PERFORMANCE ASSESSMENT OF GEOCELL REINFORCED MUNICIPAL SOLID WASTE ASH IN PAVEMENTS

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

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HIMACHAL PRADESH, INDIA

MAY – 2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled **"PERFORMNACE ASSESSMENT OF GEOCELL REINFORCED MUNICIPAL SOLID WASTE ASH IN PAVEMENTS"** submitted for partial fulfilment of the requirements for the degree of bachelor of technology in civil engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Saurabh Rawat**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"PERFORMNACE ASSESSMENT OF GEOCELL REINFORCED MUNICIPAL SOLID WASTE ASH IN PAVEMENTS"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Ashish Dangwal (151639) and Ayush Bhardwaj (151687)** during a period from August, 2018 to May, 2019 under the supervision of **Dr. Saurabh Rawat** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement is correct to the best of our knowledge.

Date: May, 2019

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ACKNOWLEDGMENTS

I would like to thank so many people who have helped in every possible way in successful completion of this project. Firstly, I would like to express my gratitude to my project guide **Dr. Saurabh Rawat**, who have provided me an opportunity to do this project under his guidance. He has provided valuable ideas and support during the course of this work. This work would not have been possible without his support. I would like to thank our project coordinator and all other faculty members and technical staff of Department of civil engineering of Jaypee university of information technology for providing valuable input through the course of this work. I would also like to thank staff of the geotechnical lab at **Jaypee University of Information Technology Waknaghat** for their support and help in the sample testing and analysis and finally my institute Jaypee University of Information Technology.

ABSTRACT

Geocells is used as a soil reinforcement which is prepared with waste P.E.T. bottles with MSW fly ash as a infill material that is lying in low graded clay bed by various test .The hydraulic jack is generally used in order to provide a uniform loading on a rigid steel plate that is square in shape. The impact of width and height of geocell mattress as well as its variation along with the depth on total performance of arrangement in term of the defrayal and vertical stress acted upon the base inorganic soil layer. Test results indicated that tetrahedral arrangement showed 1.5 times more load on the soil and P.P.B. geocell showed 6.5 times more load on the base layer as compared to octahedral. Therefore, clarifying that octahedral arrangement was more suitable then the other. The quantitative results motivate the use of waste P.E.T bottles for clayey soil strength development which in turn help solving the disposal issue.

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LIST OF ACRONYNMS AND ABBREVIATIONS

dia	Diameter
MSW	Municipal Solid Waste
PET	Polyethylene Tetraphthalate
PPB	Polypropylene Bags
UU	Unconsolidated Undrained

CHAPTER 1

INTRODUCTION

1.1 General

This chapter deals with the need of study of geocell in soil stabilization. It also brings forward the development of different soil stabilization or ground improvement technique used. The chapter outlines the basic geocell reinforcement mechanism and also the overall organization of thesis.

1.2 Need of Study

Expansive soil is hazardous for light structure and its foundation due to its expansive properties which exerts an uplifts pressure to foundation[6]. Alternatively permanent deformations are observed as per the construction on the weak soil. Fig. 1.1 shows majority of black cotton soil distributed in large portion of India. Due to its expansive nature it expands and contracts which leads to development of spaces between the soil leading to decrease in strength and stiffness of soil and ultimately leading to shear failure of the soil. Shear failure is experienced in soil due to external boundary force or due to selfweight of the soil and secondly due to expansion and contraction of soil beneath the structure[6]. So therefore reinforcement is required in order to develop tensile bond on soil reinforcement interface which will restrict he movement of soil particles. The geocell mattress made up of geotextile provides provide physical confinement to soil an helps in transferring the load through geocells[7]. The geocell of higher stiffness forms a mattress composite with bending stiffness and reduces stress on pavement. Geocells reduces plastic deformation on working platforms[8] and reduces the vertical settlement and lateral spreading [9].

Fig. 1.1 Distribution of black cotton soil in different parts of India

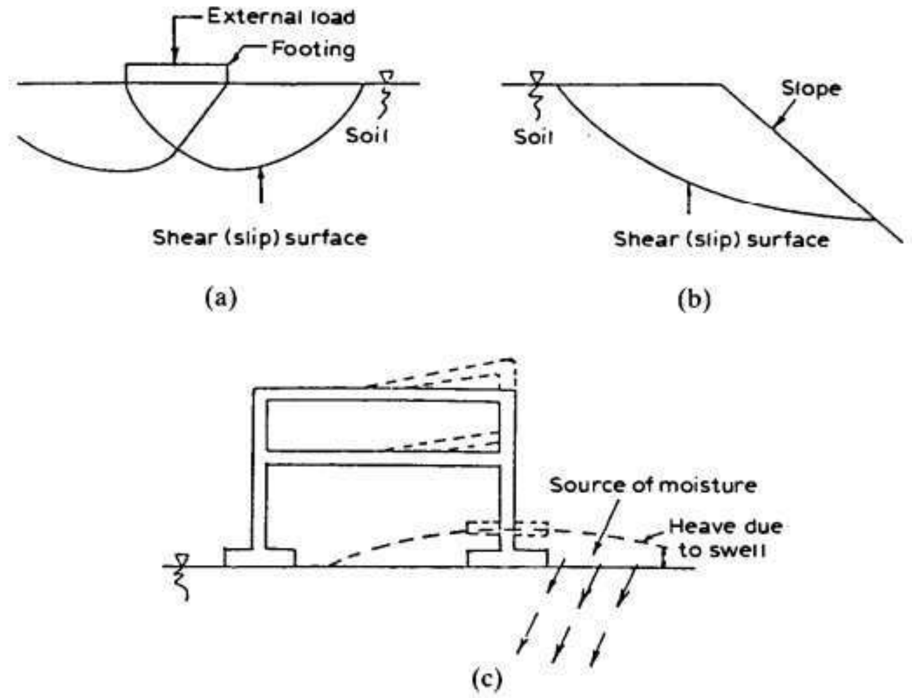


Fig. 1.2 Shear failure due to (a) external load, (b) self weight, (c) expansion of soil [6]

1.3 Waste Materials

1.3.1 Plastic

In India, 3.92 million tonnes of plastic waste is produced per year. More than half of its production is dumped into oceans and rest get dumped on land where they do not get decomposed easily and results in polluting the water. Plastic being a toxic product is non biodegradable product which enter the food chain affecting human and animal health. Burning of plastic produces various toxic gases such as sulphur dioxide, dioxins etc. These emissions causes respiratory ailments and stress human immune system. Chlorinated plastic releases harmful chemicals into the soil which seeps into the ground water and enters into the ecosystem. So, in order to minimize its harmful effects recycling of plastic is necessary as it can be used as container, jars, bottles or used as geocell for reinforcement of soil.

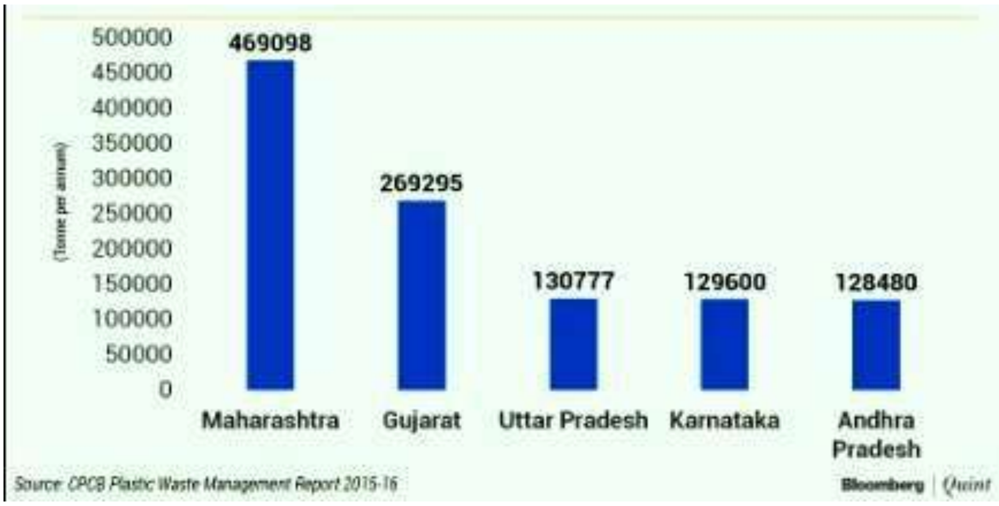


Fig. 1.3 Plastic waste generation in India

1.3.2 MSW Fly Ash

Municipal solid waste of a large quantity is produced every year. Waste management and its utilization are major concern in many countries. Incineration is commonly used techniques for treating waste as it will reduce the waste 70% by mass and 90% by volume. Generally municipal solid waste incineration produces two types of fly ash which can be grouped as bottom ash or fly ash. The chemical composition of MSW Fly Ash are Si, Fe, Al, K, Ca, Na, Cl. It also contains various oxides such as calcium oxide, ferric oxide and potassium oxide. MSW Fly Ash has various applications such as it can be used in cement and concrete production. It could be a possible alternative of raw material in Portland cement production. Nitrogen, phosphorous and potassium are the three main nutrients for plant growth therefore MSW Flyash can provide these nutrients to the soil in agriculture. For the construction of embankments when the soil do not present the desirable geotechnical properties it is common practice to stabilize them with lime or cement. It increases shear strength. MSW Flyash can be used as a substitute of lime or cement because its density is less than other fill material used in construction of embankments.

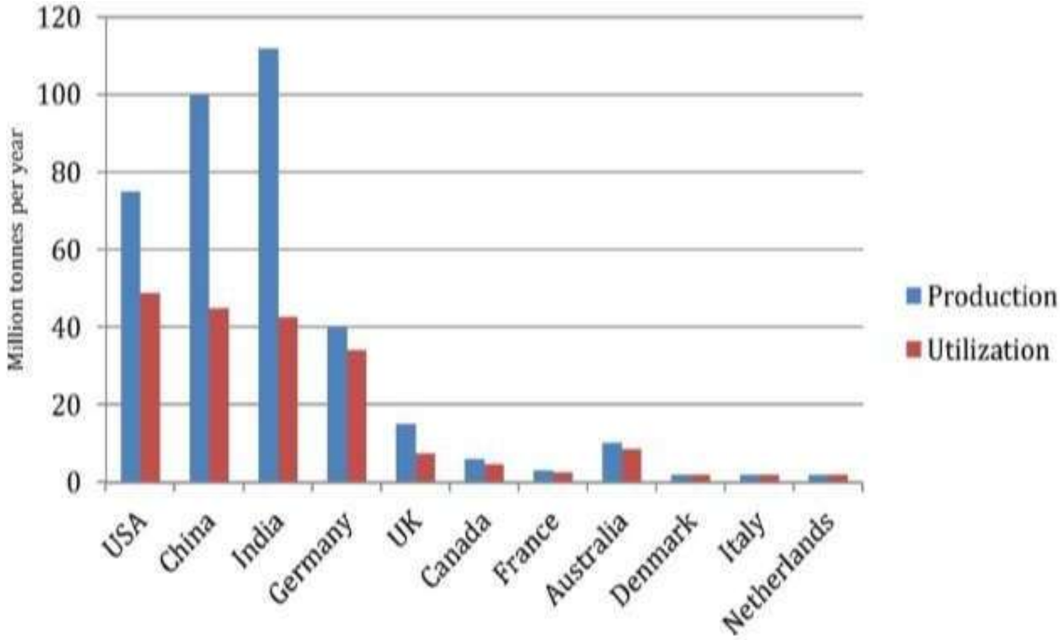


Fig. 1.4 Production and utilization of flyash in various countries

1.4 Geocells

Geocells is a three dimensional, polymeric, honeycomb like structure[2] of cell unified at joint that provide effective confinement of the encapsulated soil against being pushed away from the region under loading. The filled cells being interconnected, the panel acts like a large 3D mat. New types of geocells with advanced technological features are made of new polymeric structure characterized by low temperature flexibility similar to High Density Polyethylene.

The base layer reinforcement forced geocell mattress in road construction act as a rigid slab or mattress for distribution of traffic load vertically on a broader subgrade. Therefore, the vertical force applied to the subgrade get decreased and capacity increases. Metallic geocells especially those made up of aluminum were not chosen because of handling difficulty and high cost[2].

Geocell have also been made using geogrid sheet jointed by bodkin joints. Bodkin joints are a type of arrow head. At present high density polyethylene is the most common polymer used to making geocell by welding.

Geofoam is stretched polystyrene or extruded polystyrene (EPS) manufactured into large lightweight block. The block vary in size but are often 2m x 0.75m x 0.75m. The primary function of geofoam is to provide a lightweight void fill below a highway, bridge approach embankment or parking lot. As geofoam minimizes settlement it is used in much broader application including lightweight fill, green roof fill. Geofoam is up to 50 times lighter than other traditional fills with similar compressive strength.

Fig. 1.5 Novel Polymer Geocells are spreaded widely over the ground and infill material is compacted using vibratory rollers. Vibratory rollers of weight 8 to 10 tonnes are allowed over the pavement. Pneumatic rollers is applied over the geocell reinforced pavement after the installation of geocells. [2]

Fig. 1.6 EPS geofoam in cubical form is the extruded polystyrene large lightweight blocks easy to handle and apply[12].

1.5 Geocell Application

Being cost effective geocell reinforcement helps in improving the bearing capacity and modulus. The base layer thickness gets reduced and the service life of pavement is also increased. It helps in minimizing operational and maintenance cost. Some of its applications are listed below.

1.5.1 Prevention of Soil Erosion

As the upper layer of soil is sometimes weak of slope surface the soil particles can be easily displaced by the factors of such as wind and water forming rills and gullies with the passage of time. The geocells hold the soil particles better thus reducing the potential for erosion. The geotextile with is permeable nature allows water to freely flow between the cell thereby increasing the vegetation growth and future increasing soil erosion resistance.

Fig. 1.7 Geocell mat laid over the slope which helps in strengthening the soil and holding the top soil layer tightly.

1.5.2 Load Support

Due to the confinement effect and honeycomb structure geocells spread the load over the large area increasing the modulus of the infill material. Geocells are very effect full for pavement, ground improvement below embankments, access roads over poor subgrade such as expansive soils, black cotton area. Geocells load support solution is ideal for low CBR ground with heavy load requirements and help save on natural resource by reduction in aggregate layer.

Fig. 1.8 Geocell mat spread over an area before the soil or any soil stabilized mixture is scarified over it. Thereafter the soil is tamped using vibratory roller of weight 8 to 10 tonnes and water content required. Lime stabilization is also done in order to remove excess moisture for maximum compaction of soil within geocells.

1.5.3 Retaining Wall

In several cases when change in grade challenges are encountered, retaining wall is required. The typical retaining wall are expensive to construct and require substantial time. A geocell retaining wall is best solution for such projects. The wall can be designed as a geogrid reinforced soil wall or as a gravity wall. Since the wall panels are manufactured and shipped to site minimal site activities are required.

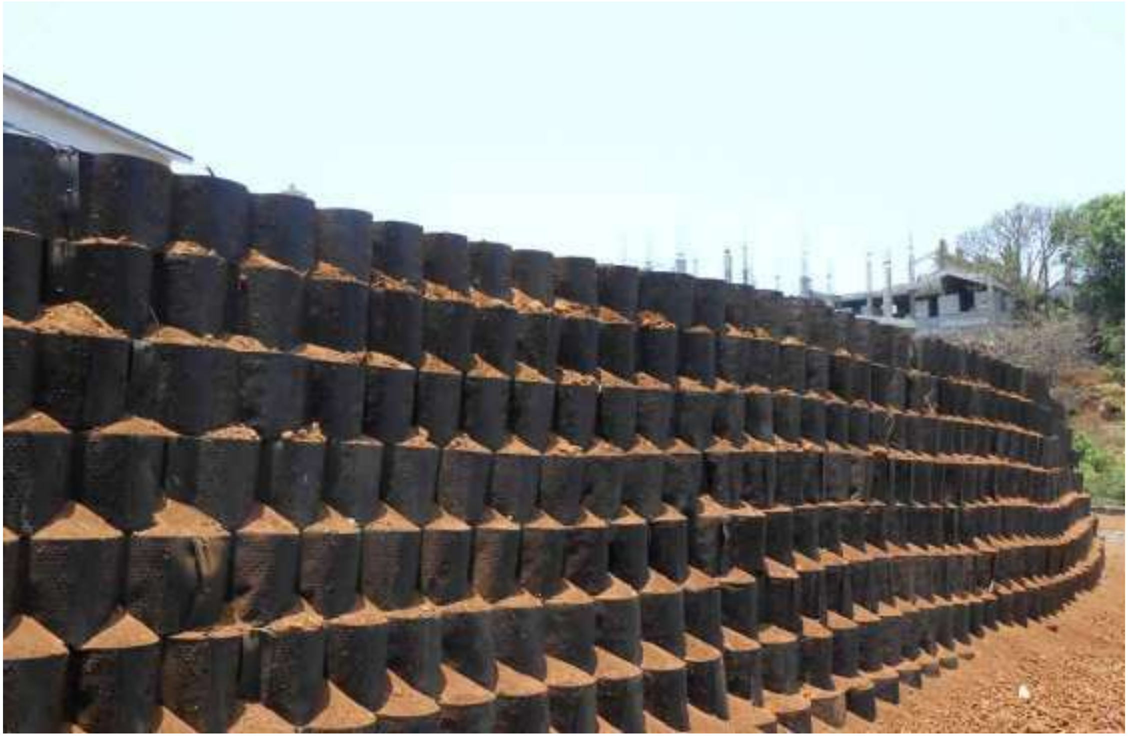


Fig. 1.9 Different layer of geocell mat are placed over each to create a mechanically stabilized retaining wall. Lime stabilization when using soil as infill and soil cement mix are generally used for placing the geocell vertically.

1.5.4 Slope Liner Protection

In cases, where a geomembrane liner or any such surface protective membrane is used on the slope which cannot be damaged or punctured, geocell liner protection system is the perfect solution. Geocell mat can be laid on the liner without any requirement for puncturing the liner and is anchored at the crest of the slope. The crest anchorage is engineered to withstand all the sliding forces arising in mat. Geocell mat liner protection system can also be designed for very steep slopes.

Fig. 1.10 Slope Concreting is done in order to protect geomembrane lined slope from uplift

1.6 Advantages and Limitations of Geocells

1.6.1 Advantages

Various advantages of geocells are easy to transport and install at the sight. Environment friendly and lightweight, low cost and higher durability. It reduces the operational and maintenance cost of roads. It is better utilization of waste product and better stabilization of weak soil or infill material.

1.6.2 Limitations

Handling, storage and installation must be assured by careful quality control and quality assurance. Long term performance of a particular resin which is used to make the geocell must be assured by proper additives including antioxidants and fillers.

1.7 Geocell Mechanism

The load carrying capacity of geocell reinforced soil is contributed by mainly contributed two mechanisms lateral resistance effect, vertical dispersion effect and membrane effect.

Lateral resistance effect used in the formulation indicates the mobilization of the additional shear strength in the soil bed due to the interaction between the inner surface of geocells and infill soil. Fig. 1.11 represents the mechanism of mobilization of shear strength due to wall soil friction. The inner surface of the geocell has a unique texture and friction force will develop between the material and geocell inner surface. The fictional force developed resist the imposed load and increase the bearing capacity.

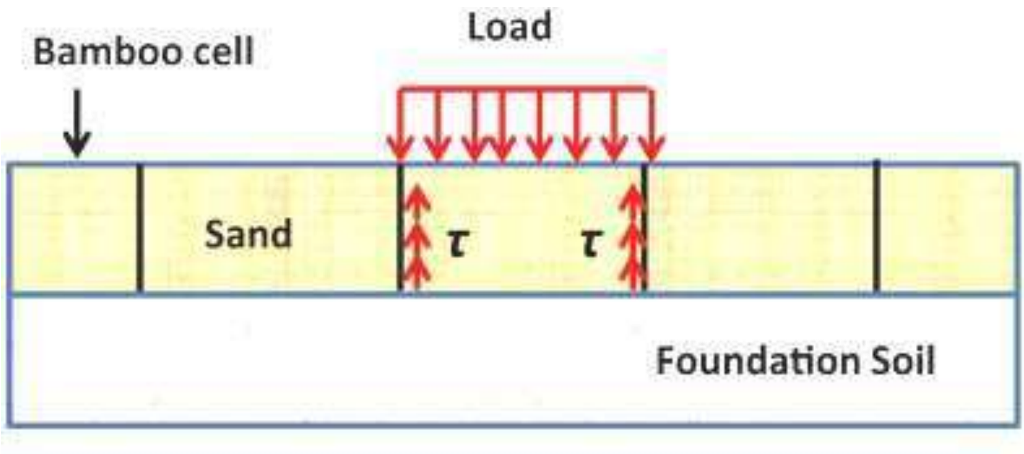


Fig. 1.11 Mechanism of mobilization of shear strength due to wall friction[10]

Vertical Dispersion Mechanism is also called wide slab mechanism. Fig. 1.12 shows the schematic representation of the vertical stress dispersion mechanism. Footing of width B resting on the bamboo reinforcement behaves as if the footing of width B+ΔB resting on soft soil at depth of D_r, where D_r is the depth of reinforcement. β is varies between a minimum value of 26 (1H;2V) to maximum of 45 (1H;1V). To be conservative the least angle of dispersion is β=26 was considered in the analysis. P_r

the pressure on the footing width B and therefore reduction in pressure is given by [11].

$$\Delta P_2 = P_r\left(1 - \frac{B}{B + 2D_r \tan\beta}\right) \quad (1)$$

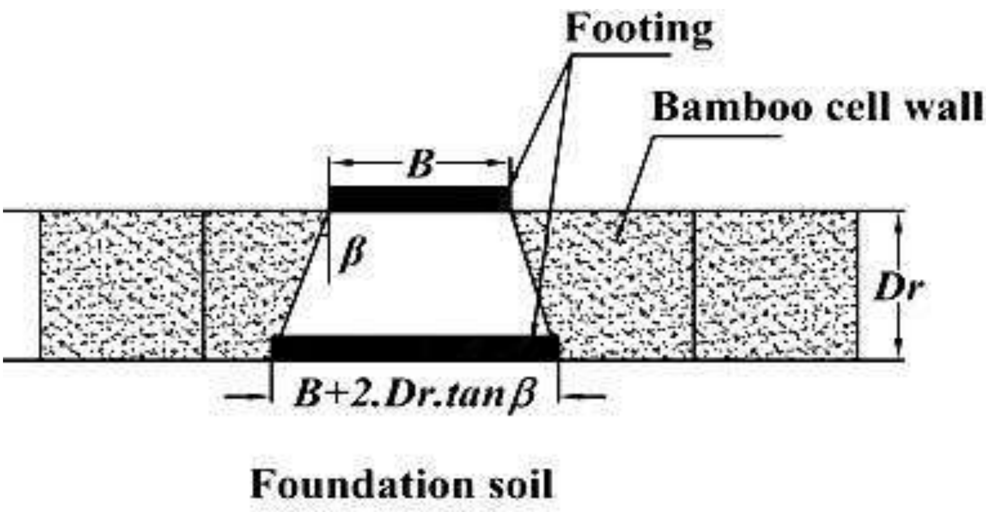


Fig. 1.12 Vertical stress displacement mechanism [10]

The membrane effect mechanism is contributed by vertical component of the mobilized tensile strength of the planer reinforcement in case it is provided. The increase in the load carrying capacity due to membrane effect is given by[11].

$$\Delta P_3 = \frac{2T \sin\alpha}{B} \quad (2)$$

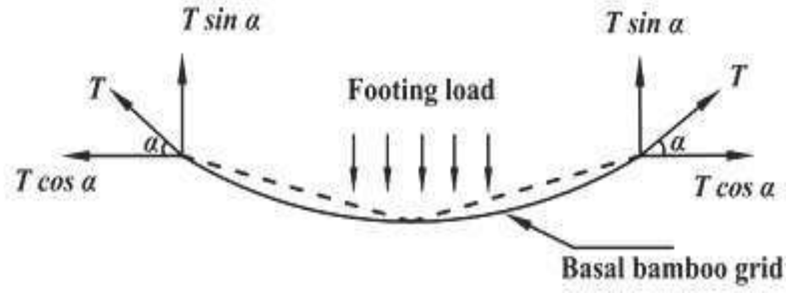


Fig. 1.13 Deformed basal geogrid contribution to membrane effect[10]

1.8 Organisation of thesis

The chapter 2 describes various parametric studies and numerical analysis conducted on the concept of soil reinforcement. The chapter highlights the affect on the behaviour structure by varying many parameters highlighting the present study, objectives and future scope. Various research paper and its summary is also described in the this chapter.

The chapter 3 describes the methodology adopted for the material required for construction, experimental set up, geocell fabrication and instrumentation are in detail.

The chapter 4 deal about the results and discussion for laboratory test, model testing and finite element modelling has been recorded . This chapter deals with validation of results obtained from the model testing.

The chapter 5 gives the conclusion form the present study conducted . The chapter also provides an insight into future of present work.

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter deals with the researches made on designing the reinforced soil structures for the past many years. The idea of cellular confinement was developed by United States Arms corps of Engineers in 1970. Geocells were then made up of paper soaked in phenolic water-resistant resin. Later metallic geocells were used to meet but due to its handling difficulties and higher cost other alternatives were searched. Researches on geocell reinforcements included studies which have varied parameters such as aspect ratio (L/D), geocell matt placed at various height from the top and working with various reinforcements od different materials such as P.E.T. bottles and P.P.B .This chapter tries to summarize the various parametric studies on the concept of soil reinforcement.

2.2 Research on Geocell Reinforced soil

Sanat K. Phoharel (2017) experiment on evaluation of geocell reinforced base under repeated loading was conducted on medium scale loading apparatus. The loading system had a 15 cm diameter air cylinder with air pressure of 900kPa.The loading plate was 15 cm in diameter which was used. The load was applied by adjusting the air pressure in the cylinder and the load was applied at 1min/cycle in trapezoidal form. The results obtained were that the geocells improved the bearing capacity, stiffness. Reduce the required thickness, extend the service life of pavement. Reduce the maintenance requirement and operational cost.

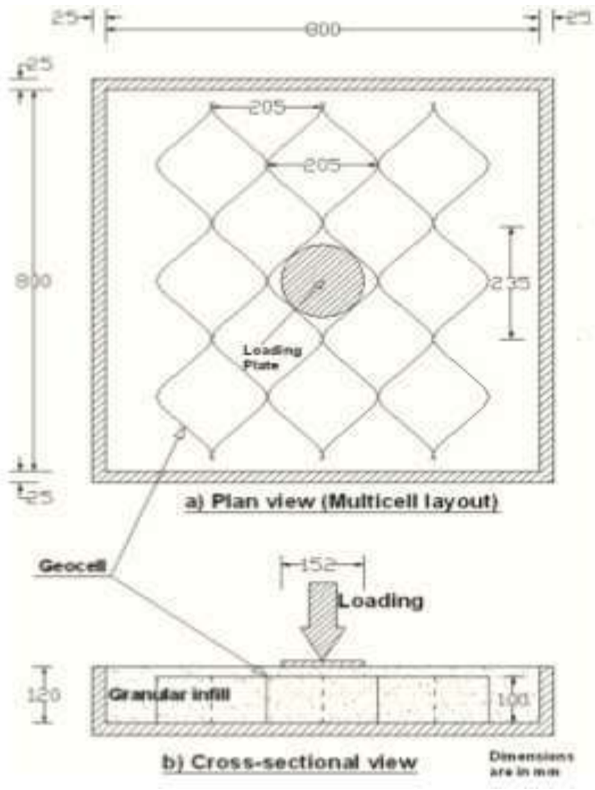


Fig. 2.1 Test box with geocell layout [2]

The Fig. 2.1 shows the plane view of geocell with loading plate at the centre and cross sectional view with granular infill material and loading plate which acts as footing

Husna Humayoo (2016) conducted the improvement on CBR using waste plastic matt as geocell . Test are conducted for sample with or without plastic matt. The waste plastic bottles are cut into different height and thickness. The rings are joined to form a map like structure. The waste plastic mats of different thickness such as 1cm,2cm,3cm,4cm and 5cm are taken. Individual test are carried out for different thickness placed at varying depth of 2cm,4cm,6cm,8cm. Maximum CBR was found at a depth of 4cm which was equal to 2.9 .At various other depths the CBR value as compared to the value at 4 cm was less and as the CBR values is less the thickness of the pavement increases as a result the structure becomes uneconomical and as the CBR value increases the thickness of pavement decreases an a result less material are required to built the pavement so therefore it will be more economical as compared.

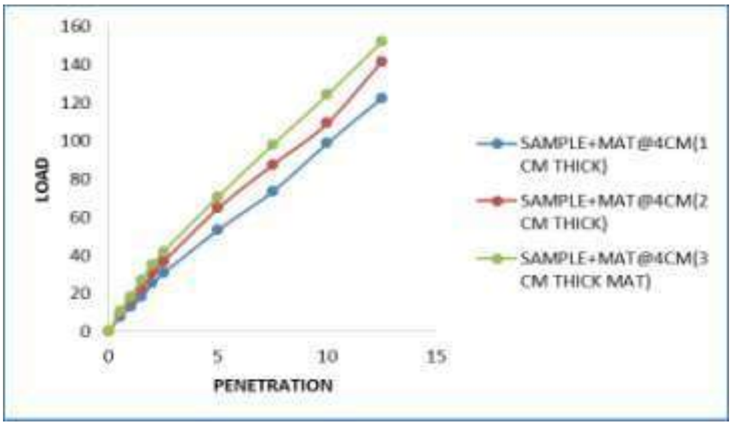


Fig. 2.2 load vs. penetration graph [3]

The Fig. 2.2 shows that load penetration curve at depth of 4 cm that when the thickness increases the load bearing capacity also increases

Chowdhury Swaraj and Suman Shakthi (2014) made an experimental investigation on geocell reinforced foundation by which they concluded that by using geocells as reinforcement there is an increase the bearing capacity of the foundation of soft soil. Material used for making geocell having higher strength and small aperture in orthogonal direction shows better performance. The effect of geocells when the foundation soil is dense is pronounced.

Aminaton Marto, Mohsen Oghabi, Amin Eisazadeh (2012) conducted various experimental test to find the effect of geocell reinforcement in sand and on the bearing capacity of footing. It was observed that optimum performance of the footing can be obtained when the geocell mattress is placed at a depth of 0.05B from the base. The optimum width and depth of cellular mattress is obtained around b/B=5 and (u/B)=0.35 . As the increase in number of reinforcement layer the footing settlement decreases and bearing capacity increases

Phani Kumar Vaddi, D.Ganga, P.Swathi Priyadashini (2015) conducted experimental investigation on CBR for mechanically stabilized expansive soil using waste rubber tyre chips . It was found that the CBR and compaction depends on the clay content present in the soil. The MDD and CBR values for expansive soil in comparison to lime and tyre chip will be low. With the increase in lime MDD decreases and with the increase in placement of lime OMC in general increases.

A.K Choudhary, K.S.Gill, J.N.Jha (2011) studied about the improvement of CBR value on expansive soil using geosynthetic as reinforcement and concluded that by providing reinforcement within the expansive soil subgrade it helps in controlling the swelling significantly. The percentage reduction will depend on the number of reinforcing layer and type of reinforcement used. CBR value increases with increase in number of reinforcing layer and their relative position.

Dash and Bora (2013) studied the effects of stone column and geocells in improvement of soft clay foundation. The maximum increase in the bearing capacity to stone column is 3.7 times and for geocell alone was 7.8 times. When used in combination with accurate spacing and depth stone column and geocell shows 10.2 times increase in the bearing capacity. The suggested optimum length and spacing of stone column that can be used are 2.5 to 5 times the diameter maximum height of geocell that can be adopted is equal to the depth of foundation.

Ansgar Emersleben (2008) evaluated the influence of geocell on bearing capacity of soil. And stress distribution large scale model test was carried in a test box with various dimensions. The load pf 150KN was applied. The load was applied by hydraulic jack and transferred by steel plate which acts as footing with a diameter of 30cm to the soil. A stress reduction between 30% and 36% was observed. Results indicate that the geocell layer helps in distributing over a wider area. As the load was applied on the steel plate it acts like footing and helps in transferring of load in trapezoidal form in the layer beneath it. The pressure cells and displacement gauges are used in order to find the amount of stress transferred to the bottom layer and amount of surface deformation. As the geocell are provided as the reinforcements it helps in transferring of load into wider area as a result of which less stresses get transferred as a result the chance of failure are less and it also increase in the stiffness of soil and helps in preventing lateral confinement. By this the construction can be done on the weak soil as the soil always fails in tension so after providing the geocell reinforcement the it will provide tensile strength to the soil. In this glyben is used as the infill material which is reinforced with geocells and then the results are obtained as we will observe that there will be significant stress reduction

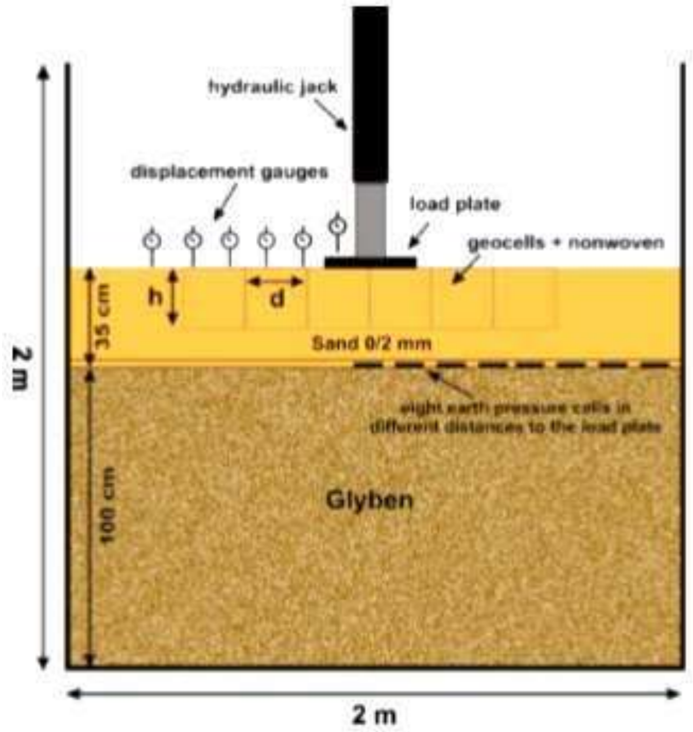


Fig. 2.3 Schematic diagram of test device

Fig. 2.3 shows schematic diagram of test device which includes earth pressure cells for measuring pressure, dial gauge for displacement measurement, hydraulic jack for load and load plate which acts as footing.[5]

Yu Quian (June 2009) experimental study on bearing capacity of geocell reinforced base. Laboratory plate load test were conducted in a medium scale loading apparatus. The loading system has diameter 15.2cm with the maximum air pressure of 2100KPa. A cyclic load of 345kPa was chosen. The bearing capacity and stiffness of geocell reinforced base increased up to 1.5 times that of unreinforced base.

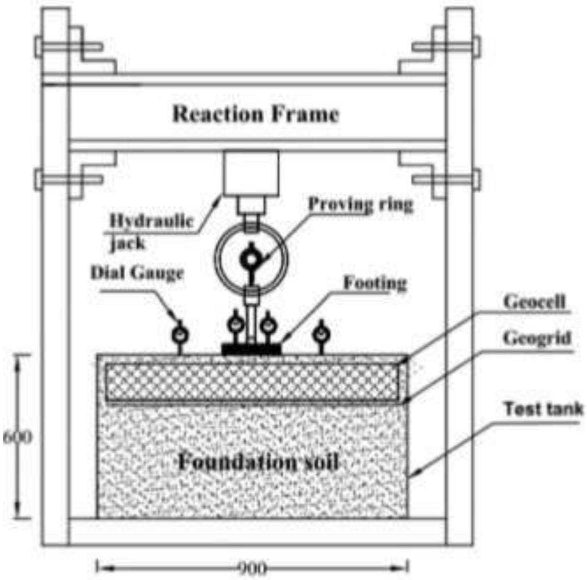
Gourav Dhan (2014) experimented on new technique of soil reinforcement in civil engineering field. On comparison the geocell reinforced base provide more lateral confinement It also imparts apparent cohesion to the cohesionless soil this will mainly depend upon tension modulus of geosynthetic used to form the geocells. When the aspect ratio (L/D) is one the footing performance is improved as the load gets distributed to larger area as compared. The formation of geocells are better in a diamond pattern. The depth of geocell reinforcement effect on bearing capacity of soil was also conducted and the results that were found were that the geocell reinforced soil at a certain depth gave 4-fold increase in the ultimate bearing capacity. The laboratory results highlight that the cyclic stress ratio and frequency has a significant influence on the settlement behaviour of geocell reinforced foundation.

Fig. 2.4 Close view of geocells

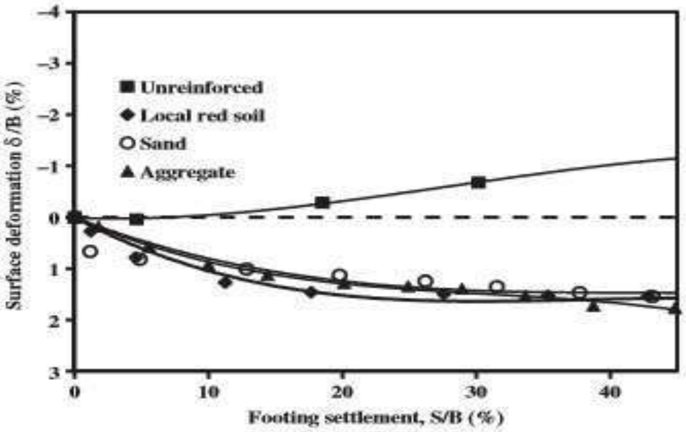
Fig. 2.4 shows geocells filled with different infill material

J.N Jha (2011) used geosynthetic for improvement of CBR value of expansive soil and studied it. Two different reinforcements like geotextile and geogrid are used in the investigation. By inserting reinforcements in it was found out that the swelling got reduced and controlled within the expansive soil subgrade. The percentage reduction in the swell potential will depend on number of reinforcing layer and the types of reinforcements used. The CBR value of soil increases significantly with the increase in number of layers and position within the soil and type of reinforcement.

Amarnath M.hedge and T.G Sitharam (2015) did experiments on the effects of infill material on the geocells which are used as reinforcements . The three infill materials which were used is red soil, sand, aggregate. The results show that load carrying capacity of geocell reinforced soil increased 13 times for aggregate infill ,11 times for sand infill and 10 times for red soil infill. Settlement also got reduced to 78%,73% and 70% for aggregates, sand and red soil material. Aggregated proved to be the most useful infill materials. In general it can concluded that the effect of infill material is marginal and it depends on the engineer what infill to use according to site conditions.



(a)



(b)

Fig. 2.5 (a) model test set up (b) surface deformation with footing settlement[10]

The Fig. 2.5 shows model test set up and the load settlement curve of unreinforced bed indicates punching shear failure mechanism.

A .Emersleben and N. Meyer (2008) made a model set up of specific dimension in order to validate the impact of geocell reinforcement on load settlement behaviour. The result in the end concluded that the infill material or the soft soil subgrade used the vertical stress reduces when compared with the unreinforced soil. Depending of the different aspect ratio the vertical stress reduces to 45% and eight earth pressure cells were used in the experiment. When the in- situ testing was done of the road K-23 it was found that the stress reduced to 30%. The geocells layer increases the modulus of layer of gravel base layer as compared to unreinforced.

J .N. Mandal and P. Gupta (1994) conducted the experiment on stability of geocell reinforced soil. It was found that the stiffness of the layer above the soft clay becomes stiffer. The settlement of ration comes out to be 5-10% and the membrane action comes when the settlement ratio is 20%. Load and settlement characteristics are improved by providing geocell reinforcement and on comparison with the unreinforced soil the bearing capacity of reinforced soil increases. The large settlement bearing capacity which has a settlement ratio of 50%. Smaller geocell opening should be preferred in the case of low settlement curve.

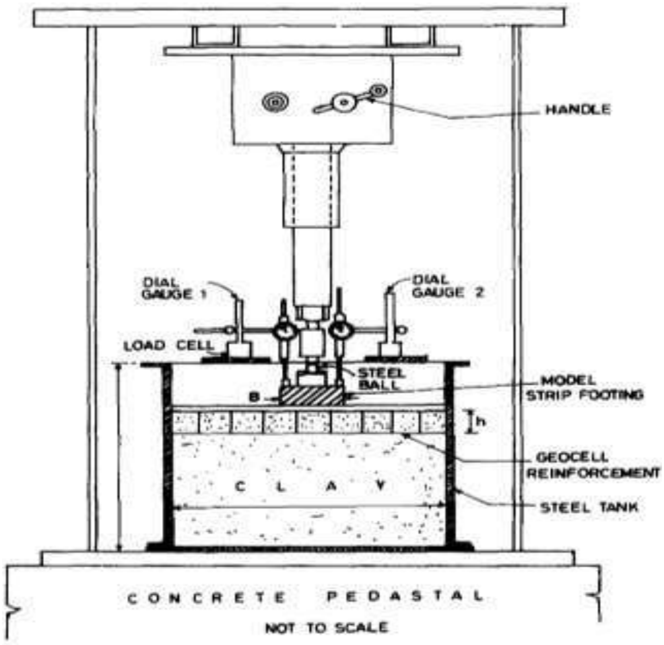
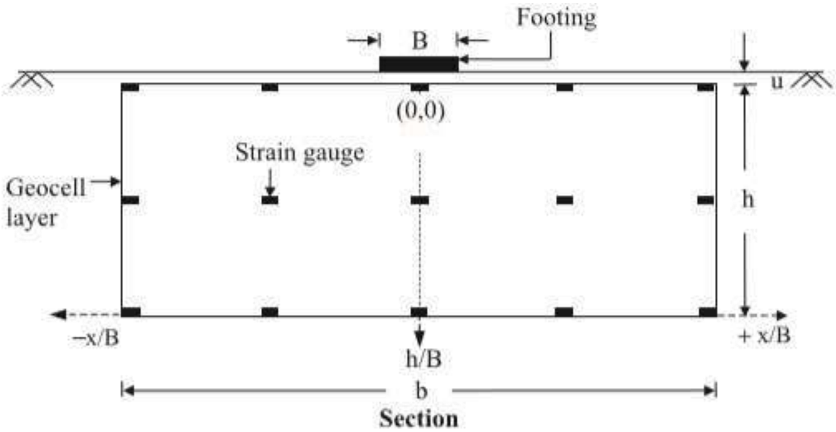


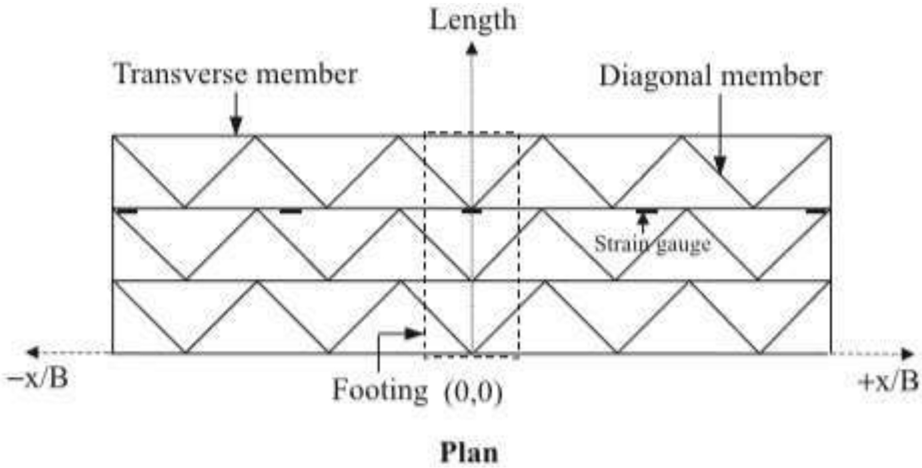
Fig. 2.6 Model test set up [13]

Fig. 2.6 shows steel tank filled with geocell reinforced soil and load applied on strip footing

Dash, S.K. Rajagopal (2007) conducted experiments on geocell reinforced sand bed under strip loading and he concluded due to the loading effect the strain in the geocell wall comes out ot be more at the centre and less towards the edges. The maximum effect of the geocell reinforcement is just below the footing and less towards the edges. The strain variation pattern will indicate that geocell mattress acts subgrade support for composite beam. The displacement pattern in the subgrade shows that geocell reinforcement intersect the potential failure plane



(a)



(b)

Fig. 2.7 Geometric parameters and layouts of strain gauges on the geocell mattress [12]

The Fig. 2.7 (a) and (b) shows the geometry of the problem in which diagonal and transverse members are shown along with strain gauge to measure strain produced.

Al-Omari, Raid R., and Faris J. Hamodi (1991) In this rather than using the tensile geogrid for the improvement of the soil strength they could also be used for controlling of the swelling of soil. This type of research had been conducted. The swelling test was conducted using an enlarged size of the oedometer apparatus. The results of the experiments show significant reduction in in the swelling of the soil when the reinforcement was provided. As the number of reinforcements increase's the there is significant reduction in the swelling. However the concept of surcharge is observed to be not valid in the case where the value of stiffness is directly taken from index test of manufacturer.

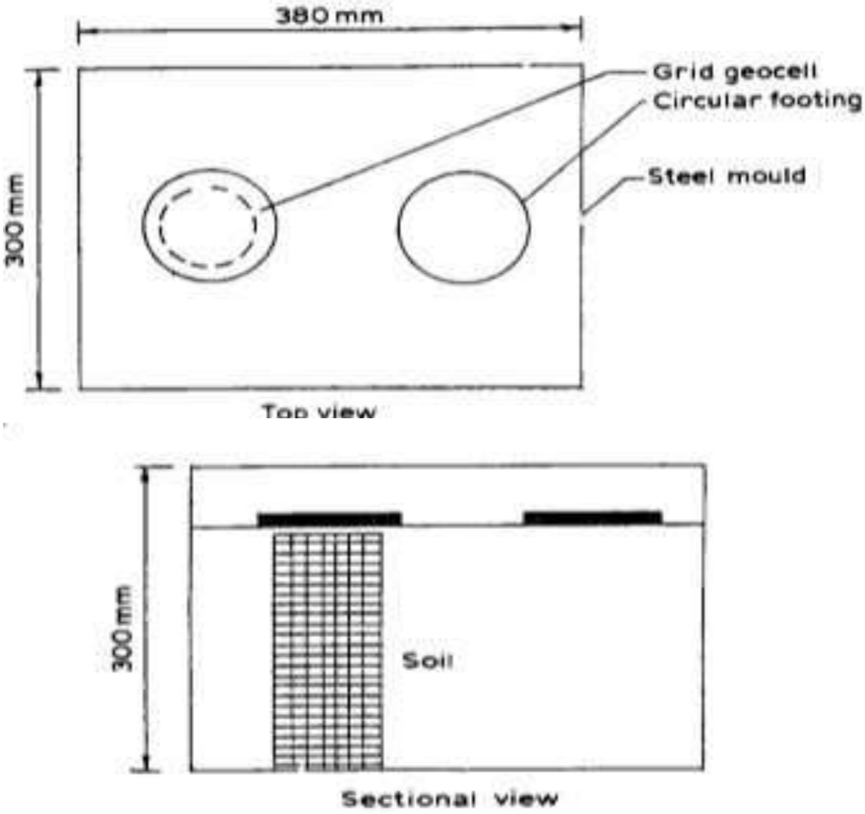


Fig 2.8 Exemplification of model test footing [6]

The Fig. 2.8 shows heavy steel mould with perforated steel base and 100 mm diameter circular rigid plate from the top and sectional view

Carter, G.R., J.H.Dixon (1991) Oriented polymer geogrid were adopted in the late 1970s in order to fulfil the need of civil engineering. By then current usage has increased. Various application area is such as providing reinforced soil walls, slopes, the base of embankments over the soft soil, the reinforcement of roads of sub base over weak soil, and the reinforcement of bituminous layer etc. Pressure on land in countries like Japan and UK suggests that development often takes place on sites with soft or weak soil. Oriented polymers can easily solve this problem raised by such sites.

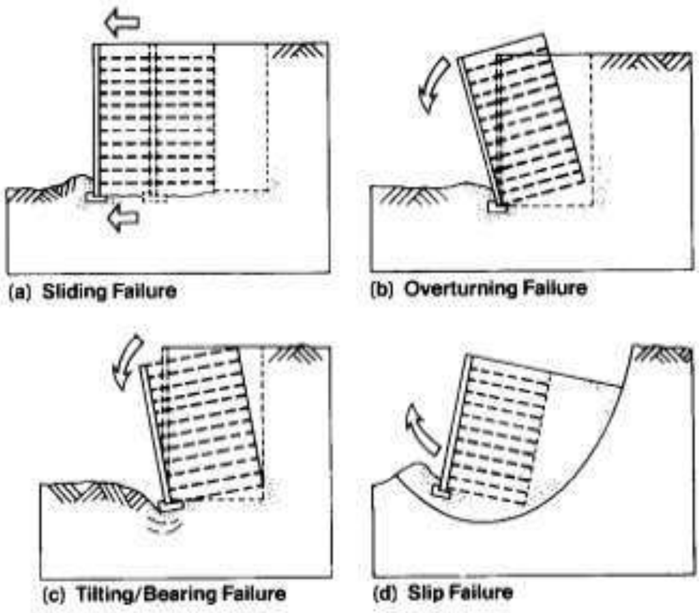


Fig. 2.9 Stability of soil wall that have been reinforced[7]

The Fig. 2.9 shows mechanism of failure of sliding, overturning, tilting and slip

Pokharel, Sanat Kumar (2011) A full scale accelerated moving wheel test was conducted on four test sections, which included one control section with AB-3 base coarse and three NPA geocell reinforced bases with AB-3,QW, and RAP as in fill materials. An NPA geocell reinforced crushed stone section 17 cm thick had equivalent and even better performance than a crushed stone control section 30-cm thick even thought the reinforced base was not compacted as well as the control base. The NPA geocell reinforced RAP section performed better than the geocell reinforced crushed stone section with same base thickness. However, the geocell reinforced QW section performed worse than the geocell reinforced crushed stone section. The NPA geocell reinforcement increases the stress distribution angle by 13.4 for the reinforced crushed stone section by 11.6 for reinforced RAP section.

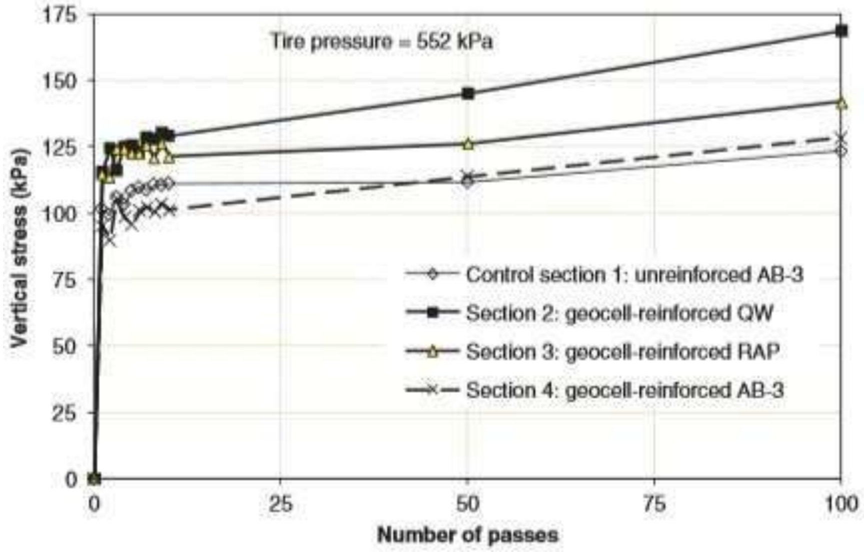


Fig. 2.10 Measured vertical stresses at subgrade base interface [8]

The Fig. 2.10 shows that the vertical stress measured are lower than the tire pressure of 552kPa

Leshchinsky, Ben, and Hoe Ling (2012) The geocell confinement helps in minimizing vertical settlement under different load such as cyclic load or monotonic load under the given conditions. By providing the reinforcement the lateral spreading can be prevented by confining mechanism. Under cyclic loading the vertical displacements are taken by geocells. On comparison between the actual and simulated lateral displacement it was not perfect in either monotonic or cyclic cases, the stimulations show the trend of reduced deformation. The highest concentration of strain and stress were found to be in lower corner of cell underlying the loading plate.

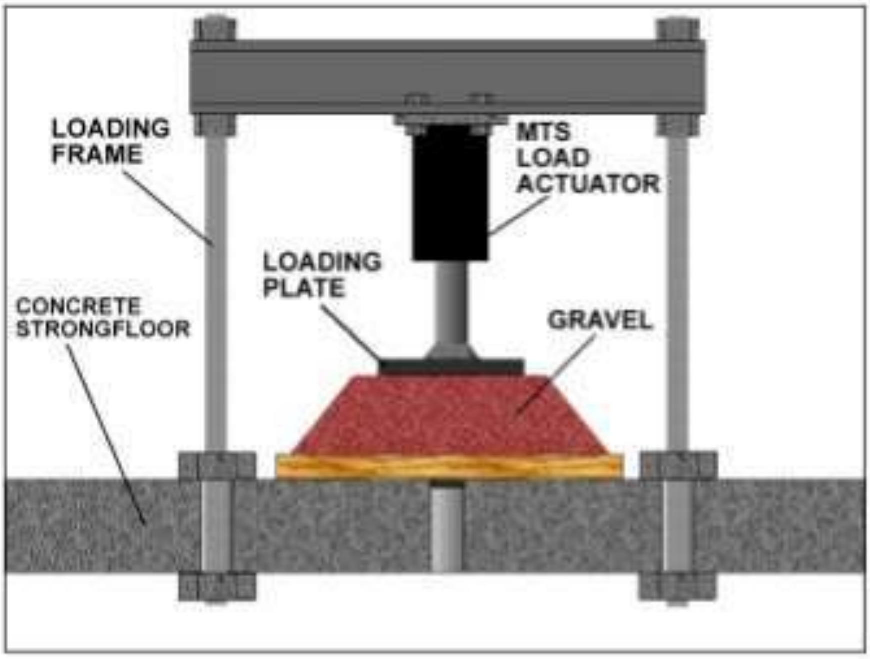


Fig. 2.11 Schematic of testing apparatus [9]

The Fig. 2.11 shows setup of model like loading frame , loading plate which acts as footing, load actuator which generates load and gravel layer in which the load distributes

2.3 Summary of Literature Review

According to various researches made by many researchers we can easily conclude that geocell reinforcement is a versatile method in terms of its cost effectiveness and it provides all around confinement to the material hence it prevents the lateral spreading of soil on the application of load. Therefore, the geocell reinforcement increases the strength and stiffness of soft soil and thereby increasing the bearing capacity. It also imparts apparent cohesion to the cohesionless soil this will mainly depend upon tension modulus of geosynthetic used to form the geocells. When the aspect ratio (L/D) is one the footing performance is improved as the load gets distributed to larger area as compared. The formation of geocells are more beneficial in a diamond pattern. The depth of geocell reinforcement effect on bearing capacity of soil was also conducted and the results that were found were that the geocell reinforced soil at a certain depth gave 4 fold increase in the ultimate bearing capacity. The CBR value also increases with geocell reinforcement due to which the thickness of pavement layer gets reduced. The performance of geocell-supported improved with higher aspect ratios, improvement being insignificant on aspect ratio beyond unity. Granular soils are preferred for fill inside the geocells to obtain the best performance in increasing in the surcharge-carrying capacity and decreasing the deformations. Geocell reinforcement has a reduction of 30% to 42%. Using the geocells to protect slope can improve its overall stability, and can reduce the displacement of slope surface effectively. The sudden increase of local displacement is also limited.

2.4 Objectives of present study

1. To investigate the effect of different configuration and aspect ratio of geocell s on bearing capacity of MSW fly ash in pavements. By placing the geocell mattress at different depth the observing behaviour and measuring the optimum value.
2. To study the behaviour of various geocell materials such as polypropylene bags, waste plastic bottles on MSW Fly Ash.
3. To study the various behaviour of geocell reinforced MSW Fly Ash in pavements. MSW fly ash being an infill material has weak properties, so to study the impact of geocell reinforcement on properties.

2.5 Scope of Work

A model test set up is to be prepared of particular dimensions. Two layers one of soil and other of MSW fly ash put. MSW Fly Ash is used as an infill material. A square wooden plate is used as footing in order to transfer load. The geocell made up of polyethylene terephthalate and polypropylene bags of different aspect ratio are used to provide reinforcement.

The load is applied through hydraulic jack and displacement gauge are also placed to get surface deformation. The pressure sensors will get the amount of load that gets transferred when the soil is reinforced and unreinforced with geocells at different heights.

CHAPTER 3

METHODOLOGY

3.1 General

This chapter deals with the process of mechanism of experimentation for setting up the material required for construction, geocell fabrication and instrumentation done. Strain gauges are used for measuring deformation in the geocells, pressure sensors are used as the equipment used for measuring the load.

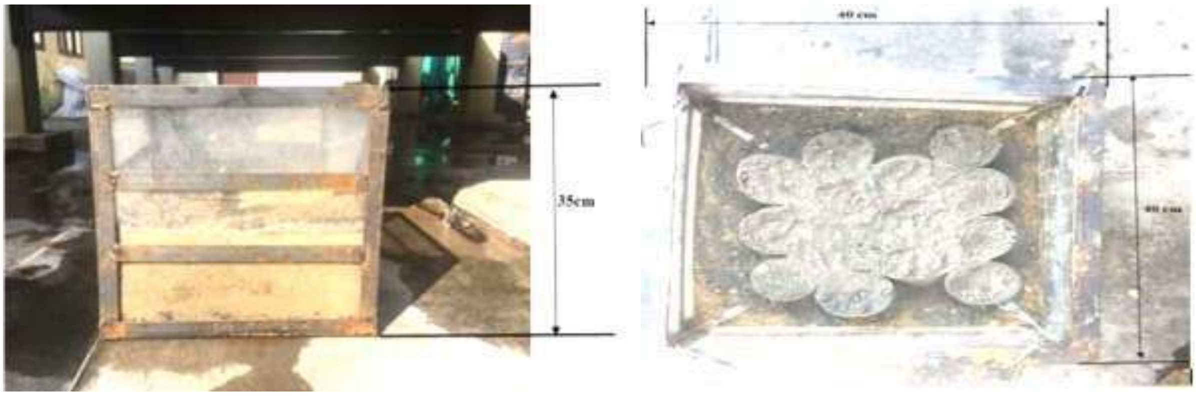
3.2 Material Used

3.2.1 Model tank

A Perspex sheet fabricated model tank of dimensions 40cm x 40cm x 35cm is made using iron angles. In the model tank, Perspex sheet of 2mm is used as walls. For better reinforcement of the box and avoiding the box to bulge out in times of model testing, extra reinforcement of steel plates are welded at height of 10 cm and 20 cm from base.

Perspex sheet Clear cast acrylic, also commonly called as Perspex sheet made up of Poly methyl methacrylate (PMMA), is a transparent thermoplastic. It is often used as an alternative against glass. Chemically, acrylic clear is a synthetic polymer of methyl methacrylate. The thickness of this sheet used are usually 2mm, 3mm upto 50mm. Cost of these sheets increases with increase in thickness.

Iron Angles and plates



(a) (b)

Figure 3.1 Dimensions of model box 40 cm x 40 cm x 35 cm. Above figures showing elevation and plan (a), (b)

Figure 3.2 Lower layer of 16 cm clayey soil and 14 cm of M.S.W. fly ash

3.2.2 Plastic bottles

Waste plastic bottles are cut in form of cylinder of height 7cm, 6cm and 5cm of diameter 7cm and 10cm (1 litre and 2 litre bottle) and joined in tetrahedral packing arrangement and octahedral packing arrangement. Therefore, providing us geocells of various aspect ratios of 1, 0.85, 0.7, 0.6, 0.5.

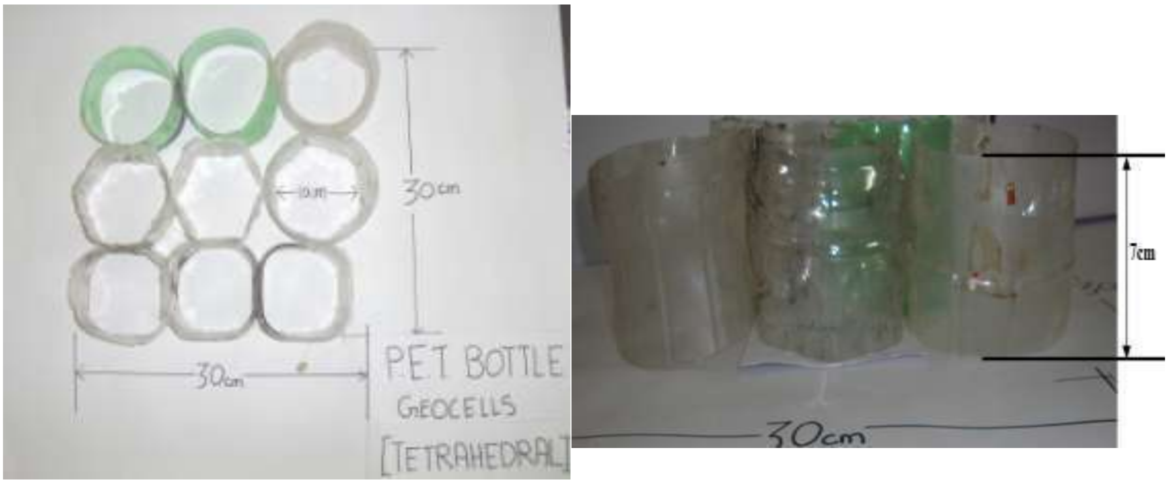
(a) (b)

Figure 3.3 Plan (a) and elevation (b) of plastic bottle octahedral packing shaped geocell of diameter=7 cm

(a) (b)

(c) (d)

Figure 3.4 Plan(a),(c) and elevation(b),(d) of plastic bottle octahedral and tetrahedral packed shaped geocells of diameter=10 cm,7 cm respectively



(e) (f)

Figure 3.5 Plan(e) and elevation(e) of plastic bottle octahedral packed shaped geocells of diameter=10 cm,7 cm respectively

3.2.3 Polypropylene bag

Polypropylene bag are cut into strips and made cylindrical of diameter 7cm and 10cm with different height providing us geocells of various aspect ratios of 1.2, 1, 0.85, 0.7, 0.6, 0.5.These are only octahedral arrangement.

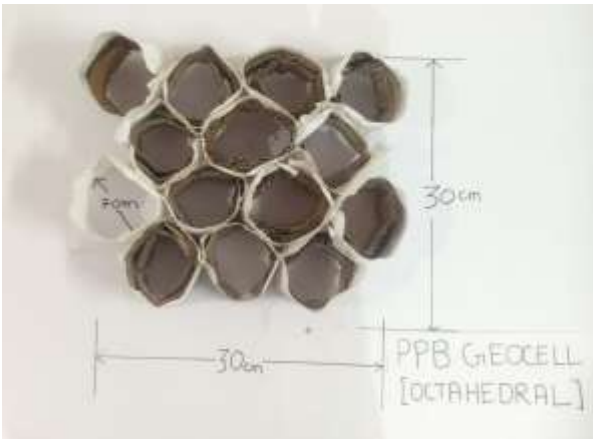


Figure 3.6 Plan of polypropylene bag geocells of diameter=7 cm of octahedral arrangement for better compaction of fly ash in it

(a) (b)

Figure 3.7 Plan (a) and elevation(b) of polypropylene bag geocells of diameter=10 cm made in octahedral arrangement

3.3 Soil tests

3.3.1 Sieve Analysis

Grain size distribution is used to calculate the particle size distribution of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a part of whole mass. Wet sieve analysis and dry sieve analysis and hydrometer analysis are done for soil classification. Make sure that sieves are clean before performing the test. Put the sieve in sieve shaker while performing the test. After sufficient time measure the mass of soil retained on every sieve.

Dispersion agents used are 200ml of sodium hexametaphosphate solution (add 8.25gm of sodium hexametaphosphate to 1.75gm of sodium carbonate to make 250ml of solution).

Taken an oven dried sample of soil and weigh about 1kg and make it pass through stack of sieves with sieve having larger opening placed above the sieves having smaller openings. Make sure that no lumps are there, if present, break the lumps. A pan is to be placed under the last sieve to collect the soil passing through it. As it's a clayey soil majority of soil will pass the 75 micron sieve depicting wet sieve analysis to be carried.

Wet sieve analysis

Taken 500 gm of oven dried soil and is sieved via 75 micron sieve and washed under tap of high pressure. The water is passed untill the clean water starts passing through it. Then mechanically shaked for about ten minutes after oven drying the sample for 24 hours. The material retained on every sieve is weighed. The curve for the soil was drawn on a semi-log graph and particle size distribution curve was obtained.

Hydrometer analysis

Taken 50gm of air dried soil sample which passed 75µm that was obtained after wet sieve analysis. 100ml of dispersion agent is mixed in the soil for 4 minutes. Mixed solution is poured in the 1litre jar and distilled water is added upto the brim of 1000ml mark. Carefully take the hydrometer and put the soil mix solution. Note the readings as soon as hydrometer is put in cylindrical jar containing soil solution at the time interval of 30 seconds, 60seconds, 120seconds, 240 seconds, and 480 seconds. Now displace the hydrometer and put in cylindrical jar filled with distilled water and dispersing agent. Take concordant readings after 15, 30, 60 minutes and 3, 6, 18, and 24 hours.

For fine grain soil determination of uniformity coefficient is not possible since the effective size is not known.

3.3.2 Liquid Limit

Liquid limit is the minimum water content at which the soil is still in the liquid state, but has a small shearing strength as a flow. Liquid limit of soil is a very important property of cohesive soil. It is used to predict the consolidation properties of soil while calculating allowable bearing capacity and settlement of foundation. This can be determined using Casagrande apparatus as well as cone penetrometer apparatus.

A soil paste is formed using soil sample passing 425 micron sieve and water. Paste is then placed in the cup of Casagrande device. The soil pat is then divided into two halves by making a groove using the grooving tool. Then the cup is dropped by turning the crank until two halves of soil crack comes in contact with each other. The test is repeated with different amount of water and a graph is plotted to determine the liquid limit of soil.

3.3.3 Plastic Limit

The plastic limit of a soil is the moisture content at which soil begins to behave as a plastic material. At this water content, the soil will crumble when rolled into threads of 3.2mm in diameter.

Select 1.5 2.0g of soil prepared from liquid limit test and reduce the moisture content of the soil to a consistency at which it can be rolled without sticking to the hands by mixing continuously on glass plate. The thread shall be further deformed on each stroke so that its diameter reaches 3.2mm, taking no more than 2minutes. Normally 70 80 strokes/minute recommended count. Now determine the moisture content of the crumbled part which gives the plastic limit of soil.

Therefore calculate the **plasticity index** of soil.

3.4 Soil Layer Preparation

The soil is used as a base layer and is laid up to 16cm of height in three layers of 6 cm each inside the fabricated model box. Then 14 cm of M.S.W. fly ash is laid such that geocells testing is carried in fly ash layer.

(a) (b)

Figure 3.8 M.S.W. Flyash (left) black in colour generated from municipal solid waste incinerator Chandigarh. Organic clayey soil (right) of brown colour obtained from Armsdale building site, Shimla

Procedure

A layer of 16 cm of soil is laid in the model test box. The soil was laid in the layers of 6 cm each with the help of tamping rod. Over the soil layer pressure sensors are placed at centre. M.S.W. fly ash is laid directly over the soil and is not tamped because of its higher fineness as compared to the soil. Fly ash is laid up to height of 14 cm such that the geocells are to be tested for depth of 5cm and the maximum height of geocells used is 7cm. M.S.W. fly ash is laid for 14 cm height above the soil. Sensors are placed over soil which gets buried under flyash and are connecting to wires which are kept out of box connected to laptop via. microcontroller for continuous readings of load developing over organic clayey soil. Over fly ash, steel plate of 30cm x 30 cm is placed. This plate acts as a footing plate for determining settlement as well as method to determine maximum load over soil without any geocells reinforcement. Different geocell arrangements are therefore put at different depths with respect to the top surface of fly ash. Depths of 1cm, 2cm, 3cm, 4cm, 5cm upto the top of the soil layer. Different aspect ratio of tetrahedral and octahedral packed arrangement of different material like polypropylene and polyethylene tetrapthalate are used. Aspect ratio equal to 1 and less than 1 are being checked with different depths. Here aspect ratio of 1,0.85,0.7,0.6,0.5 are considered for different depths with respect to fly ash.

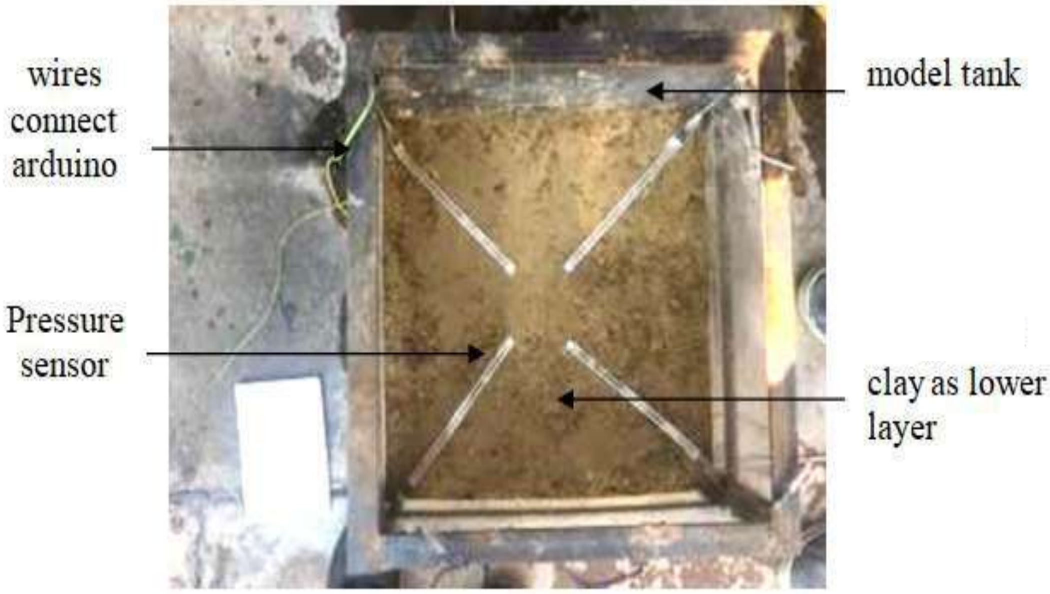
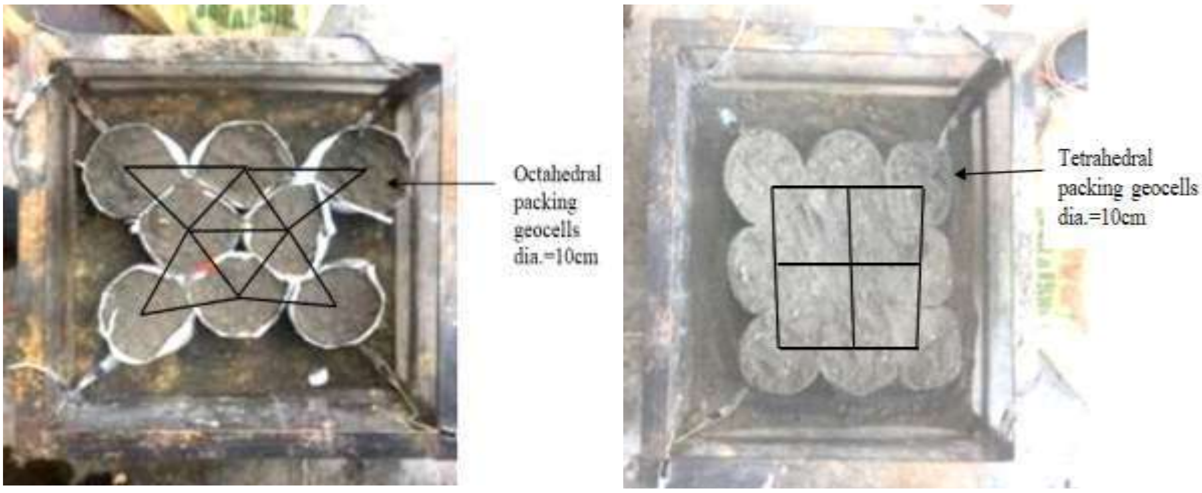


Figure 3.9 Pressure sensors placed over tamped soil such that distance between adjacent sensor is 7.5cm. This is done due to size of footing of 15cm x 15 cm. Pressure sensors are connected to computer for measuring the load using wires via arduino as a processor



(a) (b)

Figure 3.10 Octahedral (a) and tetrahedral (b) packing shaped geocells of diameter 10cm made of polypropylene (a) and polyethylene tetraphthalate (b) are placed over the low graded clay at different heights from base of MSW fly ash or top of clayey soil

(a) (b)

Figure 3.11 Octahedral packing shaped geocells of diameter 7cm made of polyethylene tetraphthalate (a) polypropylene (b) filled with fly ash are placed over the low graded clay at different heights from base of MSW fly ash or top of clayey soil

(a) (b)

Figure 3.12 Tetrahedral packing shaped geocells of diameter 7cm made of polyethylene tetraphthalate (a) filled with fly ash are placed over the low graded clay at different heights from base of MSW fly ash or top of clayey soil. (b) depicts the top layer after the geocells are embedded within the entire depth of MSW fly ash ie.,14cm

3.5 Instrumentation

3.5.1 Pressure Sensors

These are the piezoresistive force sensors from Robokits and Tekscan. The harder the force over the contact area, the lower the sensors resistance. Pressing hard changes its resistance from infinite to 300kΩ which are therefore act as an input for arduino, which thereafter processes it and output is displayed on computer screen. The overall length of the sensors is about 8.5" and diameter of sensing contact area is 1 to 1.2 cm.

These are available online on Tekscan's official website, Flexiforce sensors' and Robokits. These sensors are used as pressure sensors, weight sensor, presence sensors.

These sensors can be used with multimeter and even connected with microcontroller for outcomes. Microcontroller is connected to computer via cable and pressure sensor is soldered to microcontroller using connecting wires.

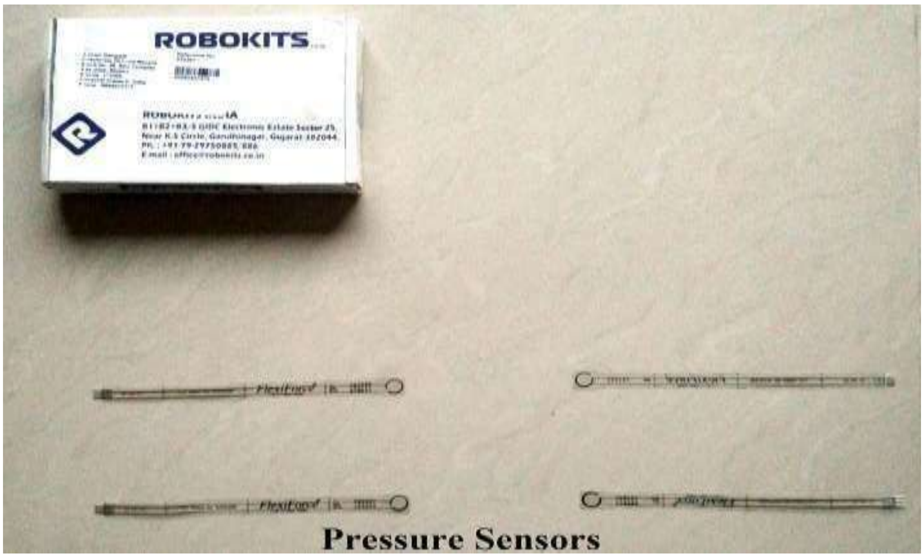


Figure 3.13 Robokits pressure sensor of infinite to 300kΩ resistance capable of 100lbs of pressure

3.5.2 Connecting Wires

Copper wire, and connecting male male, male female, female female wire are used to establish connection in microcontroller circuit. The diameter of wires used was 1mm.

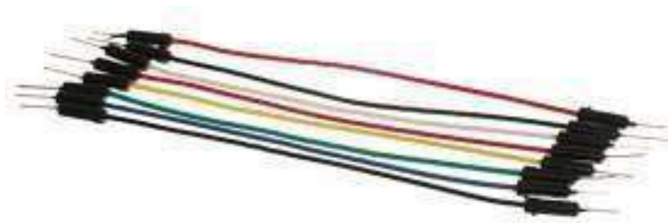


Figure 3.14 Jumper wire required for connection and to support non standard odd spaced headers.

3.5.3 Microcontroller

Arduino is an open source hardware and software company that design's and manufactures single board microcontroller and microcontroller kits for building digital service and interactive objectives that can sense and control object in physical and digital world. Arduino board design use a variety of microprocessor and the board are equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards or breadboards. Arduino converts the signals received via input and processes it using any Arduino program and output it on computer.

This is further connected to computer which thereafter displays the values.

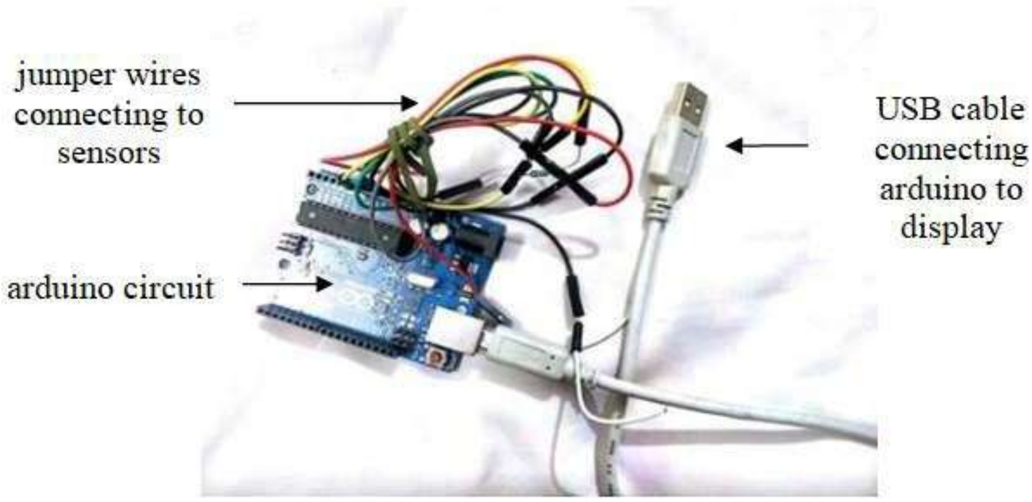


Figure 3.15 Microcontroller connected with cable that will be connected to computer . The wires thereafter connected to pressure sensors. Arduino is the company that makes best microcontroller for day to day purposes

3.5.4 Foil Strain Gauges

Foil strain gauge are pressure processing transmitters that are fixed to the surface of an object to determine the surface strain caused by any applied force. Typical uses include test and measurement applications where the strength of the object is the main consideration. These strain gauges are soldered to copper wires and connected directly to Multimeter. The strain gauges are stick to geocells.

Figure 3.16 Foil type strain gauges available from National instruments, Jaipur. These are available at resistance of 120Ω in our model. Strain gauges are soldered to wires

3.5.5 Digital Multimeter

A digital Multimeter is a test tool used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.

Digital Multimeter long ago replaced needle based analog meters due to their ability to measure with greater accuracy, reliability and increased impedance. Fluke introduced its first digital Multimeter in 1977. The face of a digital Multimeter typically includes four components:

1. Display: Where measurement readouts can be viewed.
2. Buttons: For selecting various functions.
3. Dial: For selecting primary measurements values.
4. Input jacks: Where test leads are inserted.

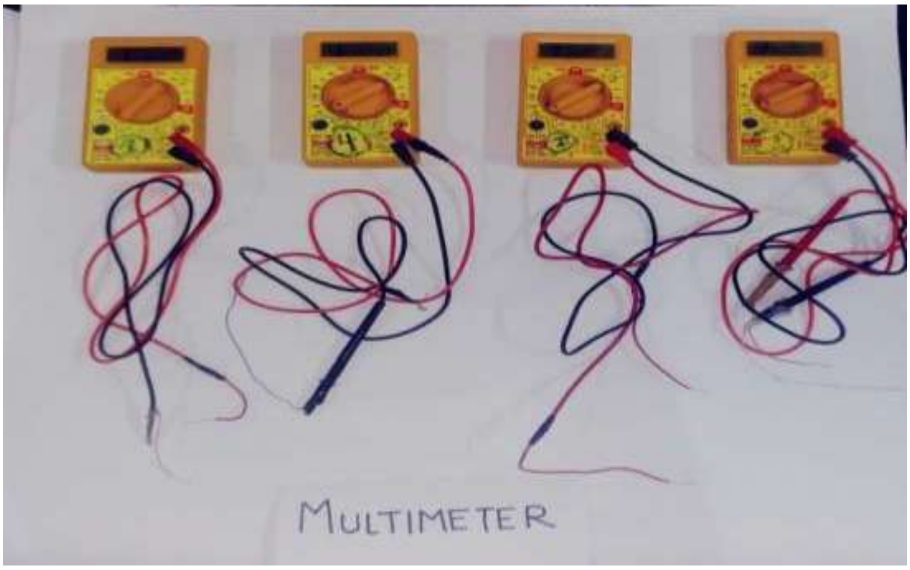


Figure 3.17 Digital Multimeter connected to strain gauges that are connected through jumper wires

Procedure for Model Testing

Strain gauges are stick to the geocells and its resistance value is noted. This is the initial resistance of strain gauge, which will remain same for all the strain gauges. Strain Gauges sticked to geocells are tested such that two wire ends of strain gauge are connected to Multimeter and continuous readings are noted. When the settlement stops, note down the final settlement.

Now to obtain the strain.

€=(Change in resistance)/(Initial resistance x Gauge factor)

Figure 3.18 Digital Multimeter displaying initial resistance of undisturbed strain gauge in ohms.

3.5.6 Dial Gauge

Dial gauge also known as distance amplifying instrument is used to check the variation in tolerance during the inspection process of a machined part, measure the deflection of a beam or ring under laboratory conditions. It gives deflection in millimetres.

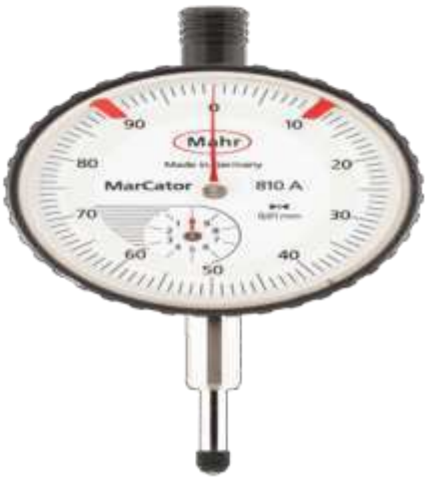
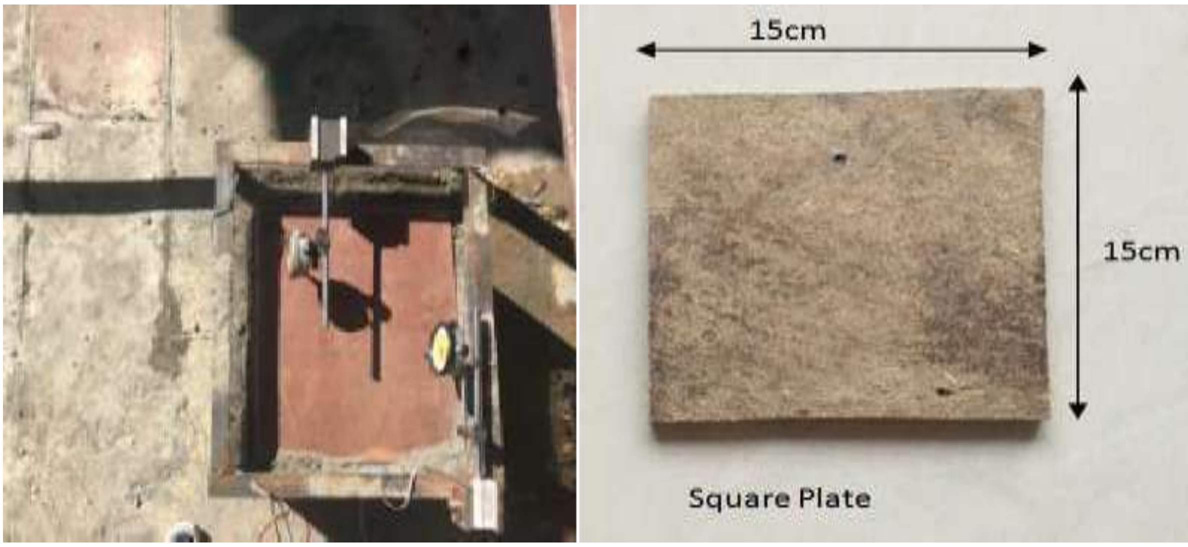


Figure 3.19 Dial gauge is clamped with fixed magnetic support to note the deflection while settlement

3.6 Model Testing

Organic clayey soil is obtained from Shimla construction site and M.S.W. fly ash from sector 25 municipal solid waste incinerator, Chandigarh. organic clayey soil is tamped at every 6 cm for height of 16 cm and pressure sensors are placed as in soil preparation. Steel plate of 30 cm x 30 cm is placed over the fly ash and dial gauges are fixed with its support to check for the settlement of fly ash with respect to load. Strain gauges are installed at the sides as well as at the centre of every geocells to check for strain development of geocells when compressed with the help of hydraulic jack. Steel plate of 30cm x 30cm is replaced by actual footing plate of 15cm x 15cm as half the dimensions of geocells.



(a) (b)

Figure 3.20 Installation of dial gauge (a) over 30cm x 30 cm steel plate (b) to note the settlement without geocells and thereafter replacing it with 15cm x 15cm plate

Figure 3.21 Final arrangement for model testing of various geocells

Therefore, pressure sensors placed at half distance of footing to not the critical vertical loading. Hydraulic jack is placed over the footing under a beam which helps as support and pressure is applied such that settlement starts, which is measured by dial gauges, with respect to increment of load in pressure sensors. When there is stagnation in settlement, the displaying load will be the maximum load transferred via. fly ash without reinforcement.

Initial model testing is done without geocells reinforcement to note the maximum settlement, load capacity that can occur in fly ash without any reinforcement. Different geocells of various aspect ratios are installed in fly ash at various depths. Vertical loading over the clayey soil, strain produced in geocells and corresponding settlement is noted.

Following readings have been noted and their corresponding graphs are plotted.

1. Load Settlement curve
2. Vertical Stress at varying Depths under footing
3. Strain at varying Depths under footing
4. Stress Strain relation
5. Settlement ratio with respect to Aspect ratio

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 General

This chapter deals with the experimentation done for stabilizing the soil and how the soil of various types can be reinforced. Scientists used polyester, geotextiles, leather waste as mixing material to reinforce soil. The experimentation on soil reinforcing technique with an aim of determining settlement corresponding to maximum vertical load and a relation between vertical stress, settlement and aspect ratio. Followed by testing, modelling is conducted and following results could be concluded

4.2 Material characterization

The results obtained from sieve analysis, UU, Attberg's Limit tests conducted on the soil and M.S.W. flyash and the results obtained are mentioned in the below section.

4.2.1 Sieve Analysis

Sieve analysis was conducted to obtain the particle size distribution of soil sample as well as fly ash. Values of reading obtained are showed in Table 4.1 and its graphical representation in Fig. 4.1. Particles with grain size less than 0.002mm are considered as clays, those ranging from 0.002mm to 0.5mm are silt, from 0.05mm to 0.10mm are classified as fine sand, 0.25mm to 0.5mm are classified as fine sand, 0.25mm to 0.50mm are classified as medium sand and 0.5mm to 2mm are coarse sand.

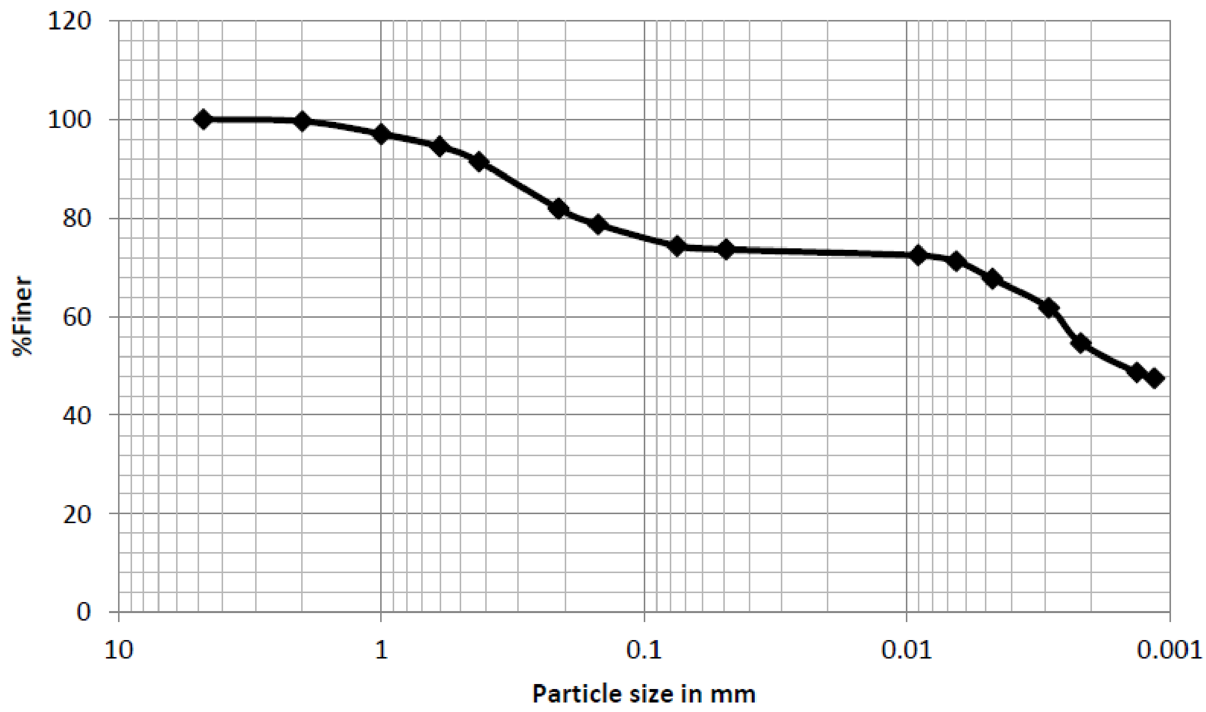


Fig. 4.1 Graph of the Sieve analysis

4.2.2 Moisture Content

Moisture content of soil and fly ash are known taking 50gm of sample of soil and fly ash. Below are the moisture content of soil and fly ash.

Organic Soil	24.7%
M.S.W. fly ash	13.2%

Table 4.1 Moisture content of soil and flyash

4.2.3 Liquid Limit

Liquid limit of soil is a very important property of cohesive soil. It is used to predict the consolidation properties of soil while calculating allowable bearing capacity and settlement of foundation. This is determined using Casagrande apparatus as well as cone penetrometer apparatus. Below are shown the results of liquid limit of soil and fly ash used.

Organic Soil	62%
M.S.W. fly ash	47.66%

Table 4.2 Liquid limit of soil and flyash

4.2.4 Plastic Limit

Plastic limit of a soil is the moisture content at which soil begins to behave as a plastic material. At this water content, the soil will crumble when rolled into threads of 3.2mm in diameter. Below are the plastic limit of soil and flyash used.

Organic Soil	34%
M.S.W. flyash	15.96%

Table 4.3 Plastic limit of soil and fly ash

4.2.5 Plasticity Index

The plasticity index is a measure of the plasticity of soil. The plasticity index is the size of the range of moisture contents where soil exhibits plastic properties. PI is the difference of Liquid limit and plastic limit.

Organic Soil	28%
M.S.W. flyash	31.7%

Table 4.4 Plasticity Index of sample

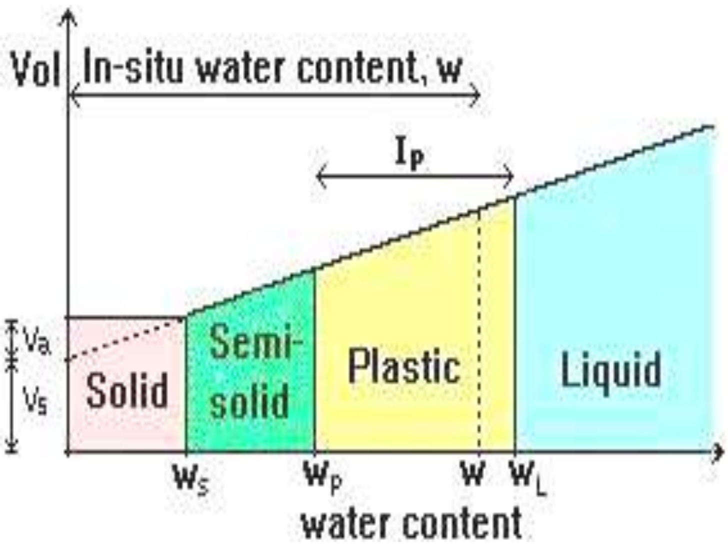


Fig. 4.2 Determination of plasticity index

4.2.6 Unconsolidated Undrained Test

An unconsolidated undrained (UU) test is one of Triaxial compression tests based on nature of loading and drainage conditions. This is a compression test, in which the soil specimen is subjected under isotropic all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress. Below mentioned are the readings from the proceeded test.

	Cohesion (c)	Angle of Shearing Resistance (Ø)
Organic Soil	18.6	20.5º

Table 4.5 Result of UU test

4.3 Results from model testing

4.3.1 Load-Settlement curve

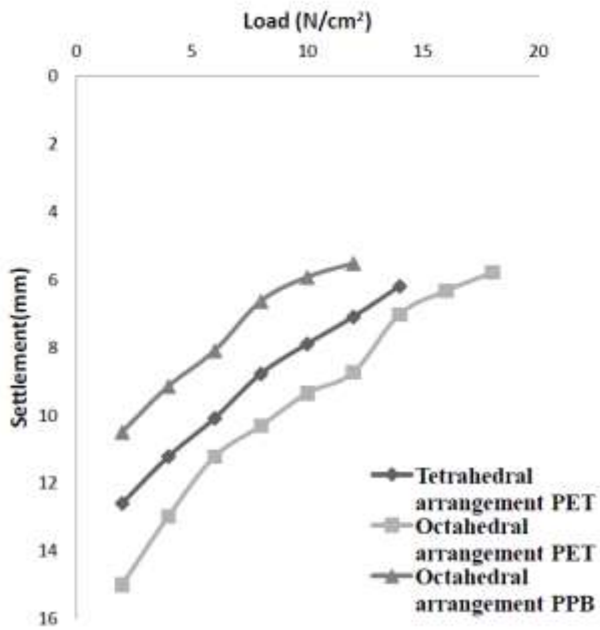


Fig. 4.3 Variation of load with respect to settlement

As seen from Fig. 4.3, it was seen that initially the settlement was more at low loads because of tamping of flyash at every stroke when the loading was provided with the help of hydraulic jack at the rate of $2N/cm^2$ per stroke. It is seen that, when the flyash got tamped inside the geocells also then settlement decreased with increase in loading. Settlement stopped at certain level for every geocells used in model testing. Tetrahedral and P.P.B. geocells showed 12.5% and 62.5% less load bearing capacity with same settlement as compared to octahedral arrangement.

4.3.2 Vertical Stress at varying Depths under footing

As specified in the methodology, variation of depth of geocells with different aspect ratios with respect to determining the vertical load over the soil. Following graph shows the variation of various types of geocells used as per the methodology. The vertical stress without any reinforcement was $33N/cm^2$.

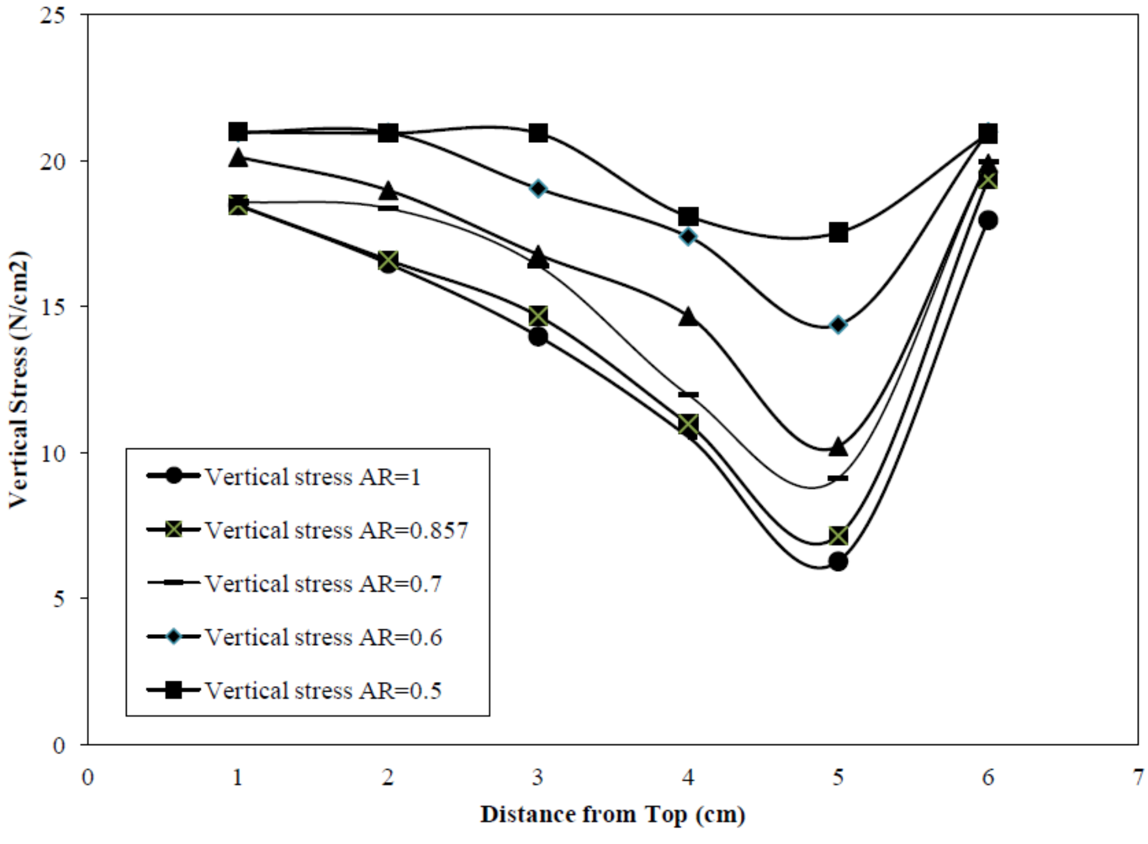


Fig. 4.4 Variation of vertical stress from top distance

As seen from Fig 4.4, it can be depicted that in tetrahedral arrangement at the depth of 4cm from surface vertical stress acted by hydraulic jack was minimum. Aspect ratio of 1 was better than the decreasing aspect ratios. At aspect ratio=1 tetrahedral arrangement showed minimum vertical stress when placed at depth of 4 cm. This was due to minimum transfer of load over soil due to increase in strength and load carrying capacity at when placed at depth of 2cm and 4 cm.

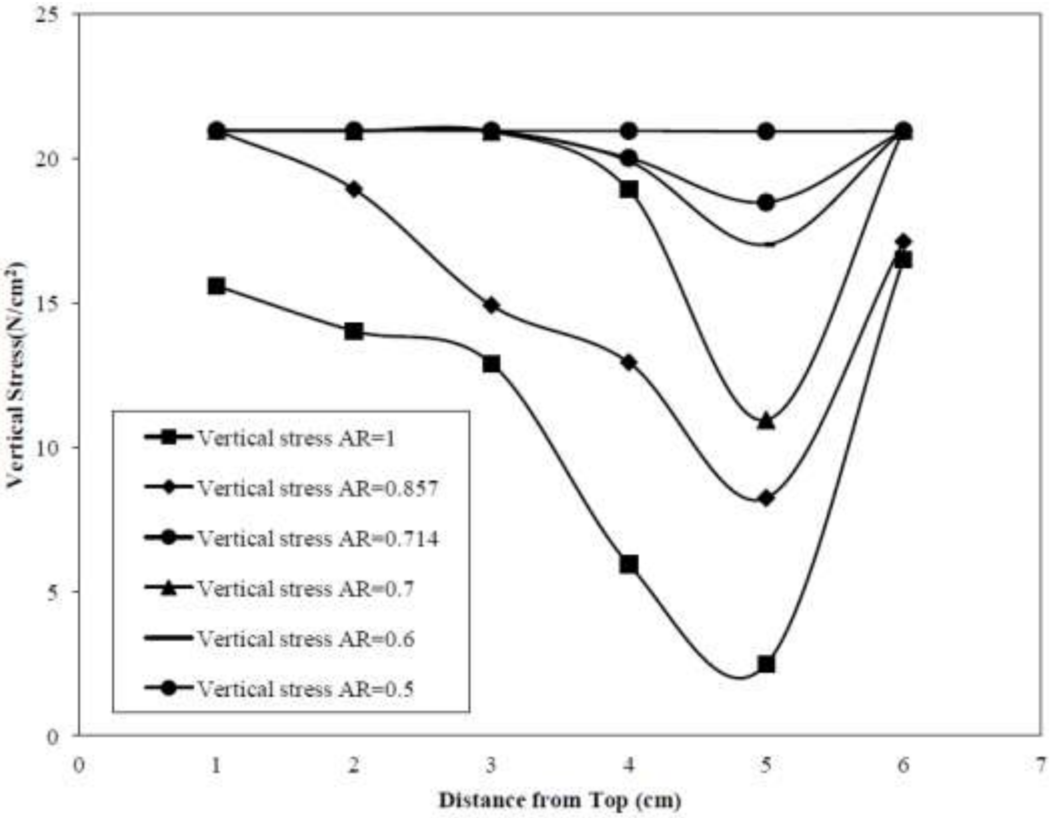


Fig. 4.5 Variation of Vertical Stress from top distance

As seen from Fig. 4.5, it is depicted that octahedral arrangement of aspect ratio=1 at the depth of 4 cm below the surface of M.S.W. flyash showed least vertical stress as compared to other arrangement. In comparison to tetrahedral arrangement, octahedral arrangement shows less vertical load, this is due to less spacing in between adjacent geocell.

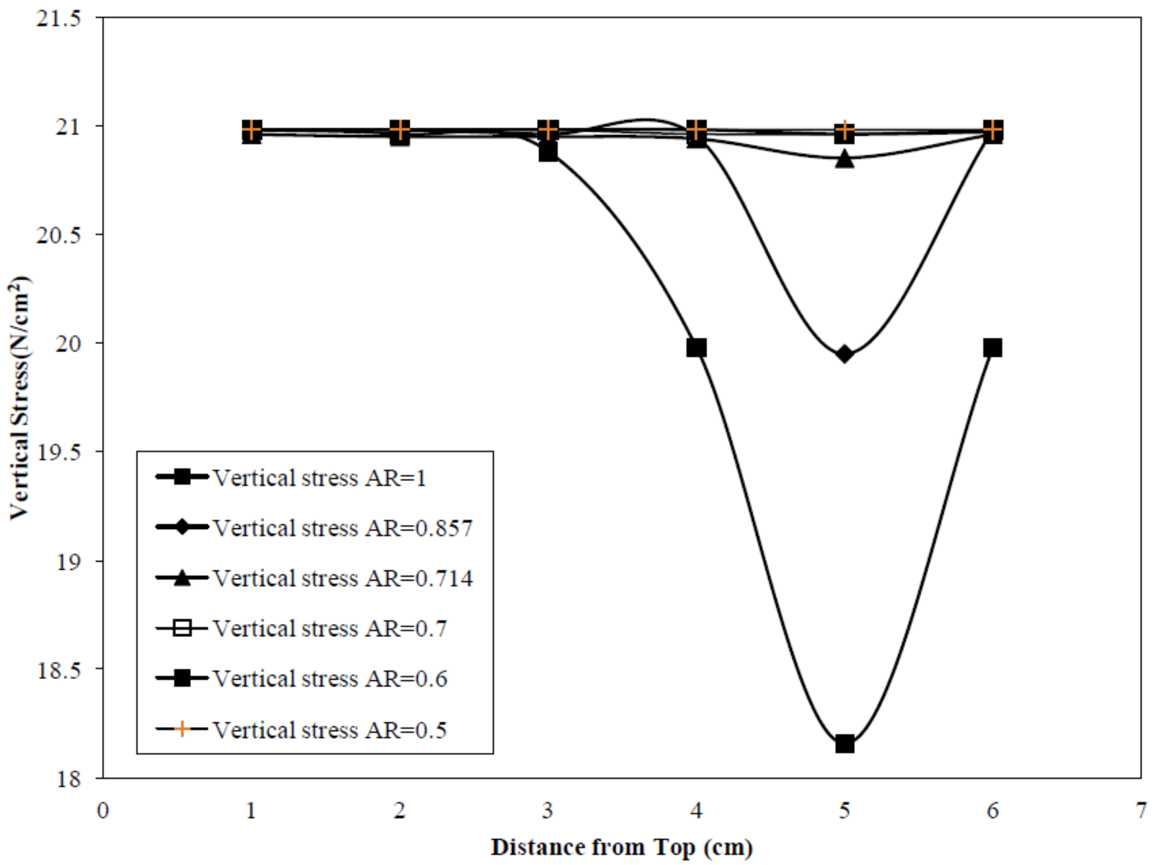


Fig. 4.6 Variation of vertical stress from top distance

As seen from Fig. 4.6, it is depicted that the vertical stress was maximum in P.P.B. geocells as polypropylene bag were not able to distribute load as precisely as octahedral and tetrahedral arrangement. This was due to less strength bearing capacity of polypropylene bags and providing its own weight towards soil, distortion in its shape leads to more compacting of soil rather than reinforcement of soil as compared to P.E.T. bottles geocells.

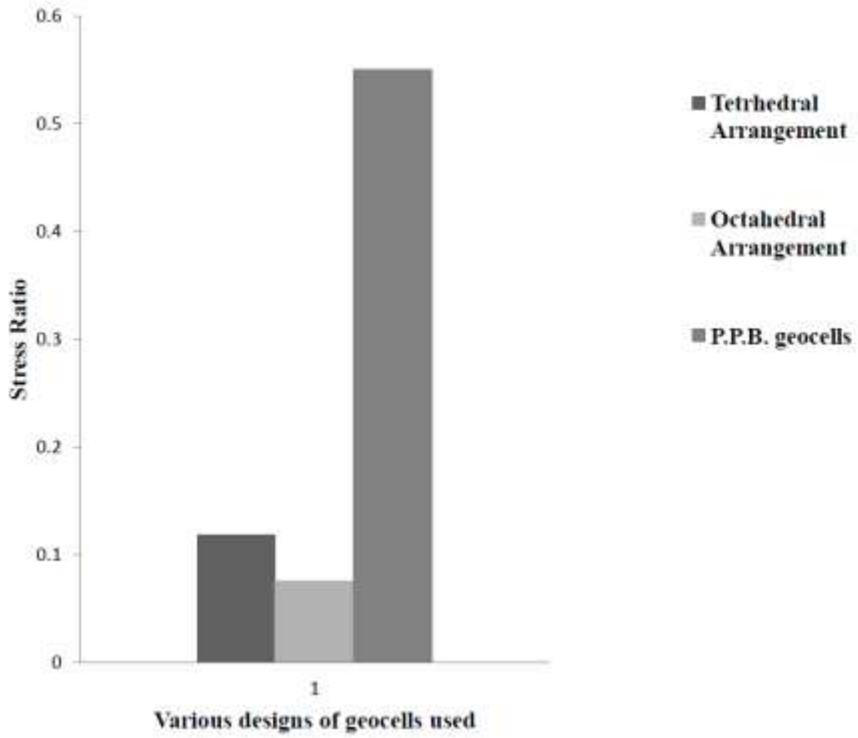


Fig. 4.7 Variation of Stress bearing ratio with respect to various designs

As seen in Fig. 4.7, it is represented that the octahedral arrangement is more strength bearing by 1.5 times lesser than tetrahedral arrangement and 6.5 times lesser than P.P.B.. This is due to less space between adjacent cells in octahedral arrangement and more packing fraction in octahedral arrangement than tetrahedral arrangement. In case of P.P.B., due its minimum stiffness the vertical load over it is greater than the tetrahedral and octahedral arrangement.

4.3.3 Strain at varying Depths under footing

Strain gauges are fixed in geocells at four sides of geocells and one at the center. These strain gauges then solder with wire and then connected with multimeter. Following graphs shows relation between geocells of various aspect ratios with varying depths from surface.

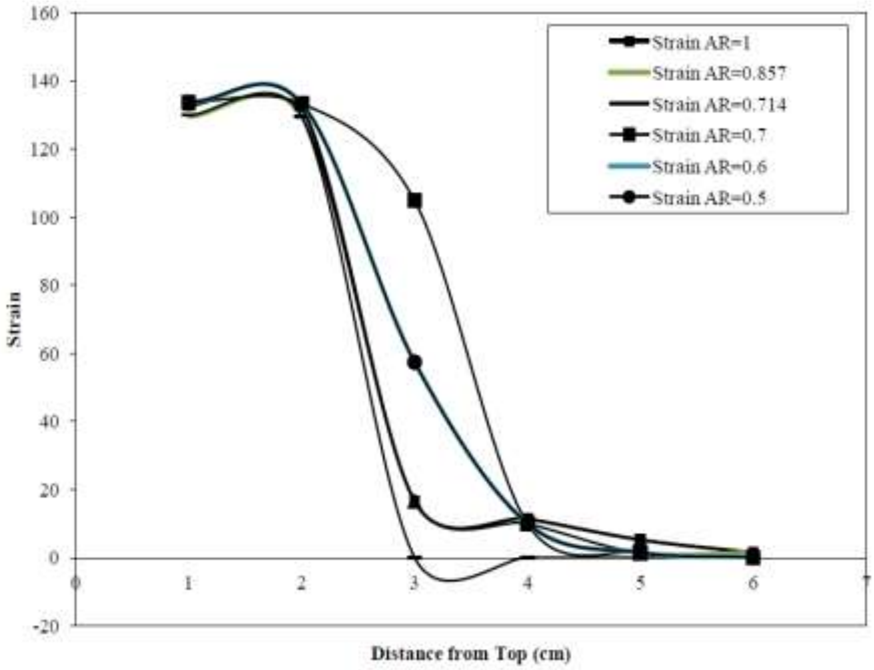


Fig. 4.8 Variation of strain with respect to depth

It can be seen in fig. 4.8 that the Geocells showed maximum strain as well as deformation when placed at surface up to depth of 2cm. Then the strain decreased drastically. This is due to burial of geocells up to a certain depth such that geocells are stacked inside the flyash and flyash itself won't let any distortion in geocells.

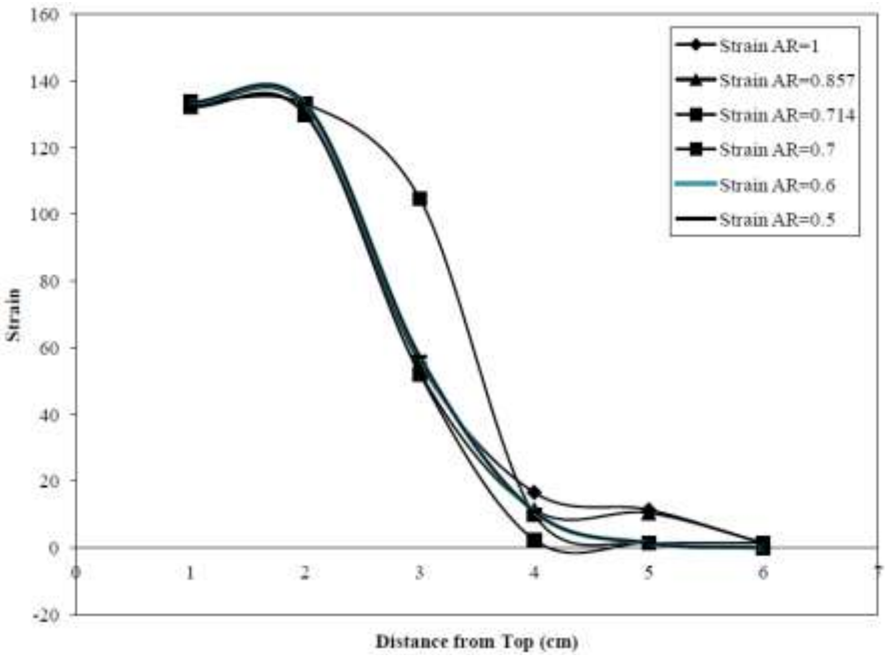


Fig. 4.9 Variation of Strain with respect to distance from top

As seen in the fig. 4.9 that in Octahedral Arrangement , due to its more packing fraction and lesser distance between adjacent voids, shows 10% lesser strain as compared to tetrahedral arrangement. Geocells at surface comes in direct contact of vertical stress leading to maximum strain for the geocells.

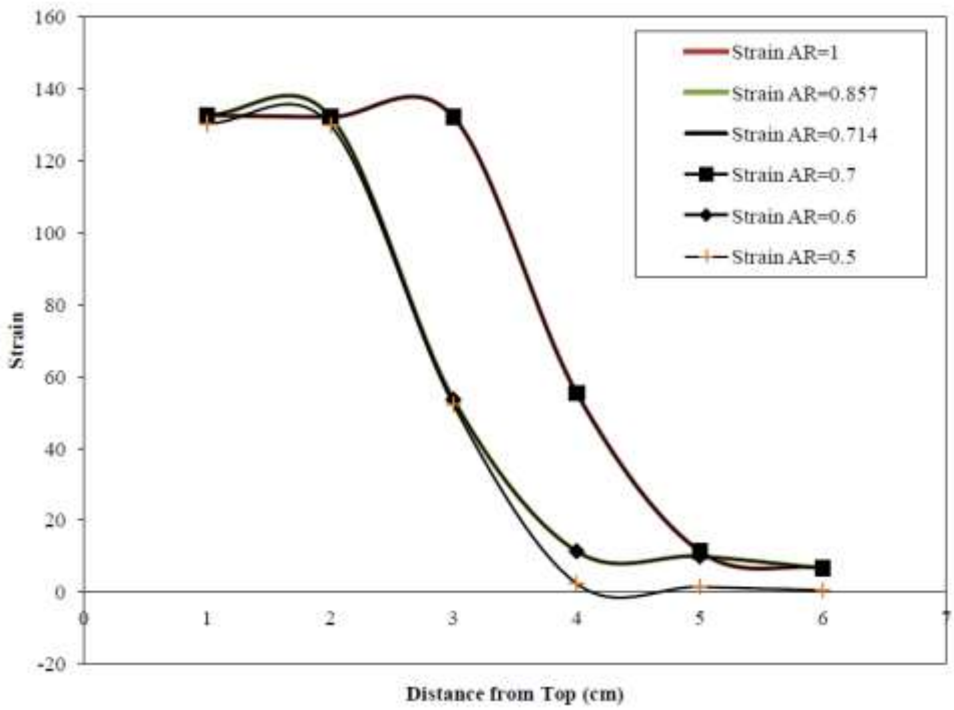


Fig. 4.10 Variation of Strain with respect to top to bottom distance

It is seen in the fig. 4.10 that in P.P.B. geocells, aspect ratio of 1 shows less strain than the decreasing aspect ratio. These geocells showed least strain at aspect ratio of 0.5 as strain was produced less at depth of 4cm and above. Strain was there maximum upto depth of 3 cm as in case of aspect ratio of 1. This is due to deformation in P.P.B. more than P.E.T. because of its more stiffness than P.P.B.

4.3.4 Stress-Strain relation

With the application of load, stress increment is shown abruptly and then stress goes constant with increase in strain in geocells. When settlement is stagnated, stress increases but the strain is produced minutely in geocells.

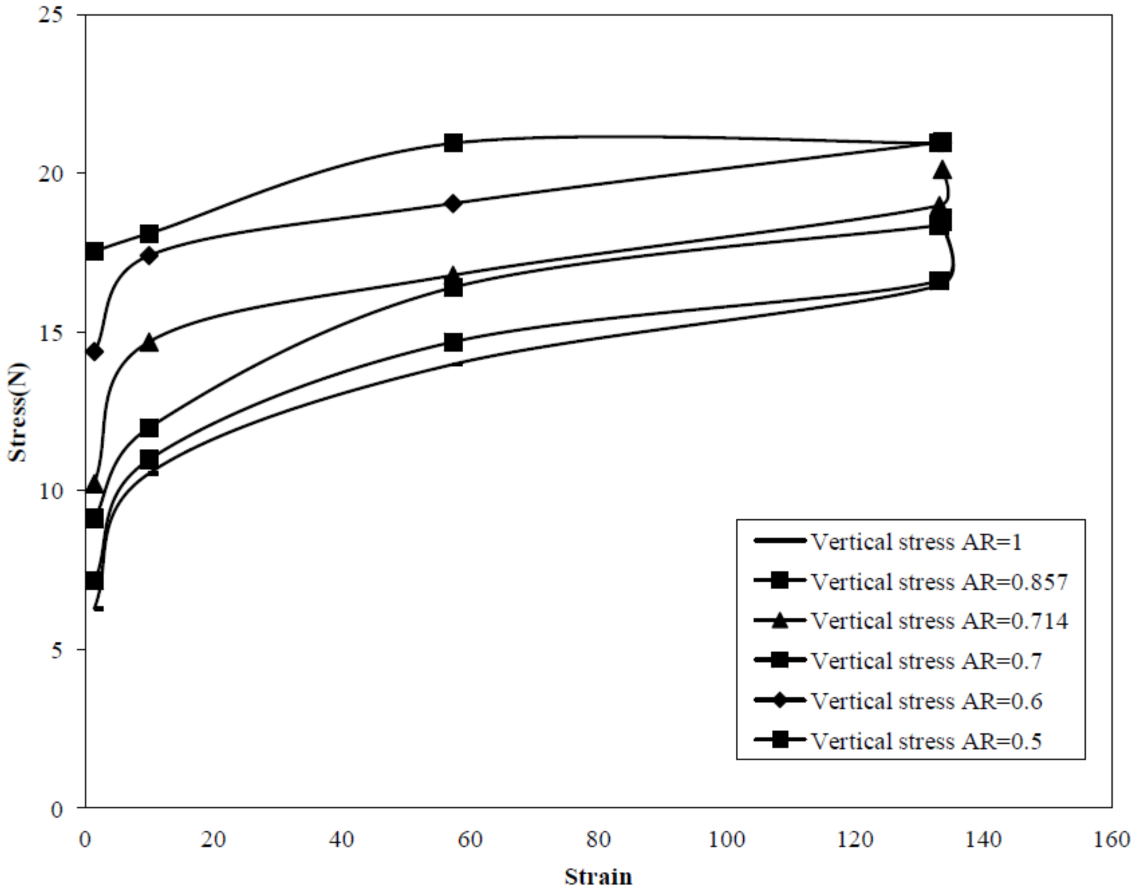


Fig. 4.11 Variation of Stress with strain

It is depicted in fig. 4.11 that the load provided by hydraulic jack increased initially such that geocells started bearing stress proportionally. Strain increased proportionally with increase in stress until there settlement stopped, showing strain produced in geocells.

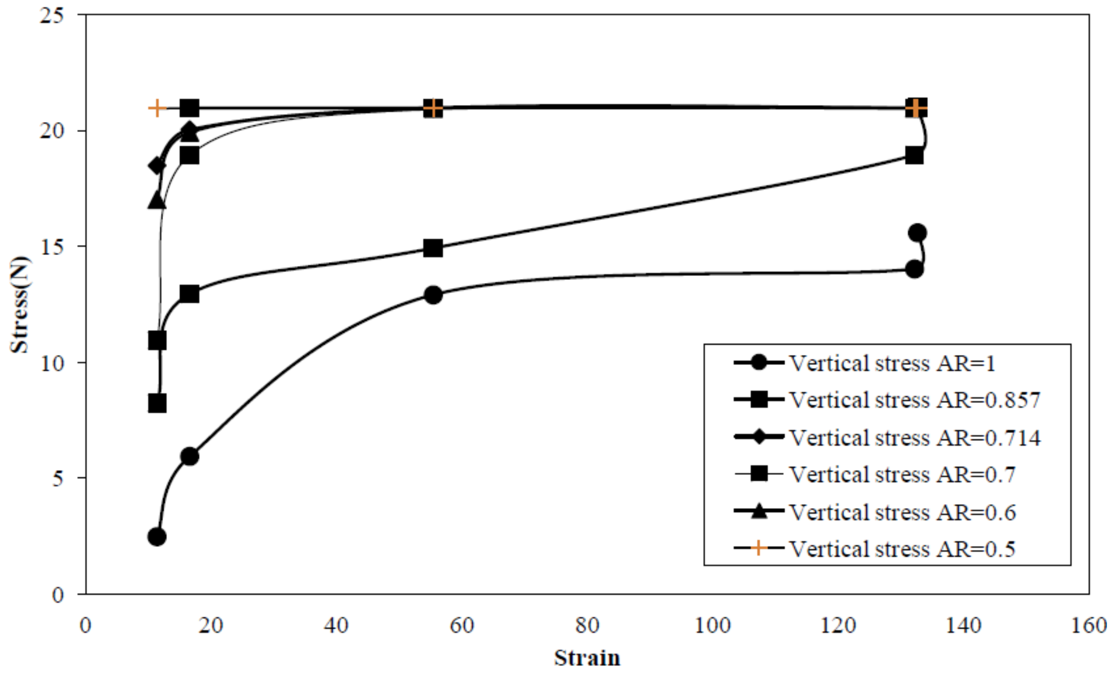


Fig 4.12 Stress strain variation

It can be seen in fig. 4.12 that the octahedral Arrangement showed direct elastic curve when aspect ratio=1 showed, minimum stress-strain as compared to decreasing aspect ratio. With decrease in aspect ratio, stress over the clay increased and become constant with increasing strain until settlement.

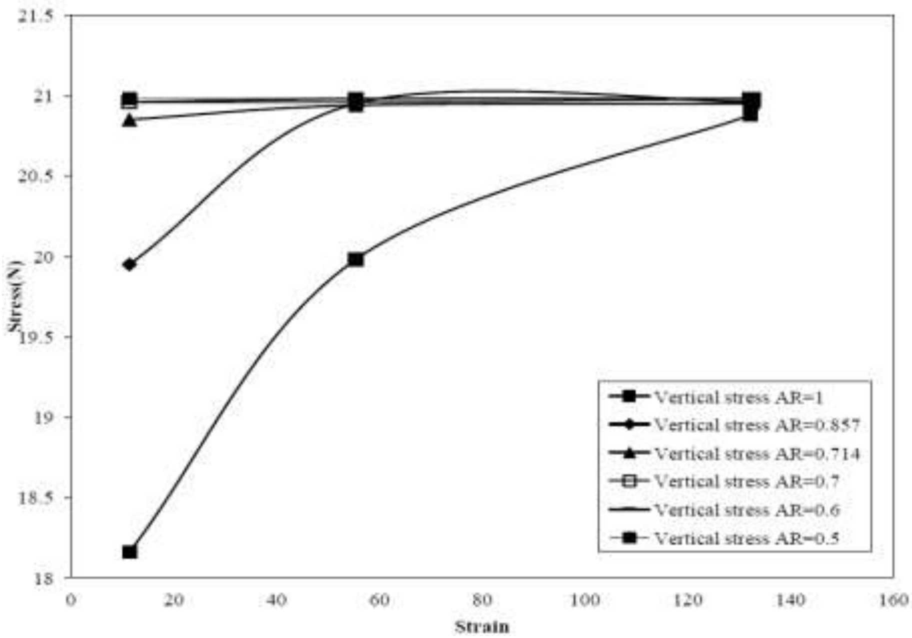


Fig. 4.13 Stress strain variation

It is seen in fig. 4.13, that the tetrahedral arrangement shows 1.5 times more stress and P.P.B. geocells shows 6.5 times more vertical stress over clay as compared to octahedral arrangement.

4.3.5 Settlement ratio with respect to Aspect ratio

Here, Settlement Ratio is the ratio of settlement, displayed in dial gauge, of flyash with geocells reinforcement to settlement of flyash without geocells reinforcement. As settlement increases, settlement ratio increases.

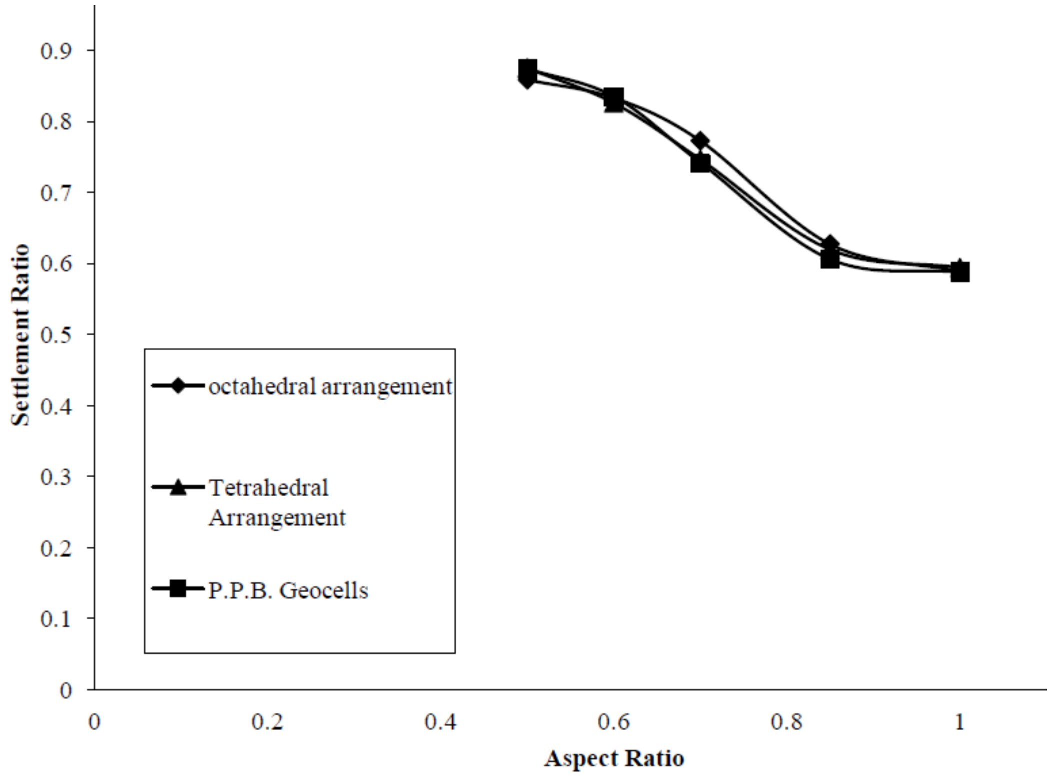


Fig. 4.14 Variation of Settlement ratio with aspect ratio

As it can be seen in fig. 4.14 it is depicted that the in tetrahedral arrangement, as aspect ratio decreases settlement increases. This shows that flyash settles more faster when aspect ratio increases. Fly ash gets accumulated more in geocells with increase in depth, and gets compacted with depth. At aspect ratio of 0.7, there is an increase in settlement ratio as diameter of geocells increased which led to accumulation of fly ash inside of geocells.

There's a sudden decrease in settlement ratio between 0.6 and 0.8. This is due to change in aspect ratio by decrease in diameter of geocells and increase in height of geocells which leads to more tamping of flyash in geocells. But due to less height the settlement is less as compared to that in aspect ratio of 1.

In P.P.B. geocells mat, settlement ratio increased abruptly due to decreasing load bearing capacity when aspect ratio decreased. P.P.B. accumulated fly ash inside of it which acted as normal loading over Organic soil.

CHAPTER 5

CONCLUSIONS

5.1 General

This chapter deals with the experiments and testing of geocell reinforcement of soil that this technique has contributed towards infrastructure developments, soil stabilization and towards the economy.

5.2 Conclusion

1. As the height of fly ash increases the performance of footing gets better. More stiffness due to geocell reinforcement causes the improvement in the performance of footing as geocells imparts tensile strength to the soil and helps in distributing the load in wider direction.
2. By reinforcing the fly ash bed with geocell mattress the bearing capacity would increase significantly and on comparison with unreinforced fly ash bed it would increase up to seven times the footing capacity of unreinforced bed.
3. As the height of mattress increases the footing pressure for a particular settlement increases due to a higher bending stiffness of composite mattress. As the height of mattress increases it transfers the load into wider area in trapezoidal form.
4. Heaving occurs when there is footing settlement in unreinforced fly ash bed and when the fly ash gets reinforced heaving gets minimized.
5. For increase in the width of mattress of a particular height results in high performance of footing
6. As the number of cells increases the heaving of surface also gets less.

5.3 Future Scope

All the literature suggested that a lot of experiments have been done regarding geocell reinforcement in weak soils. The effect of various aspect ratio like its thickness, tensile strength, cell size on bearing capacity of foundation have been done. Experimental studies on the effect of geocell with other reinforcement using techniques like stone column and geogrid were used.

Most of the studies are limited to laboratory scale model tests and appropriate dimensional analysis needed to be applied to these results for field applications.

Also the numerical studies in the field are limited. Most numerical studies can be done to develop analytical equations which can be used by practicing geotechnical engineers in the field without any scaling for real application.

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