PERFORMANCE OF GEOCELL RE WALL WITH STABILIZED COHESIVE EARTH FILLS UNDER SURCHARGE LOADING

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Abstract : An experimental study was carried out using three dimensional model of reinforced earth retaining wall, constructed to stimulate the plane strain condition. This form of model was used to get a satisfactory analysis and also to verify the semi-infinite medium of the soil. It was planned to examine the load-settlement characteristics of surcharge plate to observe whether there is local bearing capacity failure or RE wall failure. The tests were conducted on cohesive as backfill material, stabilized cohesive fill, reinforced cohesive backfill with geocell as reinforcement and reinforced stabilized cohesive fill. The cohesive soil is stabilized with 3% lime and 10% or 20% fly ash mix so as to make stronger RE wall. The study was conducted using strip surcharge and full surcharge. From experimental investigation, it was observed that with provision of reinforcement the bearing capacity of clayey soil was improved, settlement of footing reduces and lateral movement of wall facing also reduces.

***Index Terms* – Geocell, strip surcharge, full surcharge, stabilization, RE wall**

I. INTRODUCTION

Expansive soils are generally poor for construction purposes as they exhibit swelling and shrinkage properties. Also, they have low bearing capacities, low shear strength, high water absorbality and shows high settlement. Such type of soil requires removal or some treatment. By stabilizing and reinforcing, such soil can be used again and will be able to solve difficult stability issues for structure subjected to flooding or other hydrodynamic forces or those in seismically active areas. The reinforced earth is a composite construction material composed of soil fill strengthened by the inclusion of rods, bars, strips, fibers or nets. The strength of the composite material is due to the apparent cohesion between soil and reinforcement. This can be achieved by the densification of the composite material.

Present study is carried out to check efficacy of cohesive soil as backfill material in the construction of reinforced earth wall. The main theme of this research is to study the model reinforced earth wall under strip surcharge and full surcharge loading conditions. The problem of vertical surcharge strip load arises when highway, pavements, railway tracks and continuous wall footings are built on top of the reinforced earth structure.

Behavior of geocell reinforced soil was investigated by various researchers through case study, model study or laboratory tests. Rea and Mitchell (1978) and Mitchell et al. through laboratory model tests on sand reinforced by interconnected paper cells identified the modes of failure of geocell. Mhaiskar and Mandal (1992), Dash et al. (2001), Sitharam et al. have performed model tests on behavior of geocell reinforced soil and found that geocell reinforcement can increase the load carrying capacity and reduce the settlement. Webster and Watkins carried out the full scale tests on sand filled, vertical interconnected shallow thin walled aluminum cells placed over soft ground and have observed significant improvement in the load carrying capacity of soil subgrade. Bathurst (1988) and Karpurapu have carried out a series of large scale triaxial compression tests on isolated geocell encased soil specimens. They have quantified the structure gain due to geocell through an apparent cohesion. Rajagopal et al. (1999) studied the effect of multiple geocell on structure and stiffness of granular soil by triaxial tests. The improvement in the structure and stiffness due to geocell reinforcement was found to increase with increase in number of cells till 3 and beyond that the improvement was marginal.

II. MATERIALS OF INVESTIGATION

Clayey soil used in this investigation was obtained from Dethan, Gujarat where the soil was dumped near the metro rail project. It was sun dried initially and powdered to a fraction less than 4.75mm. The engineering properties obtained from preliminary laboratory studies based on relevant I.S codal provisions are tabulated in Table 1.

Geocell was made up of sheets brought from Parksons Graphics Pvt. Ltd., Bhenslore a company manufacturing playing cards was used as the reinforcement in the construction of model reinforced earth wall. Various properties of geocell are tabulated below in table 2 and the connection of geocell with the facing is shown in Fig.1.

Lime used in this investigation was obtained from shop in Nizampura of grade Quick lime (Cao). It was dry powder and white in color.

The fly ash used in the present investigation was brought from Parshwa Infracon, Ready Mix Concrete supplier, Vadodara. They obtained it from Wanakbori thermal power station situated in Gujarat (India). It was of class F type. The tests were performed on dry fly ash. The various engineering properties and chemical analysis of the fly ash are tabulated in Table 3 and Table 4 respectively.

Table 1 Engineering properties of cohesive soil

Sr.no	Properties of cohesive soil	IS code followed	Values
1.	Gravel % 4.75mm and above	IS:2720 (Part IV) 1985	-
2.	Sand % 0.075mm to 4.75mm	IS:2720 (Part IV) 1985	5%
3.	Clay and silt fraction	IS:2720 (Part IV) 1985	95%
4.	Liquid limit	IS:2720 (Part V) 1985	65.29%
5.	Plastic limit	IS:2720 (Part V) 1985	30.56%
6.	Plasticity index	IS:2720 (Part V) 1985	34.73%
7.	IS Classification	IS:1498 1970	CH
8.	MDD	IS:2720 (Part VII) 1980	1.486gm/cc
9.	OMC	IS:2720 (Part VII) 1980	27.22%
10.	Specific gravity	IS:2720 (Part III)	2.58
11.	UCS at OMC MDD	IS:2720 (Part X)	214.765 kPa
12.	Cohesion	IS:2720 (Part XII)	107.38 kPa
13.	Free swell	IS:2720 (Part XL)	85%
14.	Swelling potential	IS:2720 (Part XLI)	0.5089 kg/cm^2
15.	CBR at OMC MDD	IS:2720 (Part XVI) 1979	2.50%

Table 2 Properties of geocell

Sr.no	Properties of geocell	Values
1.	Polymer	Polyvinyl chloride(PVC)
2.	Cell size (mm x mm)	65 x 60
3.	Number of cells/m^2	270
4.	Mass per unit area (gm/cm^2)	0.035
5.	Cell depth	3cm
		5cm
6.	Strip thickness (micron)	250
7.	Tensile strength (N/knot)	3cm-43 N
		5cm-58 N

Table 3 Engineering properties of fly ash

Sr.no	Properties of fly ash	Values
1.	Gravel % 4.75mm and above	Nil
2.	Sand % 0.075mm to 4.75mm	52%
3.	Silt size % 0.002mm to 0.075mm	41%
4.	Clay size % less than 0.002mm	7%
5.	Liquid limit	36.8%
6.	Plastic limit	Non-plastic
7.	IS classification	SC
8.	MDD	1.21 gm/cc
9.	OMC	22.5%
10.	Experimental density	1.15 gm/cc
11.	IS light compaction density in dry condition	1.18
12.	Specific gravity	2.59
13.	Soaked CBR	1.18
14.	Permeability coefficient	102 x 10^{-5} cm/s
15.	Cohesion	0^o
16.	Angle of internal friction	30^o
17.	Compression index Cc at 95% of MDD & OMC	0.0797

Table 4 Chemical analysis of fly ash

Sr.no	Chemical	Values
1.	Silicon dioxide + Aluminium oxide + Ferrous oxide	95%
2.	Silicon dioxide % by mass	62%
3.	Total Sulphur as Sulphur Trioxide (SO_3)	0.3%
4.	Magnesium Oxide	0.5%
5.	Available Alkali as Sodium Oxide (Na_2O)	0.9%
6.	Loss of Ignition % by mass	1.2%
7.	Total Chloride content	35%

Figure 1 Connection of geocell with the facing used

III. RESEARCH METHODOLOGY

3.1 Construction of earth wall

Construction of model RE wall was carried out in a tank having dimension 0.84m x 0.20m x 0.50m. For its construction, packing was kept in order to achieve a length of 0.70m. The wooden panel was placed as facing, after that one-third part of backfill material i.e. clay was thoroughly mixed with water at OMC 27.22% in a tray and was laid as first layer. On laying each layer a container was kept in order to find the achieved dry density after performing the test. Each layer was compacted using a rammer of size 10cm x 10cm and weighing 4.68 kg to achieve desired dry density. Number of blows given to each layer was 300. Similarly all the layers were laid and the complete construction of reinforced earth wall was done.

3.2 Construction of reinforced earth wall

For the construction of reinforced earth wall a facing was first laid, then one-third part of backfill material was mixed with water at OMC 27.22% and was laid. At the same time a geocell of height either 3cm or 5 cm was laid in each layer and was compacted properly. The achieved dry density was found with the help of cylinder sections Fig.4.3 which was placed at centre of each layer. Dry density was achieved with the help of a rammer of size 10cm x 10cm and weighing 4.68 kg. Number of blows given to each layer was 300. Similarly all the layers were laid and the complete construction of reinforced earth wall was done.

3.3 Construction of stabilized earth wall

For the construction of stabilized earth wall firstly the facing was laid, and then one-third part of backfill material was thoroughly mixed with varying fly ash (10% or 20%) and lime 3% at OMC found from proctor test. Each layer was compacted using rammer weighing 4.68 kg properly to achieve desired dry density. Similarly all the layers were laid and the complete construction of reinforced earth wall was done.

3.4 Construction of stabilized reinforced earth wall

For the construction of stabilized reinforced earth wall firstly the facing was laid, then one-third part of backfill material was thoroughly mixed with varying fly ash (10% or 20%) and lime 3% at OMC found from proctor test and the reinforcement of height 3cm or 5 cm was laid. Each layer was compacted using rammer weighing 4.68 kg properly to achieve desired dry density. Similarly all the layers were laid and the complete construction of reinforced earth wall was done.

3.5 Loading for strip surcharge load test

After construction of the reinforced earth wall the top surface was made fully level using level tube. The mild steel strip footing (test plate) size 10 cm x 20 cm x 2cm thick was firmly seated at a distance of 5cm from the face of wall. Mechanical screw jack is used for axial loading. The load is applied by mechanical screw jack which was fixed with mild steel plate of 12 mm thickness, which in turn is fixed up with the horizontal girder of the reaction frame for axial loading. The proving ring along with steel ball was placed between the mechanical screw jack and top most plate aligns centrally over the strip footing. Two dial gauges fixed with stand were placed at the opposite corner of the test plate. Those two dial gauges record the settlement of strip footing under the applied load. For the lateral movement of facing along the height of the reinforced earth wall, two dial gauges were arranged against the facing of reinforced earth wall at the middle of top two layers. The complete setup for strip surcharge load test is shown in Fig.2.

After completion of all arrangement initially a seating load equivalent to 6.67 kPa contact pressure was applied till there was no further settlement of plate. After that the next increment of load equivalent to 13.34 kPa was applied till the rate of settlement was negligible. The process of giving incremental load was continued till reinforced earth wall fails. The reading of loading intensity and settlement of strip footing are to be plotted on graph paper to obtain ultimate bearing capacity of the footing.

Along static load test, lateral movement of facing of R.E wall is observed with increasing loading intensities. Similarly all the cases were plotted and the ultimate bearing capacities were found out.

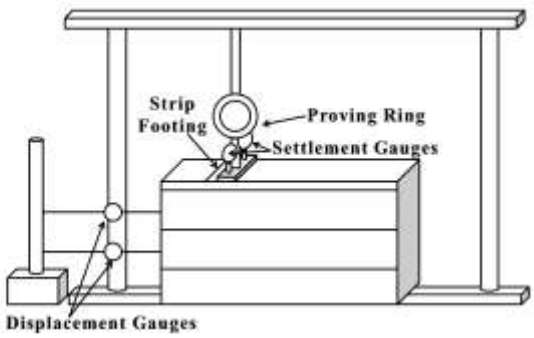

Figure 2 Setup for strip surcharge

3.6 Loading for full surcharge load test

After construction of the reinforced earth wall the top surface was made fully level using level tube. The mild steel surcharge footing (test plate) size 70cm x 20cm x 2cm thick was firmly seated at the top of wall. Mechanical screw jack is used for axial loading. The load is applied by mechanical screw jack which was fixed with mild steel plate of 12mm thickness, which in turn is fixed up with the horizontal girder of the reaction frame for axial loading. The proving ring along with steel ball was placed between the mechanical screw jack and top most plate aligns centrally over the surcharge footing. Two dial gauges fixed with stand were placed at the opposite corner of the test plate. Those two dial gauges record the settlement of surcharge footing under the applied load. For the lateral movement of facing along the height of the reinforced earth wall, two dial gauges were arranged against the facing of reinforced earth wall at the middle of top two layers. The complete setup for full surcharge load test is shown in Fig.3.

After completion of all arrangement initially a seating load equivalent to 42 kPa contact pressure was applied till there was no further settlement of plate. After that the next increment of load equivalent to 56.6 kPa was applied till the rate of settlement was negligible. The process of giving incremental load was continued till reinforced earth wall fails. The reading of loading intensity and settlement of surcharge footing are to be plotted on graph paper to obtain ultimate bearing capacity of the footing.

Along static load test, lateral movement of facing of R.E wall is observed with increasing loading intensities. Similarly all the cases were plotted and the ultimate bearing capacities were found out.

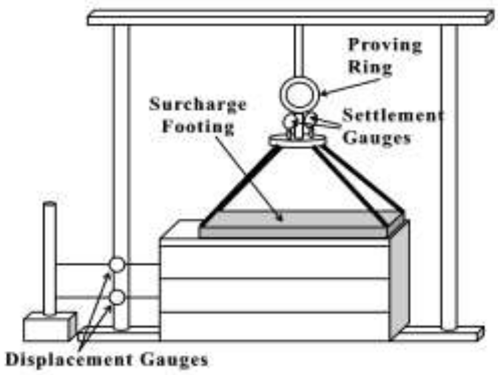

Figure 3 Setup for full surcharge

IV. RESULTS AND DISCUSSION

The settlement of only soil at different loading intensities are found out at $q_u/2$, $q_u/3$ and $q_u/4$ where q_u is the ultimate loading intensity from the loading intensity v/s settlement characteristic of earth wall backfilled with only soil. At the same loading intensity levels the settlements are obtained for all the cases.

% Settlement reduction= $\frac{Se-Sre}{Se}$ x 100

where, Se is settlement for earth wall backfilled with only soil

Sre is settlement for reinforced earth wall

% Settlement reduction= $\frac{Se-Sse}{Se}$ x 100

% Settlement reduction= $\frac{Se-Ssre}{Se}$ x 100

where, Sse is settlement for earth wall backfilled with stabilized soil

Ssre is settlement for reinforced stabilized earth wall

Bearing capacity ratio (BCR) is defined as the ratio of improved bearing capacity to the bearing capacity of earth wall without any reinforcement provided.

BCR= $\frac{\text{Bearing capacity of reinforced soil}}{\text{Bearing capacity of unreinforced soil}}$

4.1 RE wall loaded under strip surcharge loading conditions

4.1.1 Comparison of earth wall backfilled with only soil and reinforced earth wall backfilled with cohesive soil and geocell reinforcement

Figure 4 shows loading intensity v/s settlement characteristics of surcharge strip footing on surface of earth for earth wall backfilled with only soil and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcement each of height 3 cm or 5 cm was provided. It can be seen that as the loading intensity increases the settlement of surcharge strip footing also increases. Initially this settlement is very low with progress of loading, the settlement characteristic is linear which afterwards turns to almost downward straight line for soil and soil with 3 cm geocell but for soil with 5 cm geocell it is curvilinear with concave downwards which shows progressive settlement.

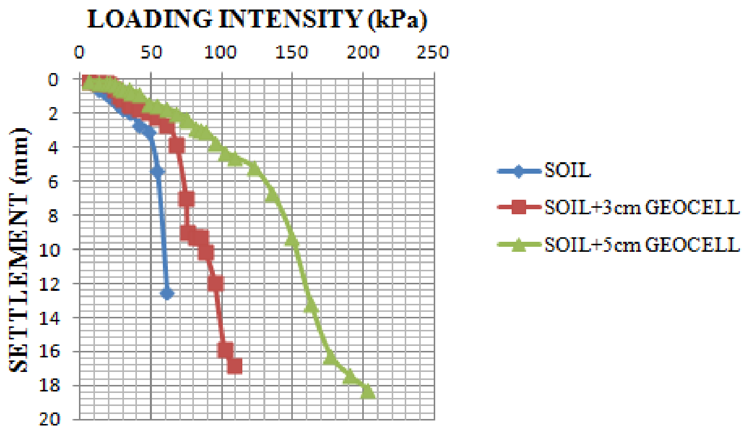

Figure 4 Load v/s Settlement characteristics of earth wall backfilled with only soil and reinforced earth wall backfilled with reinforced soil

Figure 5 shows bearing pressure v/s settlement reduction for 3cm geocell and 5cm geocell as reinforcement along with soil as backfill material. It can be seen that for the same loading intensities the settlement reduction factor has been found to increase for 5cm geocell as compared to 3cm geocell when used as reinforcement.

Figure 6 shows S/B * 100 v/s bearing capacity ratio for 3cm geocell and 5cm geocell as reinforcement along with soil as backfill material. It can be seen that for the same S/B ratio the bearing capacity factor has been found to increase for 5cm geocell as compared to 3cm geocell when used as reinforcement.

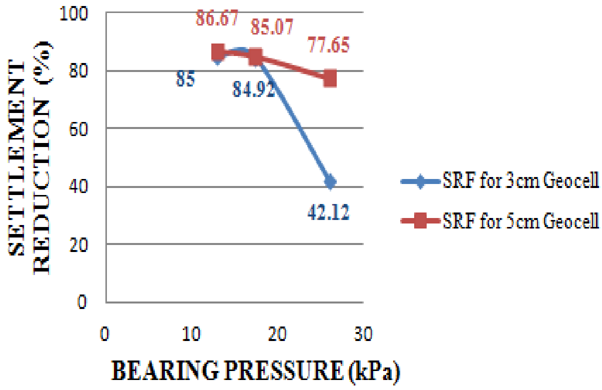

Figure 5 Bearing pressure v/s Settlement reduction

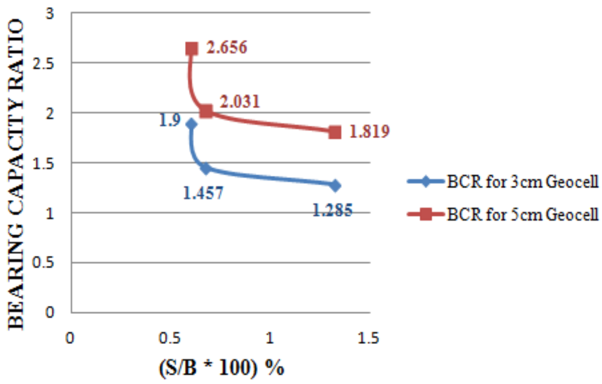

Figure 6 S/B * 100 v/s bearing capacity ratio

4.1.2 Comparison of earth wall backfilled with only stabilized soil using 3% lime and 10% fly ash and reinforced earth wall backfilled with same stabilized soil and geocell as reinforcement

Figure 7 shows loading intensity v/s settlement characteristics of surcharge strip footing on surface of earth and reinforced earth wall backfilled with stabilized soil using 3% lime and 10% fly ash and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcements each of height either 3 cm or 5 cm were provided. It can be seen that as the loading intensity increases the settlement of surcharge strip footing also increases. Initially this settlement is very low but with progress of loading; the settlement characteristic is linear which afterwards turns to curvilinear with concave downwards which shows progressive settlement.

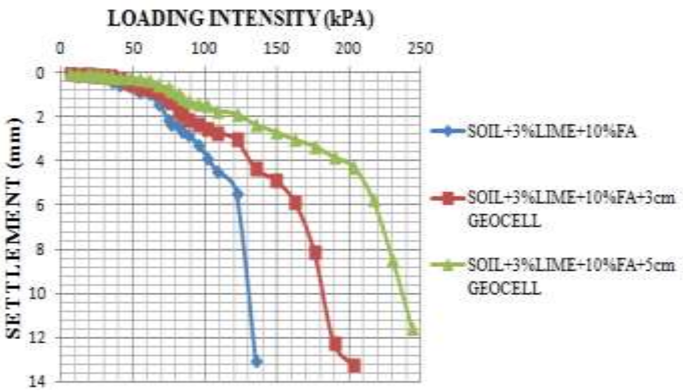

Figure 7 Load v/s Settlement characteristics of earth wall backfilled with only stabilized soil using 3% lime and 10% fly ash and reinforced earth wall backfilled with same stabilized soil along with reinforcement

Figure 8 shows bearing pressure v/s settlement reduction for stabilized backfill using 3% lime and 10% fly ash, as well as with reinforcement as 3cm geocell and 5cm geocell along with same backfill material. It can be seen that for the same loading intensity the settlement reduction has been found to increase for stabilized backfill with 5cm geocell as compared to 3cm geocell and for only stabilized backfill.

Figure 9 shows S/B * 100 v/s bearing capacity ratio for stabilized soil using 3% lime and 10% fly ash as backfill material and 3cm geocell and 5cm geocell as reinforcement along with same stabilized soil. It can be seen that for the same S/B ratio the bearing capacity factor has been found to increase for 5cm geocell as compared to 3cm geocell when used as reinforcement and for only stabilized soil as backfill material.

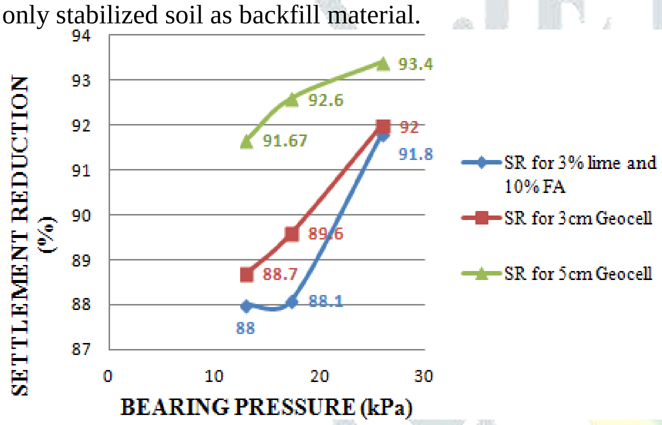

Figure 8 Bearing pressure v/s Settlement reduction

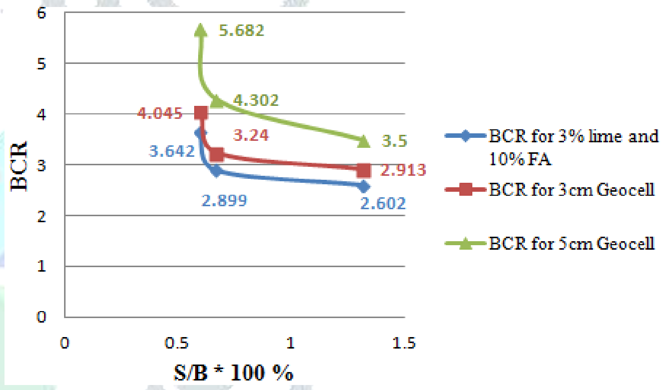

Figure 9 S/B * 100 v/s Bearing Capacity Ratio

4.1.3 Comparison of earth wall backfilled with only stabilized soil using 3% lime and 20% fly ash and reinforced earth wall backfilled with same stabilized soil and geocell as reinforcement

Figure 10 shows loading intensity v/s settlement characteristics of surcharge strip footing on surface of earth and reinforced earth wall backfilled with stabilized soil using 3% lime and 20% fly ash and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcement each of height either 3 cm or 5 cm was provided. It can be seen that as the loading intensity increases the settlement of surcharge strip footing also increases. Initially this settlement is very low with progress of loading, the settlement characteristic is linear which afterwards turns to almost downward straight line and then turns to curvilinear with concave downwards which shows progressive settlement.

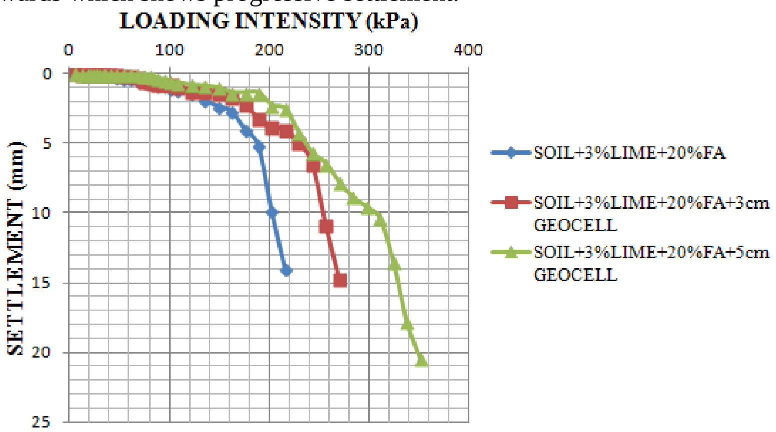

Figure 10 Load v/s Settlement characteristics of earth wall backfilled with only stabilized soil using 3% lime and 20% fly ash and reinforced earth wall backfilled with same stabilized soil along with reinforcement

Figure 11 shows bearing pressure v/s settlement reduction for stabilized backfill using 3% lime and 20% fly ash, as well as with reinforcement as 3cm geocell and 5cm geocell along with same backfill material. It can be seen that for the same loading intensity the settlement reduction has been found to increase for stabilized backfill with 5cm geocell as compared to 3cm geocell and for only stabilized backfill.

Figure 12 shows S/B * 100 v/s bearing capacity ratio for 3cm geocell and 5cm geocell as reinforcement along with stabilized soil using 3% lime and 20% fly ash as backfill material. It can be seen that for the same S/B ratio the bearing capacity factor has been found to increase for 5cm geocell as compared to 3cm geocell when used as reinforcement.

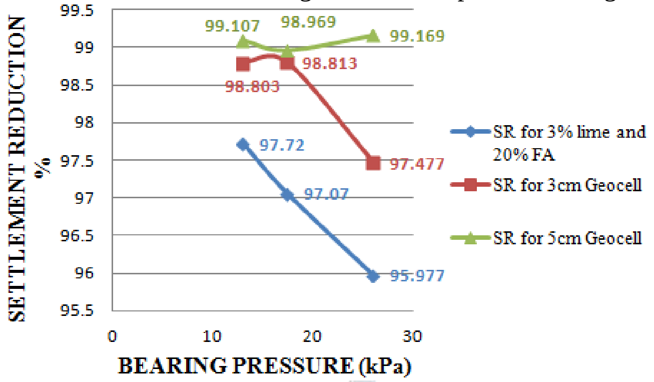

Figure 11 Bearing pressure v/s Settlement reduction

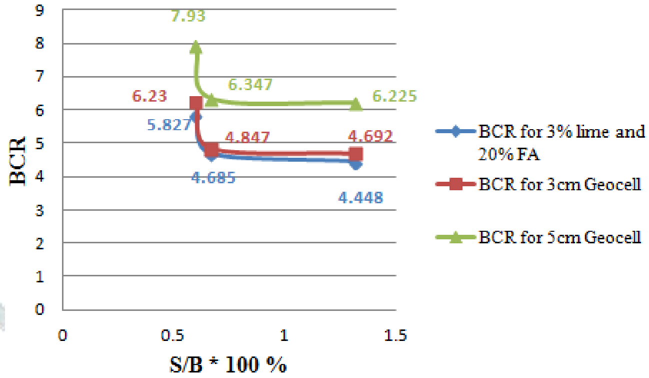

Figure 12 S/B * 100 v/s Bearing Capacity Ratio

Figure 13 shows the loading intensity v/s settlement characteristics for all the above mentioned cases. It is clearly visible that the magnitude of settlement for the unreinforced soil was much more than that for the reinforced soil under the same loading intensity. There is reduction in the settlement through increased rigidity of geocell layer by confinement of foundation soils.

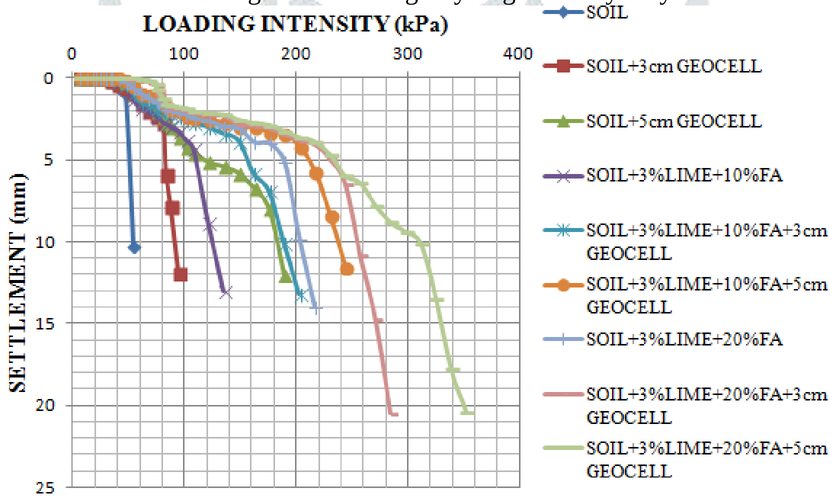

Figure 13 Loading intensity v/s settlement for earth wall, stabilized earth wall, reinforced earth wall and reinforced stabilized earth wall

Table 5 shows the ultimate bearing capacities for various combinations

Table 5 Ultimate bearing capacities for various combinations

Combinations	Ultimate bearing capacity (kPa)
Soil	52
Soil+3cm Geocell	68
Soil+5cm Geocell	140
Soil+3%Lime+10%Fly ash	120
Soil+3%Lime+10% Fly ash+3cm Geocell	173
Soil+3% Lime+10% Fly ash+5cm Geocell	203
Soil+3%Lime+20% Fly ash	189
Soil+3%Lime+20% Fly ash+3cm Geocell	240
Soil+3%Lime+20%Fly ash+3cm Geocell	311

4.1.4 Lateral movement of wall facing under strip surcharge loading

To check the effect of strip surcharge footing on the lateral movement of face of R.E wall the lateral displacement was measured during static load application. The lateral movement of wall facing was measured at the centre of top facing panel in line of top reinforcement and at centre of second facing panel in line with second reinforcing layer from top.

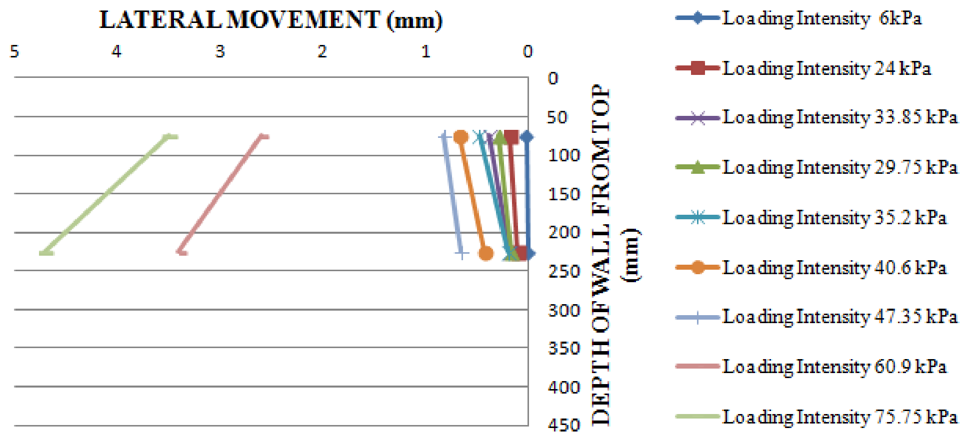

Figure 14 Depth of RE wall from its top v/s lateral movement for RE wall backfilled with only soil

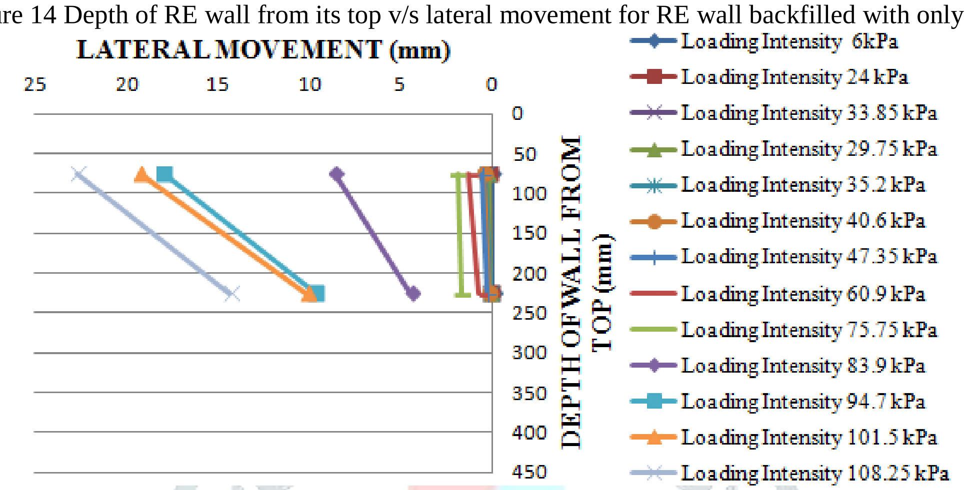

Figure 15 Depth of RE wall from top v/s Lateral movement for earth wall backfilled with soil and reinforced using 3cm geocell

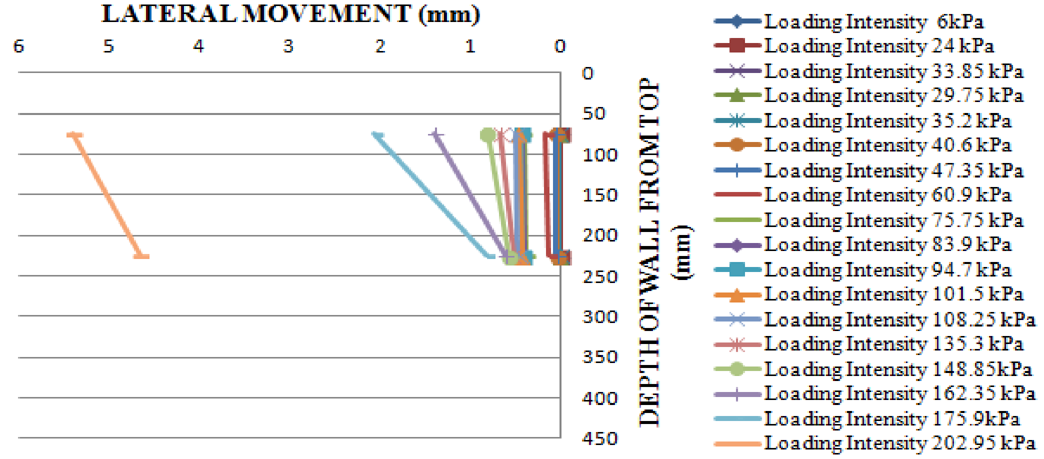

Figure 16 Depth of RE wall from top v/s Lateral movement for earth wall backfilled with soil and reinforced using 5cm geocell

From Fig.14, 15 and 16 it is clear that the lateral movement for the unreinforced earth wall is more as compared to the reinforced case. Also, for the 5cm geocell the lateral movement was less as compared to 3cm geocell, which means as the height of geocell increases the lateral movement decreases. However, this can't be completely true as the tests were performed for only two heights.

4.2 RE wall loaded under full surcharge loading conditions

4.2.1 Comparison of earth wall backfilled with only soil and reinforced earth wall backfilled with soil and geocell as reinforcement

Figure 17 shows loading intensity v/s settlement characteristics of full surcharge footing on surface of earth and reinforced earth wall backfilled with only soil and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcements each of height 3 cm or 5 cm was provided at each layer. It can be seen that as the loading intensity increases the settlement of full surcharge footing also increases. Initially this settlement is very low with progress of loading, the settlement characteristic is linear which afterwards turns to almost downward straight line for all the cases and turns to curvilinear with concave downwards which shows progressive settlement.

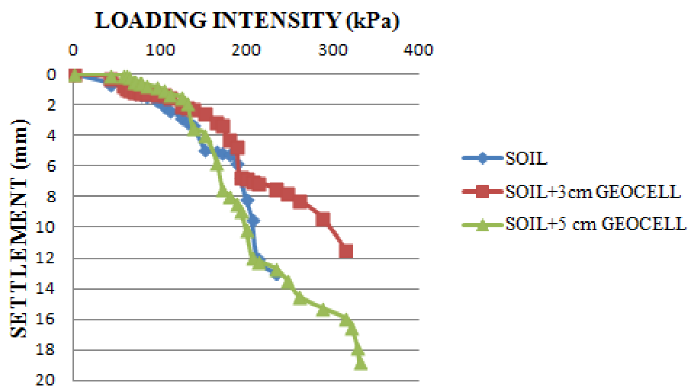

Figure 17 Load v/s Settlement characteristics of earth wall backfilled with only soil and reinforced earth wall backfilled with reinforced soil

Figure 18 shows bearing pressure v/s % settlement reduction for 3cm geocell and 5cm geocell as reinforcement along with soil as backfill material. It can be seen that for the same loading intensities the % settlement reduction has been found to increase for 5cm geocell as compared to 3cm geocell when used as reinforcement.

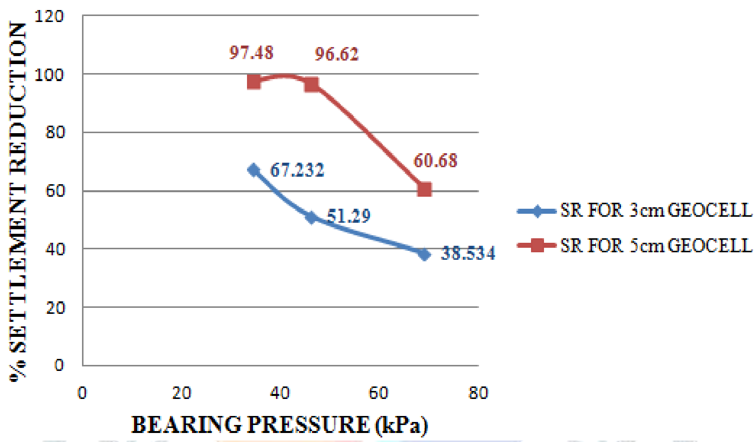

Figure 18 Bearing pressure v/s % Settlement reduction for 3cm Geocell and 5cm Geocell as reinforcement along with soil as backfill

4.2.2 Comparison of earth wall backfilled with only stabilized soil using 3% lime and 10% fly ash and reinforced earth wall backfilled with same stabilized soil and geocell as reinforcement

Figure 19 shows loading intensity v/s settlement characteristics of full surcharge footing on surface of earth and reinforced earth wall backfilled with stabilized soil using 3% lime and 10% fly ash and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcements each of height 3 cm or 5 cm were provided. It can be seen that as the loading intensity increases the settlement of full surcharge footing also increases. Initially this settlement is very low with progress of loading; the settlement characteristic is linear which afterwards turns to curvilinear with concave downwards which shows progressive settlement.

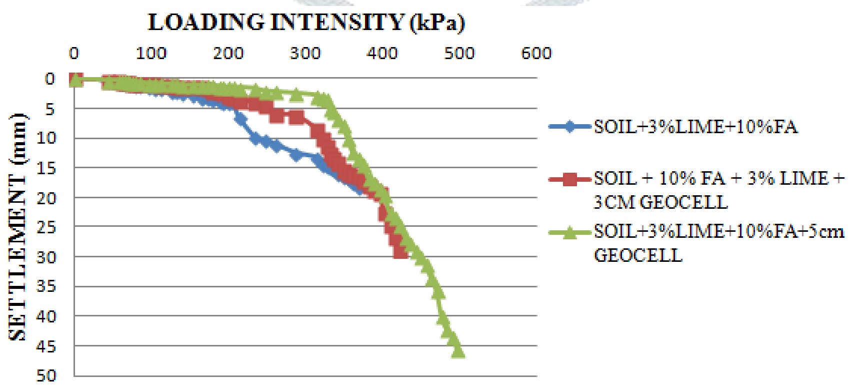

Figure 19 Load v/s Settlement characteristics of earth wall backfilled with only stabilized soil using 3% lime and 10% fly ash and reinforced earth wall backfilled with same stabilized soil along with reinforcement

Figure 20 shows bearing pressure v/s settlement reduction for stabilized backfill using 3% lime and 10% fly ash, as well as with reinforcement as 3cm geocell and 5cm geocell along with same backfill material. It can be seen that for the same loading intensity the settlement reduction has been found to increase for stabilized backfill with 5cm geocell as compared to 3cm geocell and for only stabilized backfill.

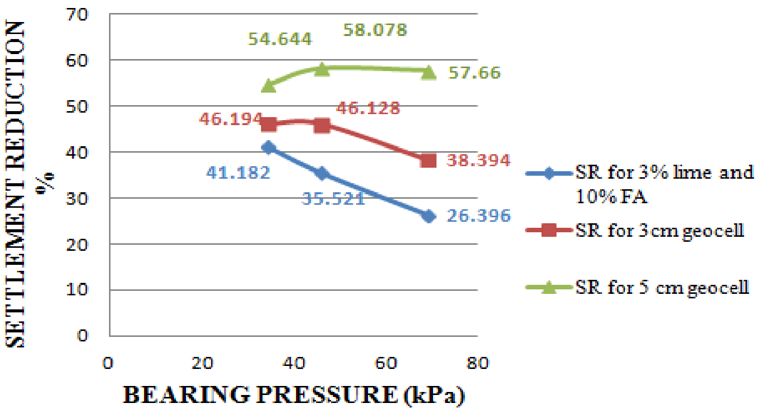

Figure 20 Bearing pressure v/s Settlement reduction for 3cm Geocell and 5cm Geocell as reinforcement along with stabilized soil using 3% lime and 10% fly ash as backfill

4.2.3 Comparison of earth wall backfilled with only stabilized soil using 3% lime and 20% fly ash and reinforced earth wall backfilled with same stabilized soil and geocell as reinforcement

Figure 21 shows loading intensity v/s settlement characteristics of full surcharge footing on surface of earth and reinforced earth wall backfilled with stabilized soil using 3% lime and 20% fly ash and reinforced soil having three reinforcing layers each at the centre of each facing. Reinforcements each of height 3 cm or 5 cm were provided. It can be seen that as the loading intensity increases the settlement of full surcharge strip also increases. Initially this settlement is very low with progress of loading, the settlement characteristic is linear which afterwards turns to almost downward straight line and further turns to curvilinear with concave downwards which shows progressive settlement.

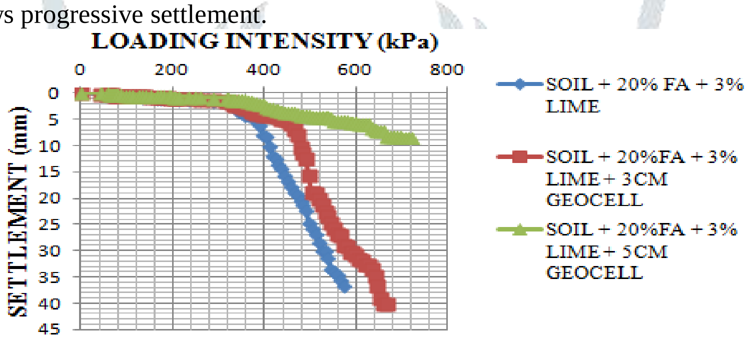

Figure 21 Load v/s Settlement characteristics of earth wall backfilled with only stabilized soil using 3% lime and 20% fly ash and reinforced earth wall backfilled with same stabilized soil along with reinforcement

Figure 22 shows bearing pressure v/s settlement reduction for stabilized backfill using 3% lime and 20% fly ash, as well as with reinforcement as 3cm geocell and 5cm geocell along with same backfill material. It can be seen that for the same loading intensity the settlement reduction has been found to increase for stabilized backfill with 5cm geocell as compared to 3cm geocell and for only stabilized backfill.

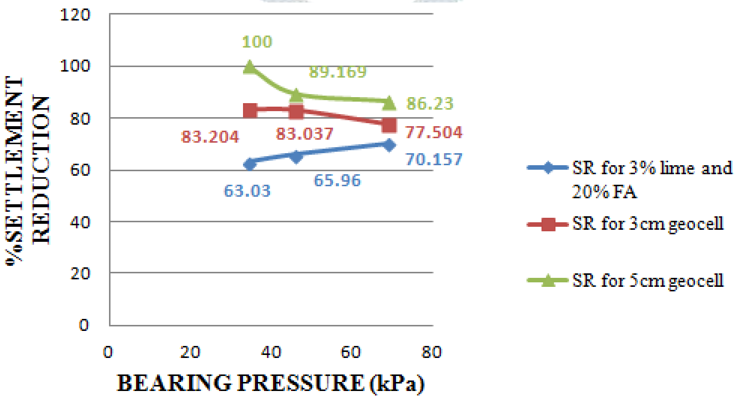

Figure 22 Bearing pressure v/s Settlement reduction for 3cm Geocell and 5cm Geocell as reinforcement along with stabilized soil using 3% lime and 20% fly ash as backfill

Figure 23 shows the loading intensity v/s settlement characteristics for all the above mentioned cases. It is clearly visible that the magnitude of settlement for the unreinforced soil was much more than that for the reinforced soil under the same loading intensity. There is reduction in the settlement through increased rigidity of geocell layer by confinement of foundation soils.

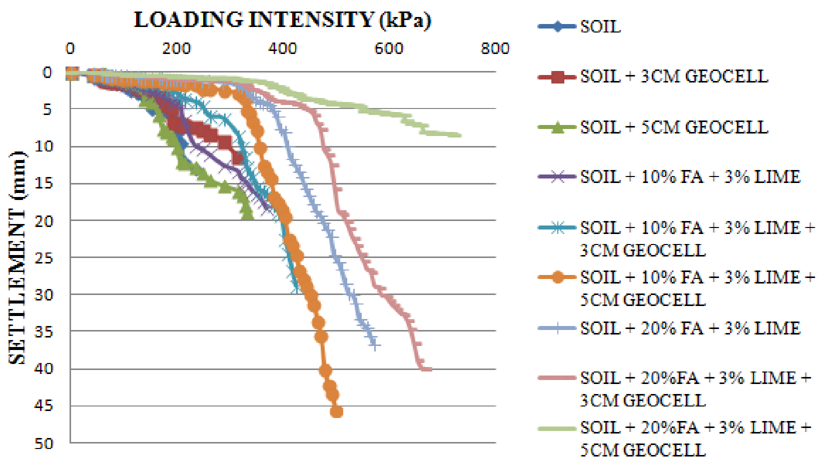

Figure 23 Loading intensity v/s settlement for earth wall, stabilized earth wall, reinforced earth wall and reinforced stabilized earth wall

Table 6 shows the ultimate bearing capacities for various combinations for full surcharge loading

Table 6 Ultimate bearing capacities for various combinations for full surcharge loading

Combinations	**Ultimate bearing capacity (kPa)**
Soil	138
Soil+3cm Geocell	188
Soil+5cm Geocell	198
Soil+3%Lime+10% Fly ash	205
Soil+3%Lime+10%Fly ash+3cm Geocell	388
Soil+3%Lime+10%Fly ash+5cm Geocell	414
Soil+3%Lime+20%Fly ash	350
Soil+3%Lime+20%Fly ash+3cm Geocell	449
Soil+3%Lime+20%Fly ash+5cm Geocell	611

4.2.4. Lateral movement of wall facing under full surcharge loading

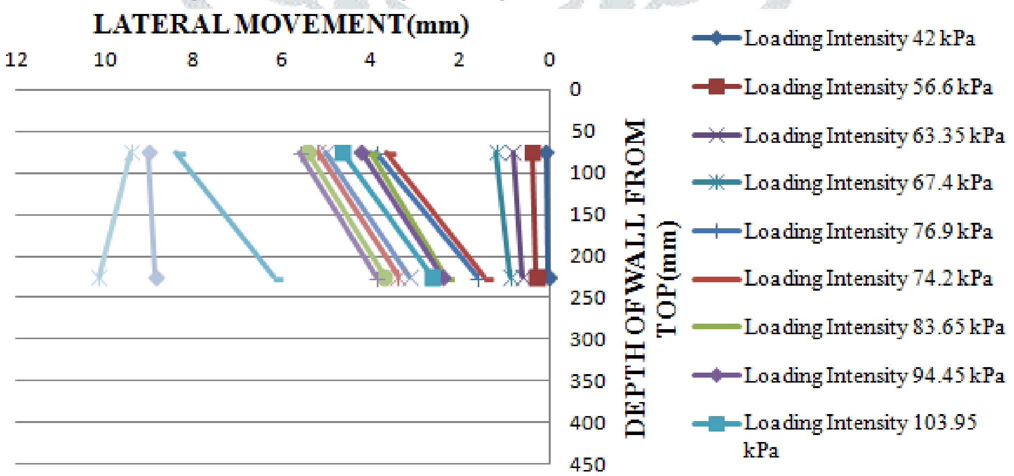

Figure 24 Depth of RE wall from its top v/s lateral movement for RE wall backfilled with only soil

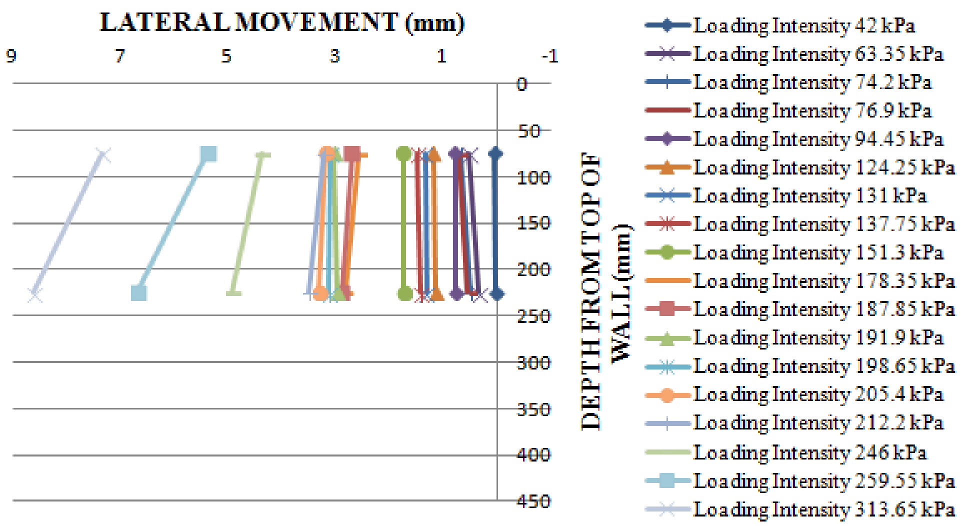

Figure 25 Depth of RE wall from top v/s Lateral movement for earth wall backfilled with soil and reinforced using 3cm geocell

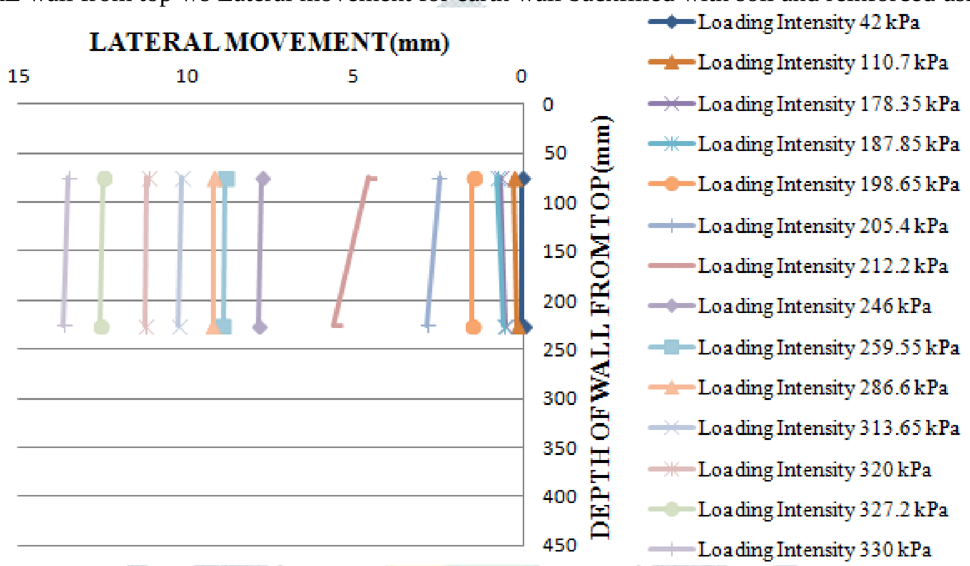

Figure 26 Depth of RE wall from top v/s Lateral movement for earth wall backfilled with soil and reinforced using 5cm geocell

V. Conclusion

- The load settlement characteristic of strip footing as well as surcharge footing is linear with increase in loading intensity.
- As the height of geocell increases the load carrying capacity increases.
- Lateral movement was more at the top as compared to the middle layer. In case of reinforced backfill this movement was found less as when compared to RE wall backfilled with only soil.
- In all the cases except RE wall backfilled with only soil, failure is due to settlement of footing and not due to rupture of the reinforcement i.e. complete R.E wall failure was not observed for those cases but the local failure due to excessive settlement of the footing on the surface of the wall was observed. Whereas for RE wall backfilled with only soil failure was observed due to falling off of the facing followed by failure wedge which means catastrophic failure.
- For RE wall tested for full surcharge failure was due to crack appearance at the top of RE wall and no damage was caused to the reinforcement.

VI. References

[1] Khushboo Vishwakarma and Vaishali Hotchandani,2018. Study of model RE wall backfilled with cohesive soil and geocell reinforcement. Challenges in Geotechnical Investigations, Analysis, Design and Construction of foundations: 94-99

[2] Dash, S.K Rajagopal K and Krishnaswamy N.R, 2001b. Strip Footing on Geocell reinforced sand bed with additional planar reinforcement. Geotextiles and geomembranes, 19(8): 529-538.

[3] S.W Thakare, Tanveer Ahmed, Performance of Footing on Clayey soil with Encased Stone Columns and Geocell Mattress International Journal of Engineering Research, vol.5, Issue special: 04-08.

[4] Gourav Dhane, Dhiraj Kumar, Akash Priyadarshee, Geocell: An Emerging Technique of soil Reinforcement in Civil Engineering field. IOSR-JMCE: 59-63.

[5] Bathurst, R. J. and Jarrett, P. M., 1988. Large-scale model tests of geocomposite mattresses over peat subgrade. Transportation Research Record, 1188: 28-36.
[6] Dash, S. 2003. Model studies on circular footing supported on geocell reinforced sand underlain by soft clay. Geotextiles and Geomembranes, 21(4): 197–219.
[7] Chowdhary Swaraj and Suman Shakti, 2014. A Review of Studies on Geocell-reinforced Foundations. Research Journal of Recent Sciences, Vol.4:24-30
[8] Koerner, R.M. and Soong, T. Y. 2001. Geosynthetic Reinforced Segmental Retaining Walls, Geotextiles and Geomembranes, 19 (2001): 359-386.
[9] Kwon, J., Tutumluer, E. and M. Kim (2009b). Development of a Mechanistic Model for Geosynthetic-Reinforced Flexible Pavements, Geosynthetics International, 12(6): 310-320.
[10] McGown, A., K.Z. Andrawes and M.M. Al-Hasani, 1978. Effect of Inclusion Properties in the Behavior of Sand. Geotechnique, Vol. 283. 327-346.
[11] Udayashankar D.Hakari, Stabilisation of Black Cotton Soils Using Fly Ash. Hubballi-Dharwad Municipal Corporation Area, Karnataka, India.
[12] S. Bhuvaneshwari, R. G. Robinson and S. R. Gandhi, "Stabilization of expansive soil using fly ash.
[13] R. Saravanan, Roopa Saira Thomas, Merlin Joseph. A Study on Soil Stabilization of Clay Soil Using Fly ash.
[14] N.Krithiga, D.Pujitha, T. Palayam and A.revathy. Soil stabilization using lime and fly ash.