then passed through the 4.75mm sieve. It is then mixed with known percentage of water by weight of the soil. Generally, for sand we start with 4% and for clay with 8%. The mixture is put into the mould in three layers by giving each layer 25 no. of blows by the rammer of 2.6kg dropped from a height of 310mm. The dry density is calculated by noting the mass of the compacted soil and its water content. A graph is then plotted between dry density and water content which gives us the OMC and MDD.

3.2.2 Properties of Coir Geocell

The coir geocell has been taken from the K.K. Envirotech Private Limited, Kolkata. Generally coir geocells are called Cellular Confinement Systems(CCS). They are used in the construction of slope protection structures, earth retention structures, channel protection, etc.

These geocells improve the shear strength of the confined soil which serves the following purposes.

1. It forms a stiff mattress to distribute the applied load over a larger area.
2. It improves and increases the shear resistance and bearing capacity of the soil used.

3. It decreases deformation and settlement up to a great extent.
4. It reduces the punching of the soil.

The neighboring cells provide an extra resistance against the cell which is loaded through passive resistance. They have a very high hoop strength and hence the lateral expansion of the infill is restricted by the coir geocells.

3.2.3 Plate Load Test

It is field test and it provides us the ultimate bearing capacity of the soil and the amount of settlement under any load. In this study, load settlement characteristics of coarse sand have been calculated and to do so model tests have been conducted on a model test plate as per IS 1888:1982. The tests consisted of the test tank, mild steel plate, dial gauge and the loading frame whose detailed explanation has been given in the previous chapter. The load was given using a hydraulic jack in the intervals if 2kN and the settlement was recorded on the dial gauge.

Different conditions in which test has been performed are:

1. Soil in unreinforced condition.
2. Soil reinforced with coir geotextile in planar condition at placement depth of 0.1D.
3. Soil reinforced with coir geotextile in planar condition at placement depth of 0.2D.
4. Soil reinforced with coir geotextile in planar condition at placement depth of 0.3D.
5. Soil reinforced with coir geotextile in planar condition at placement depth of 0.4D.
6. Soil reinforced with coir geotextile in planar condition at placement depth of 0.2D and 0.4D.
7. Soil reinforced with two layers of coir geotextile in planar condition at placement depth of 0.3D.
8. Soil reinforced with coir geocell at placement depth of 0.1D.
9. Soil reinforced with coir geocell at placement depth of 0.2D.

3.2.3.1 Advantages of Plate Load Test

1. We can understand the behavior of the foundation under different loading conditions.
2. Settlement can be predicted for different loads.
3. Calculation of shallow foundation can be done by considering the allowable bearing capacity.

4. It is time efficient and cost efficient too.
5. It is very simple to perform and is a reliable option.

3.2.3.2 Limitations of Plate Load Test

1. It doesn't take into consideration the influence zone of the foundation which is up to a greater depth than the depth at which the test is performed.
2. It cannot give us the prediction of the settlement for a longer period of time as it is performed for a shorter period of time.
3. It provides a somewhat lesser value of the bearing capacity of the dense sand which in actual is higher.
4. The settlement also is a bit greater than the settlement estimated by the plate load test for loose sandy soil.

3.2.3.3 Density of Sand Filled In The Tank

The plate load test can be carried out at different densities of sand. It can be achieved by providing different number of blows to each layer while filling the sand in the tank so that more weight of sand is filled in the tank of the same volume. It can also be conducted at different relative densities of sand achieved by the sand raining technique.
To eliminate the effect of density, the test has been done on sand whose density is same and it has been maintained throughout the test. The weight of the sand poured in the sand is 148kg. Sand has been filled in four layers of 120mm each and 50 blows have been given to each layer by the rammer used in Standard Proctor Test.

The density obtained is:

Density = Mass / Volume

d = 148 / 0.141371669

d = 10.46kN/m^3

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Properties of Sand

Various properties of the sand have been evaluated by conducting different tests on the sand. All the properties will be discussed in this section.

4.1.1 Grain Size Distribution

For the grain size distribution, fine sieve analysis has been done of the sand by following the procedure prescribed in the code discussed in the previous section. The results are being displayed here.

Table 4.1 Properties of Sand

Properties	Values
Specific gravity	2.60
Color	Light brown
D_{10} mm	0.104
D_{30} mm	0.175
D_{60} mm	0.291
Uniformity coefficient, C_U	2.798
Coefficient of curvature, C_C	1.012
Maximum density,γ_{dmax} (kN/m^3)	15.60
Minimum density, $\gamma_{d\ min}$ (kN/m^3)	14.23
Classification	SP
Angle of internal friction	41.1^o
Cohesion	0
OMC	11.3%
MDD	18.7kN/m^3

Table 4.2 Gradation Analysis of Sand

Sieve Size(mm)	Weight Retained (g)	% Weight Retained	%Cumulative Weight Retained	% Finer
4.75	0	0	0	100
2.36	9	0.45	0.45	99.55
1.18	29	1.45	1.9	98.1
0.600	26	1.3	3.2	96.8
0.212	1150	57.5	61.35	38.65
0.150	288	14.4	75.75	24.25
0.075	460	23	98.75	1.25
Pan	25	1.25	100	0

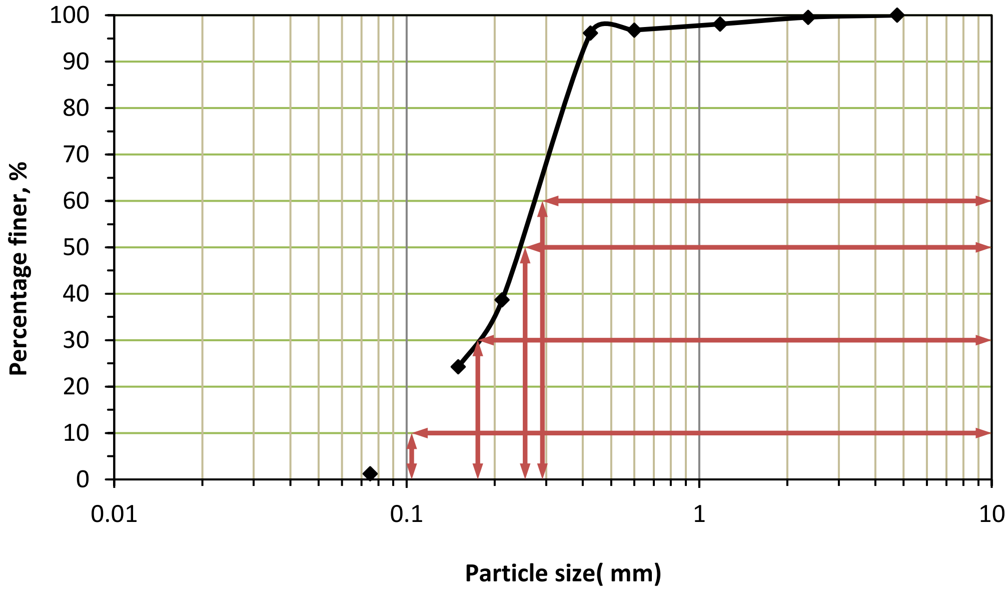

Fig. 4.1 Gradation Of Sand

4.1.2 Effect Of Reinforcement On The Load Settlement Behavior Of Soil

Various tests have been performed on sand in unreinforced and reinforced condition and the results have been noted.

4.1.2.1 Soil In Unreinforced Condition

Plate load test has been performed on sand in unreinforced condition and the results have been noted.

Table 4.3 Settlement and Applied Pressure for Unreinforced Soil

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
2.148	1.790	176.85
4.434	3.695	353.7005
6.339	5.282	530.55
7.863	6.552	707.401
10.784	8.986	884.251
11.977	9.981	1061.101
13.324	11.103	1237.952
14.492	12.077	1414.802
15.406	12.839	1591.652
16.168	13.474	1768.502
16.918	14.099	1945.353
17.630	14.690	2122.203

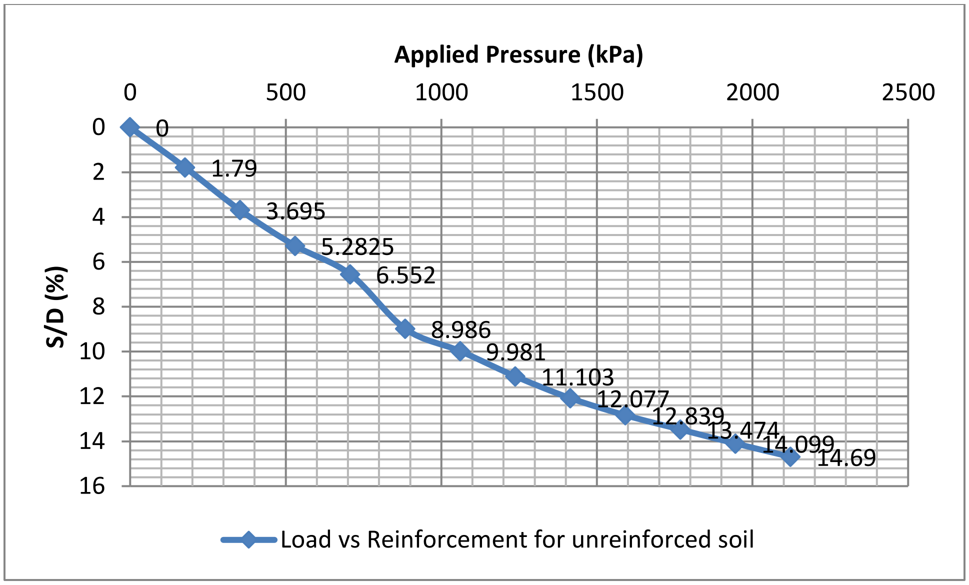

Fig. 4.2 S/D vs Applied Pressure for unreinforced soil

4.1.2.2 Soil Reinforced With Coir Mat In Planar Condition At 0.1D

Table 4.4 Settlement and Applied Pressure for Soil Reinforced With Coir Mat at 0.1D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.944	1.620	176.850
4.230	3.525	353.700
5.373	4.478	530.550
6.770	5.642	707.401
9.158	7.632	884.251
10.326	8.605	1061.101
11.080	9.233	1237.952
12.358	10.299	1414.802
13.120	10.934	1591.652
13.832	11.526	1768.502
14.467	12.056	1945.353
15.127	12.606	2122.203

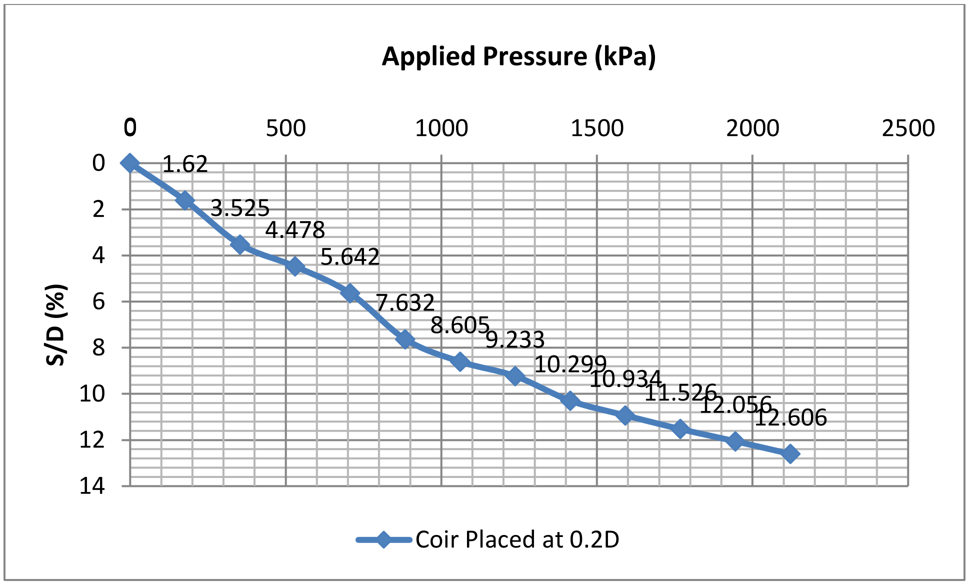

Fig. 4.3 S/D vs Applied Pressure For Soil Reinforced With Coir Mat At 0.1D

4.1.2.3 Soil Reinforced With Coir Mat In Planar Condition At 0.2D

Table 4.5 Settlement and Applied Pressure for Soil Reinforced With Coir Mat at 0.2D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.640	1.360	176.850
3.214	2.670	353.700
4.687	3.900	530.550
5.957	4.960	707.401
8.497	7.080	884.251
9.690	8.075	1061.101
10.629	8.850	1237.952
11.645	9.700	1414.802
12.356	10.290	1591.652
13.169	10.970	1768.503
13.804	11.500	1945.353
14.413	12.010	2122.203

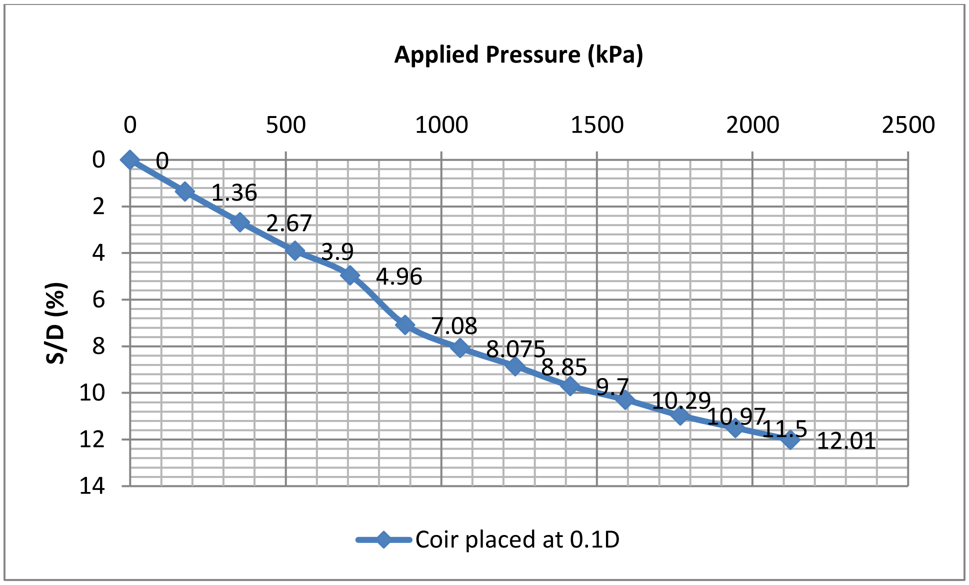

Fig. 4.4 S/D vs Applied Pressure For Soil Reinforced With Coir Mat At 0.2D

4.1.2.4 Soil reinforced with coir mat in planar condition at 0.3D

Table 4.6 Settlement and Applied Pressure for Soil Reinforced With Coir Mat at 0.3D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.944	1.620	176.850
3.621	3.017	353.700
4.738	3.949	530.550
6.339	5.283	707.401
8.371	6.975	884.251
9.260	7.716	1061.101
10.147	8.455	1237.952
11.290	9.408	1414.802
12.052	10.043	1591.652

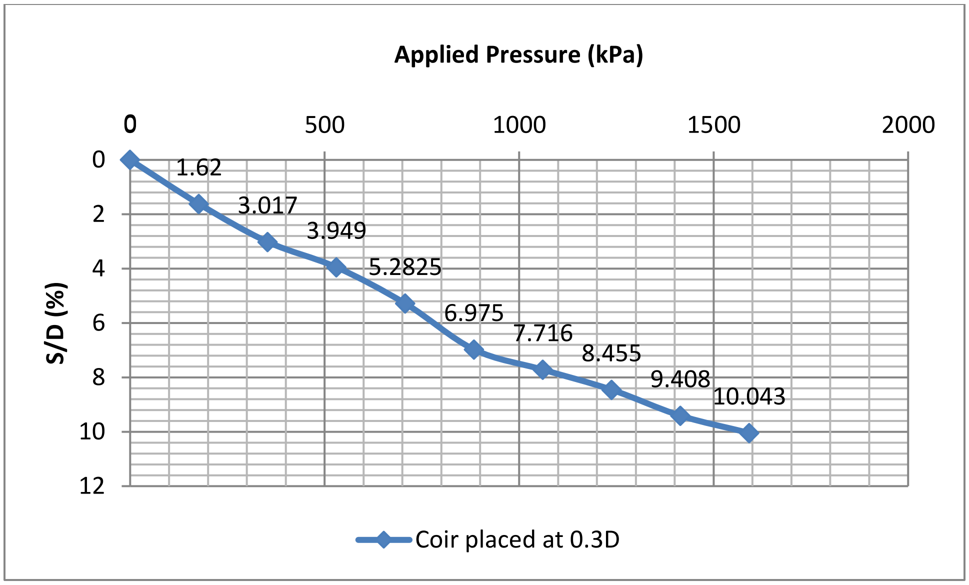

Fig. 4.5 S/D vs Applied Pressure For Soil Reinforced With Coir Mat At 0.3D

4.1.2.5 Soil Reinforced With Coir Mat In Planar Condition At 0.4D

Table 4.7 Settlement and Applied Pressure for Soil Reinforced With Coir Mat at 0.4D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.767	1.472	176.850
4.307	3.589	353.700
5.933	4.944	530.550
6.821	5.684	707.401
9.361	7.801	884.251
10.758	8.965	1061.101
11.927	9.939	1237.952
13.349	11.124	1414.802
14.517	12.098	1591.652
15.787	13.156	1768.502

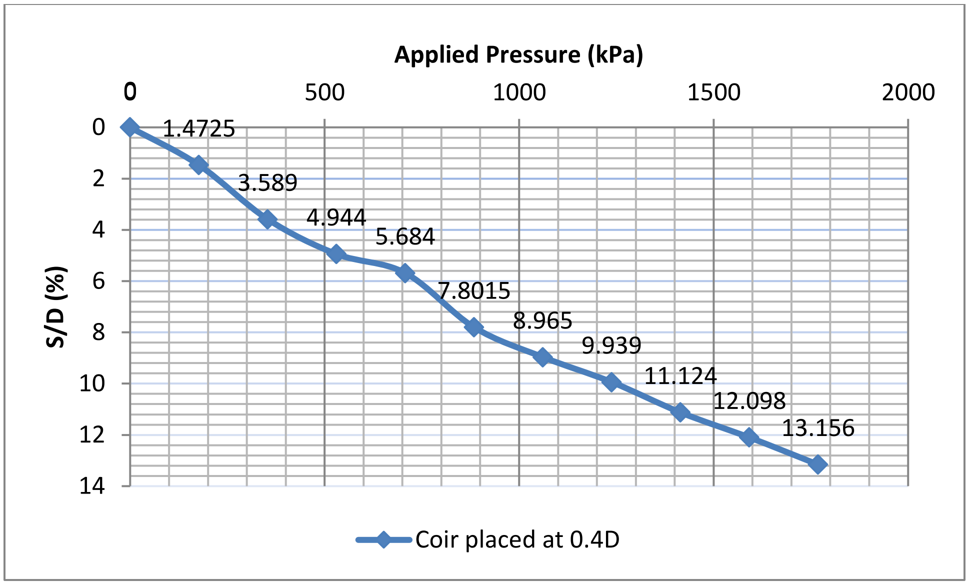

Fig. 4.6 S/D vs Applied Pressure For Soil Reinforced With Coir Mat At 0.4D

4.1.2.6 Comparison Of Settlement Of Soil When Coir Is Placed At Different Depths

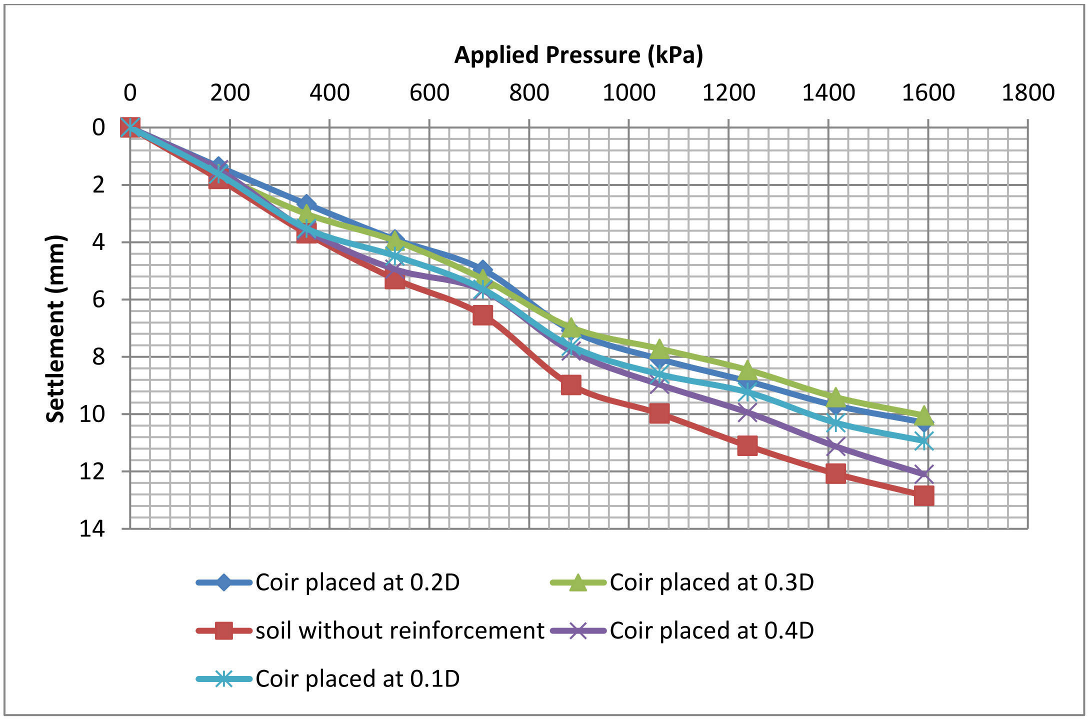

Fig. 4.7 Comparison of Unreinforced Soil With Soil Reinforced With Coir Mat At Different Placement Depths

4.1.2.7 Soil Reinforced With Coir Mat In Planar Conditions At 0.2D And 0.4D

Table 4.8 Settlement and Applied Pressure for Soil Reinforced With Coir Mat at 0.2D and 0.4D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.640	1.366	176.85
3.037	2.530	353.700
4.4848	3.737	530.550
5.196	4.330	707.401
7.736	6.446	884.251
8.625	7.187	1061.101
9.539	7.949	1237.952
10.403	8.669	1414.802
11.114	9.261	1591.652
11.673	9.727	1768.502
12.536	10.446	1945.353
13.146	10.955	2122.203

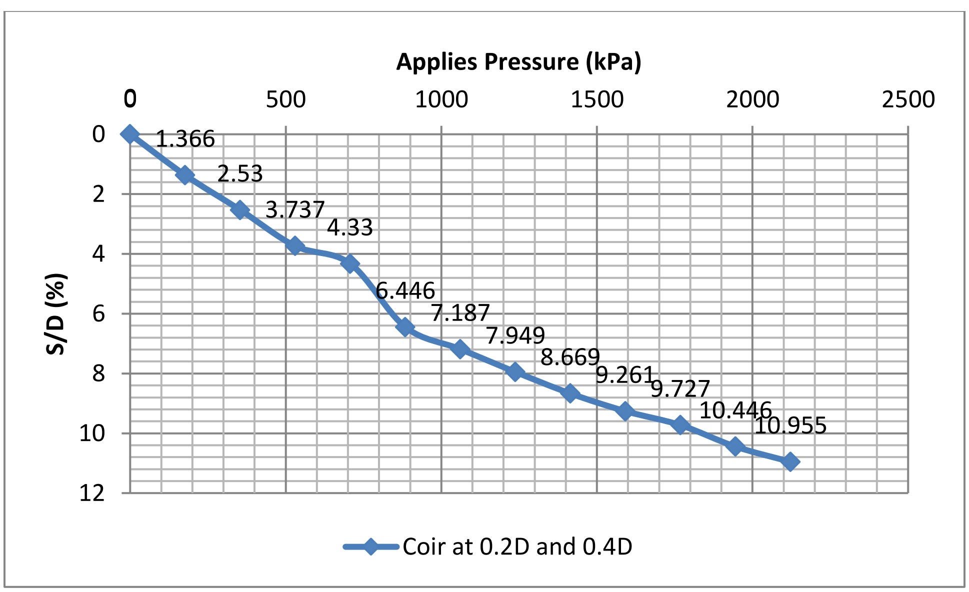

Fig. 4.8 S/D vs Applied Pressure For Soil Reinforced With Coir Mat At 0.2D and 0.4D

4.1.2.8 Soil Reinforced With Two Coir Mat Layers In Planar Condition At 0.3D

Table 4.9 Settlement & Applied Pressure for Soil Reinforced With 2 layers of Coir Mat at 0.3D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
0	0	176.850
0	0	353.700
0	0	530.550
0	0	707.401
1.436	1.197	884.251
2.960	2.467	1061.101
3.849	3.208	1237.952
4.929	4.108	1414.802
5.754	4.795	1591.652
6.567	5.473	1768.502
7.202	6.002	1945.353
7.964	6.637	2122.203

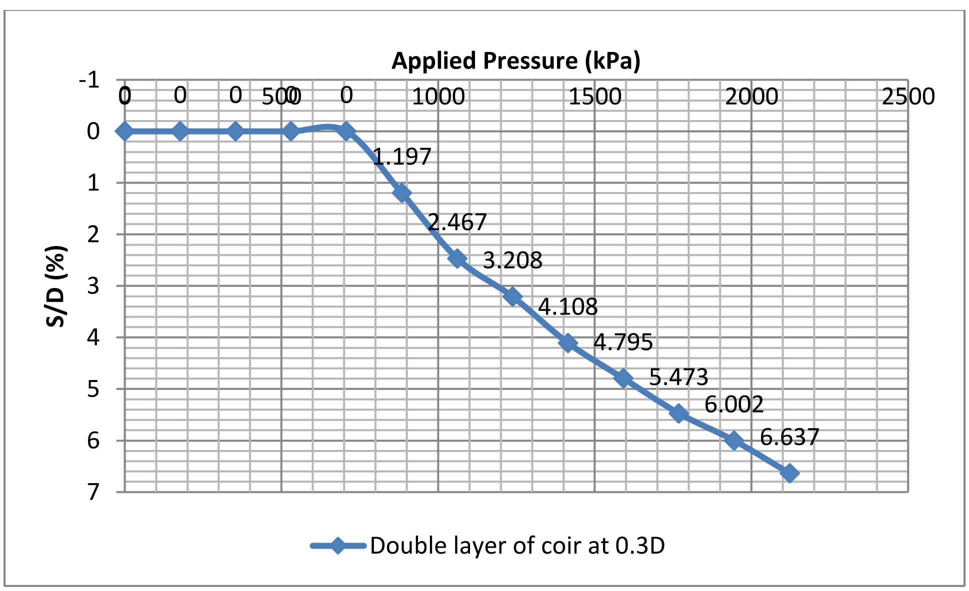

Fig. 4.9 S/D vs Applied Pressure For Soil Reinforced With 2 layers of Coir Mat At 0.3D

4.1.2.9 Soil reinforced with coir geocell placed at 0.1D

Table 4.10 Settlement & Applied Pressure for Soil Reinforced With Coir Geocell at 0.1D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
0.1905	0.158	176.850
1.206	1.005	353.700
2.959	2.465	530.550
4.432	3.693	707.401
6.922	5.768	884.251
7.988	6.656	1061.101
8.888	7.406	1237.952
9.880	8.233	1414.802
10.769	8.974	1591.652
11.684	9.736	1768.502
12.447	10.372	1945.353
13.005	10.837	2122.203

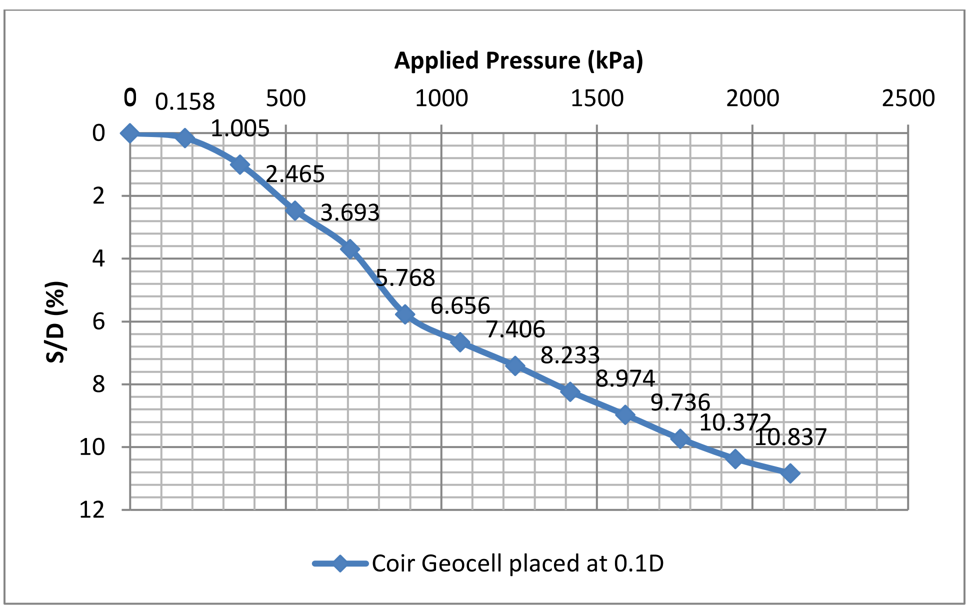

Fig. 4.10 S/D vs Applied Pressure For Soil Reinforced With Coir Geocell At 0.1D

4.1.2.10 Soil Reinforced With Coir Geocell Placed At 0.2D

Table 4.11 Settlement & Applied Pressure for Soil Reinforced With Coir Geocell at 0.2D

Settlement(mm)	S/D (%)	Applied Pressure (kPa)
0	0	0
1.013	0.844	176.850
3.121	2.600	353.700
4.950	4.125	530.550
6.143	5.119	707.401
8.423	7.019	884.251
9.572	7.976	1061.101
10.334	8.611	1237.952
11.223	9.352	1414.802
11.985	9.987	1591.652
12.620	10.516	1768.502
13.128	10.940	1945.353
13.686	11.405	2122.203

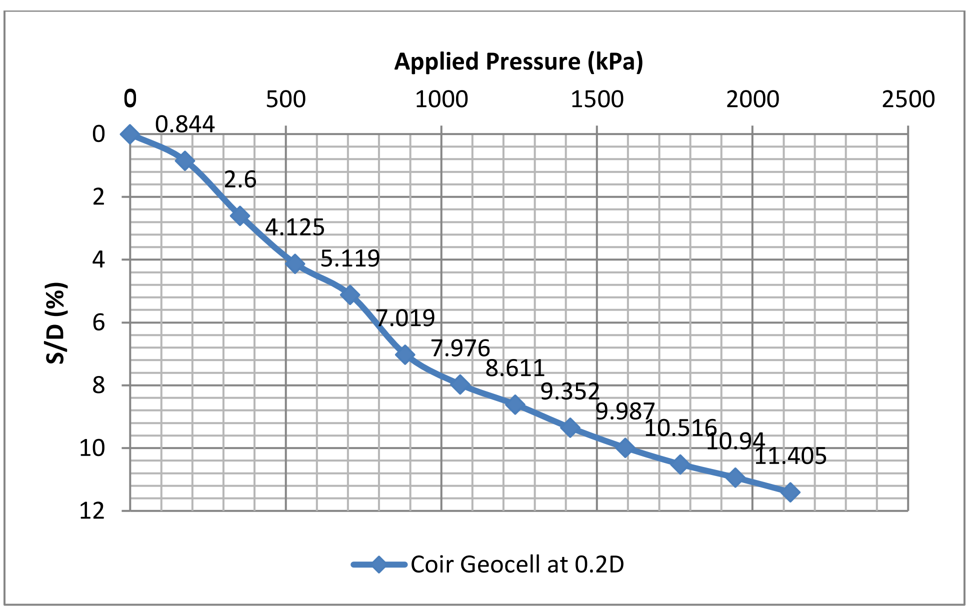

Fig. 4.11 S/D vs Applied Pressure For Soil Reinforced With Coir Geocell At 0.2D

4.1.2.11 Comparison Of Settlement Of Soil When Coir Geocell Is Placed At Different Depths

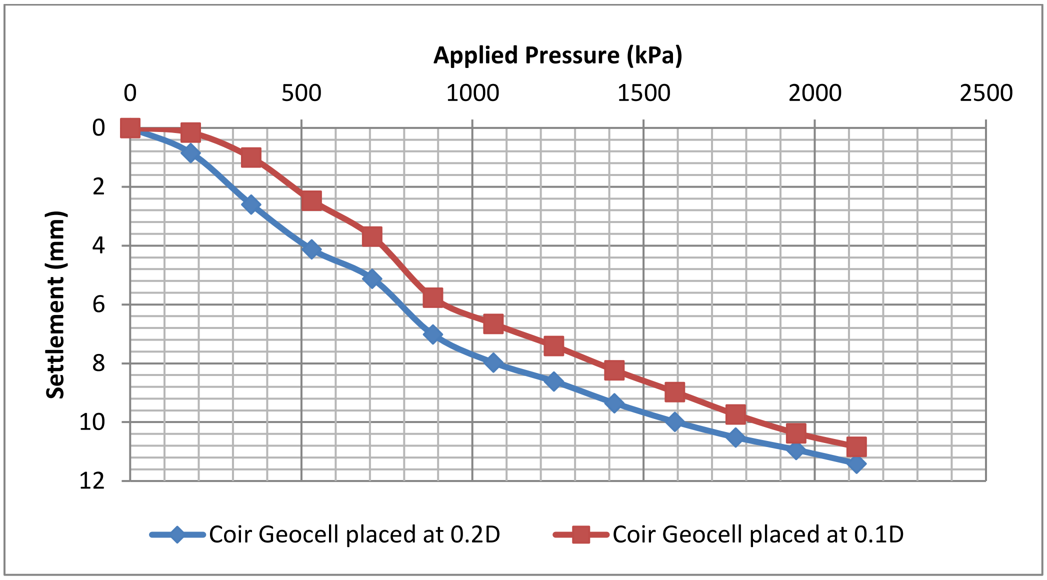

Fig. 4.12 Comparison of Unreinforced Soil With Soil Reinforced With Coir Geocell At Different Placement Depths

4.1.2.12 Improvement Factor For Various Placement Depths Of Coir Geotextile

Table 4.12 u/D & Improvement Factor (IF) for Soil Reinforced With Coir Mat

u/D	IF
0.1	1.283
0.2	1.412
0.3	1.484
0.4	1.172
0.5	1.056
0.6	0.749
0.7	0.592

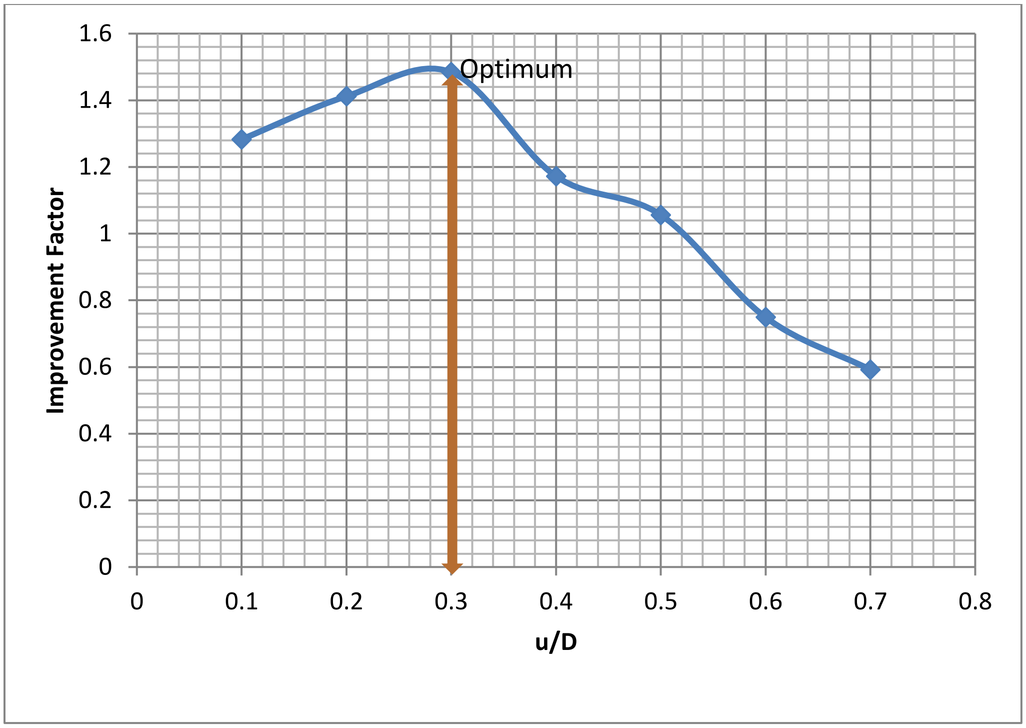

Fig. 4.13 IF vs u/D For Soil Reinforced With Coir Mat

4.1.1.13 Improvement Factor For Various Placement Depths Of Coir Geocell

Table 4.13 u/D & Improvement Factor (IF) for Soil Reinforced With Coir Geocell

u/D	IF
0	1.5
0.1	1.73
0.2	1.66
0.3	1.2
0.4	1

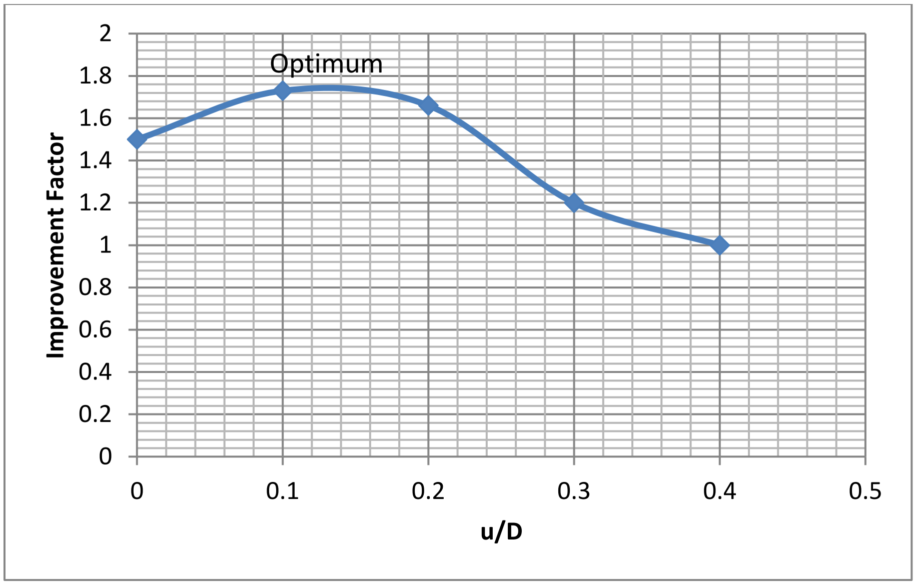

Fig. 4.14 IF vs u/D For Soil Reinforced With Coir Geocell

4.2 Discussion Of Results

From the above graphs and results, following things can be discussed:

1. It is observed that with increase in the pressure, the settlement increases. This may be due to the fact that when the pressure is applied, a pressure bulb is created beneath the plate and its size varies with the intensity of pressure.

2. The geotextiles have been placed at 0.1D, 0.2D, 0.3D and 0.4D from the base of the footing and it has been examined that the settlement decreases in each case as compared to that of unreinforced soil, because due to the placement of geotextiles at various depths, the pressure bulb is being cut by the geotextiles and hence the size of the pressure bulb is being reduced resulting in decrease of settlement.

3. The values of settlement at 0.1D, 0.2D, 0.3D and 0.4D are 13.120mm,12.356mm, 12.052mm, 14.517mm respectively. This clearly indicates that the settlement is decreasing in each case compared to the unreinforced soil where settlement is 15.406mm.

4. Various research papers have been read thoroughly and according to them, the height of the geocell is an important factor in governing the characteristics of soil. Hence, the height of the geocell is taken as 0.6 times the diameter of the plate which is 7cm (Dharmesh Lal et al. 2017). All the tests have been done taking the height of the geocell as mentioned above.

5. A comparison has been done between planar coir geotextile and coir geocells. From the results, it can be clearly noted that settlement reduction is more when geocells are used as compared to the coir geotextile. Moreover, bearing capacity of soil reinforced with coir geocell is calculated as per IS code at D/10 and it comes more than that of the soil reinforced with coir geotextile.

6. Also, according to various studies conducted before, the optimum depth of the placement of coir geotextile and coir geocell has been calculated. The same has been done by calculating an Improvement Factor value at each depth of the placement of the coir geotextile and coir geocell and the results are more or less coinciding with the previous studies which verify the test.

7. It has been seen that for coir geotextile the optimum depth of the reinforcement is 0.3 times the diameter of the plate after which the improvement factor starts to decline and for the coir geocell it is 0.1 times the diameter of the plate after which the improvement factor starts to decline at a great pace. Improvement Factor of coir geocell is greater than that of the coir geotextile.

8. Improvement factor has been calculated by the formula:

$$IF = \frac{\text{Bearing capacity of geo-textile reinforced soil}}{\text{Bearing capacity of Unreinforced soil}}$$

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS FOR FUTURE

5.1 Conclusions

From the results produced, following conclusions can be drawn:

1. Characteristics of the foundation can be greatly enhanced by the incorporation of the coir geotextiles and coir geocells. This is because the coir geocells provide a confining effect due to their 3D structure and interlock the soil between their apertures.

2. The arrangement of the reinforcement and its configuration play a very decisive and important role in the performance of the reinforced soil.

3. A significant increment was recorded in the bearing capacity when coir geotextile and coir geocell were placed at a depth of 0.3D and 0.1D respectively from the base of the foundation.

4. Coir geocells have proved to a better reinforcement material than the coir geotextile in its planar form as Improvement factor in their case is 48.24% greater than that of the coir geotextile.

5.2 Recommendations for the Future Work:

1. The results obtained in the research work are specific to conditions of the soil and test parameters.

2. The results are also prone to scale effect and hence can't be directly applied to the field but the basic mechanism is more or less same.

3. The above tests can be performed for various soil types and different test parameters other than the present study and various results can be drawn.

4. Effect of coir geotextile and geocell for long term reinforcement can be evaluated as this study gives the effect for the short term.

5. These geotextiles can be applied to the field and studies can be carried out.

6. Numerical modeling on the present study and the coir geotextile can be performed by using ABAQUS FEA or PLAXIS 3D softwares.

7. Durability of coir can be increased by applying cement or bitumen coating and tests can be performed accordingly.

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EDUCATION

S.NO.	QUALIFICATION	YEAR	COLLEGE/UNIVERSITY	SCORE	DEPT. RANK
1	M.TECH. (GEO-TECHNICAL ENGG.)	2016-18	Delhi Technological University, Delhi	8.0(CGPA)	3rd
2	B.TECH. (CIVIL ENGG.)	2011-15	Arya College Of Engg. & Research Centre, Jaipur (ACERC)	67.20%	NA
3	AISSCE (Class XII)	2011	Adarsh Bal Niketan, IITR, Roorkee	80.6%	NA
4	AISSCE (Class X)	2009	Montfort Senior Secondary School, Roorkee	94.0%	3rd

INTERNSHIPS

- Summer Intern, SBHEP, L&T UTTARAKHAND LIMITED, RUDRAPRAYAG, (13 JUNE – 10 JULY 2014)
- Larsen & Toubro Limited, commonly known as L&T, is an Indian multi-national conglomerate headquartered in Mumbai. Two Danish engineers taking refuge in India founded it. The company has business interests in engineering, construction, manufacturing goods, information technology, and financial services.
- Studied the construction methodology of barrage, its various parts and internal structures.
- It enhanced my knowledge by practical visualization at site.

ACADEMIC PROJECTS

1. Final Year Project: Construction of GREEN CONCRETE and to find out its advantage over conventional concrete.
    - My role was to make a mix of all the aggregates required for the construction of green concrete and pour them in the mould.
2. Research Project: Various uses of fly ash in construction.

- It was a team project and various uses of fly ash were studied and future advancements were proposed.

ACADEMIC ACHIEVEMENTS AND AWARDS

1. Awarded the scholarship by YOUTHFORWORK team for scoring highest marks in college in test conducted by them.
2. Awarded scholarship from NASSCOM under the initiative started by National Skill Development Corporation (NSDC) for qualifying the exam conducted by them for engineers.
3. NCC ‘C’ and ‘B’ certificate holder in senior division in Uttarakhand battalion (2009-11).
4. Awarded scholarship by ABN School, IITR for securing good marks in X standard.
5. Scored 49.3 marks in GATE 2016 with a score of 616, rank 1974 and 98.35 percentile.

POSITIONS OF RESPONSIBILITY

1. Senior Cadet – ABN SCHOOL NCC TEAM (2009-11).
2. Coordinator –SHRADHANJALI, 2014- The Annual National level cultural fest, ACERC, Jaipur.
3. Coordinator – ETUDE, Elite club of student development cell of ACERC.
4. Representative of Uttarakhand state – In national trekking camp, LEDO, Assam (2009).
5. Campus Ambassador of DTU and Executive at Indian Roads Safety Campaign(IRSC).

EXTRA CURRICULAR ACTIVITIES

1. Participated in National Trekking Camp held at LEDO, Assam & MIAO, Arunachal Pradesh (2009).
2. Participated in state level camp of NCC held at RNI College, Bhagwanpur (Haridwar), Uttarakhand.
3. Participated in CORONA, annual tech fest of Anand international college of engineering, Jaipur.
4. Member – ACERC cricket team and participated in ARYA CUP – The national level cricket tournament.

DECLARATION

I hereby declare that the details furnished above are true and correct to the best of my knowledge and belief.