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Performance of Soft Clay stabilization using GEOCELLSUNDERSHALLOWFOOTINGS

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Abstract. Geocell is a three-dimensional cellular confinement system, used to stabilize foundations by reducing settlement and increasing bearing capacity. This paper presents alaboratory study to investigate inclusion of high-density Polymer–Polyethylene geocell as a reinforcement material in soil under footing which carrying vertical loads. The actual behaviour of soil reinforced with geocell under different load conditions has been investigated in this research. It has been found that pressure-settlement characteristics are improved owing to inclusion of geocell as reinforcement system.

Keywords: Geocell, Confinement, Bearing capacity, Settlement; Strap footing, eccentric loads.

1. INTRODUCTION

Among the various techniques available for ground improvement, Soil reinforcement is one of the most popular soil reinforcement techniques. Availability of different material, ease in construction, overall economy, and less time consuming are the major reasons for the continuous increase in the application of the soil reinforcement. The behavior of this technique depends mainly on frictional resistance between reinforcement layers and surrounding soil, as reported by Salama (2014). Jayamohan (2016) reported that the beneficial effects of using different geosynthetic reinforcing materials in foundations have received considerable attention. Geocell used primarily for soil reinforcement and its benefits reported by several researchers such Chowdhury and Suman. (2015), Mandal and Gupta. (2011), Manish. (2014), Dash. (2007), and Zou and Wen. (2008).Several researchers reported the beneficial use of geo cell as reinforcement material in embankments and construction of foundations as Shimizu and Inui. (1990),Rea and Mitchell. (1978). Jenner. (1988), Krishnaswamy. (2000), Cowland and Wong. (1993), Dash. (2001) a, (2001) b, (2003) a , and (2003) b.

Laboratory models to Study the effect of inclusion of geo cell reinforcements under vertical loading on small and large-scale physical models have conducted by many researchers .Bathurst and and Jarret (1988) compared the results of large-scale model tests of geo cell and geo grid cell mattresses over soft sub grade and showed that the stiff geo cell shows a better load-settlement response . Agrawal, R. K., Prasad, A. (2007) presented an experimental study concerning on the influence of soil confinement system on bearing capacity of square footing under effect of eccentric and inclined pressure. Eccentricity width ratio becomes 0.1, 0.2 and 0.3. The results showed that with the increase in load eccentricity and load inclination, there was a reduction in ultimate bearing capacity, but this ultimate bearing capacity was found to show a remarkable improvement with footing with confinement. Sireesh. (2009) showed that geo cell mattress over clay sub grade with void can improve the performance substantially, provided that the geo cell mattress extends at least a distance equal to the diameter of void. Madhavi. (2009) investigated the performance of different types of soil reinforcement material (planar layers, geo cell, and randomly distributed mesh elements) and concluded that geo cell is the most advantageous reinforcement.Pokharel. (2010) studied parameters affecting on the behavior soil reinforced with single geo cell under static loading. He reported that performance of geo cell-reinforced sand depends on the elastic modulus of the geo cell. Dash (2010) investigated the influence of relative density of soil, he showed that for the effective utilization of geo cell reinforcement, the soil should be compacted to higher density. Moghaddas(2010) investigated the improvement in the ultimate bearing capacity of three-dimensional geotextiles and planar geotextiles and concluded that the inclusion of geocell as reinforcement system carries greater loading and much stiffer. Dash (2012) indicated that the aperture size, strength and orientation of the ribs of geocell prepared using geogrids, stiffness influence the performance of the reinforced sand foundations. Biswas (2013) concluded that the subgrade strength has important effect on the performance of geocell as reinforced foundation system.

2. Laboratory model.

The test model was designed to study the pressure-settlement behavior of soft clay soil reinforced by geo cell affected by centric and eccentric vertical loads. This model was used to verify the reinforcement capability, the influence of confinement and pattern of failure of geo cell when used to reinforce the foundation soil. The setup of the used apparatus is shown in Figure 1.Themodel test apparatus mainly consists of test tank, loading system, and measurement tools. The test tank has rectangular shape with inner dimension of 200 cm in length, 50cm in width, and 110 cm in depth. All of the faces were stiffened by steel frames. The test tank has arrangement specially fabricated movable load device for applying centric and eccentric vertical loads load to the plate.

Fig 1. Setup of the used apparatus

Footing was loaded byhand-operatedgearb0x 0f 50KNcapacity Supp0rtedagainst self-reacting frame. The pressure applied to the f00ting was measured through pre-calibrated proving ring which was placed between gearb0x and the footing with the ball bearing arrangement which provides possibility of applying centric and eccentric loads as sh0wn in Figure 2

Fig 2. Loading System installation

3. Materials Properties

3.1 Sand.

Sandproperties used in the tests are listed inTable.1.

Table.1Parameters considered for sand in testing program

P		Value
Maximum dry density. $(\gamma d)_{Max}$(KN /m^3).		19.6
Minimum dry density.$(\gamma d)_{min}$ (KN/m^3).		14.6
Specific gravity. (Gs).		2.58
Maximum void ratio.(e_{max}).		0.78
Minimum void ratio. (e_{min}).		0.32
Grain size distribution.	Uniformity coefficient. (c_u).	2.67
	Coefficient of curvature.(c_c).	0.612
	Mean grain size.	0.425
	Effective size diameter. (D_{10}).	0.18
Unified soil classification system.		SP
Internal friction angle (∅) at degree of compaction of 90%.		42.5^0

3.2 Clay Properties

There are many tests were performed in order to determine the physical properties of the clay soil used in this research such as grain size distribution, unit weight , atterberge limits ,and specific gravity. The clay properties determined by laboratory tests are listed in Table.2.

Table 2. Parameters considered for clay intesting program

Parameter.	Value.
Specific gravity. (Gs).	2.74
Liquid limit, w_L(%).	65
Plastic limit, w_P(%).	31
Plasticity index, I_P(%).	34
Bulk density, □□□kN/m^3□□	17.0±0. 1
Water content in model test, w_c(%).	48±1
Undraind shear strength, c_u□□kN/m^2□□	19
% Sand.	2.1
% Silt.	29.9
% Clay.	68
Unified soil classification system.	CH

3.3 Geocell

Geocell sections are available in various cell type and depths, and section lengths to most economically meet project requirements. In the testing program, GW20Vwere used. They are known commercially as Presto HDPEgeocell sand manufactured by Presto Products Company. The type used in this research is GW20V-75mm(3in) Depth which made of high density Polymer–Polyethylene. Table 3, show the physical properties of this geocell (as supplied by the manufacturer).

Table 3. Physical properties of geocell GW20V used in testing program

Physical property	GW20V
Form	3D cells
Color	Black
Polymer	HDPE
Density per (Kn /m²)	36.4
Cell Nominal Dimensions ±10%	
Cell Depth (mm)	75
Cell Width (mm)	259

4. Testing program.

In the experimental model testing program, the pressure was applied in different loading cases, centric and eccentric loads. The performance of soft clay soil, soft clay with sand replacement layer and soft clay with geocell as reinforcement material were investigated. The studied parameters were as follows:

1- Performance of soft clay soil without reinforcement or replacement.
2- Sand replacement layer over underlying soft clay soil.
3- Optimum length of geocell layer.
4- Performance of optimum geocell section.

The results of the model tests for the reinforced and unreinforced case were compared. Four series of tests were conducted under the variable conditions shown in Table 4.

5. Testing Procedures

The experimental model test procedure was carried out as follows:

1. The clay was placed in lifts, 50 mm thick and compacted by steel tamper (500x1480x8mm) weighted 46 kg. After every lift, the surface was scratched before placing the next lift to create interlocking between layers, and the surface of top lift was leveled.
2. The Loading system and measuring tools precisely set.
3. The load were applied by handle gear box in small increments until the footing (plate) failure.
4. Settlement at the center of the footing corresponding to each increment in load was recorded.

Table 4. Varied conditions used in testing program.

Variable / Studied parameter	eccentricity	Length of geocell layer	No.of geocell layer	No. of tests
Test Series A: Clay without replacement.	Centric , $\frac{B}{18}$, $\frac{B}{9}$, $\frac{B}{6}$ and $\frac{B}{4.5}$	Without geocell	Without geocell	5
Test Series B: Sand replacement layer over clay subgrade.	Centric , $\frac{B}{18}$, $\frac{B}{9}$, $\frac{B}{6}$ and $\frac{B}{4.5}$	Without geocell	Without geocell	5
Test Series C: Optimum Length of geocell layer.	Centric	1 cell to 9 cells	1 layers	9
Test Series D: Performance of optimum geocell section.	Centric , $\frac{B}{18}$, $\frac{B}{9}$, $\frac{B}{6}$ and $\frac{B}{4.5}$	7 cells	2 layers	5

6. Results and discussion.

In this part, results of experimental tests are presented. Pressure-settlement curves were drawn for each series of tests.

6.1. Test Series A.

Settlement of the footing on unreinforced soft clay soil was measured under vertical load with varied eccentricities as shown in test series A .This series performed as a reference tests to be compared with the corresponding reinforced cases. The pressure-settlement curve for series A is shown in Figure 3.

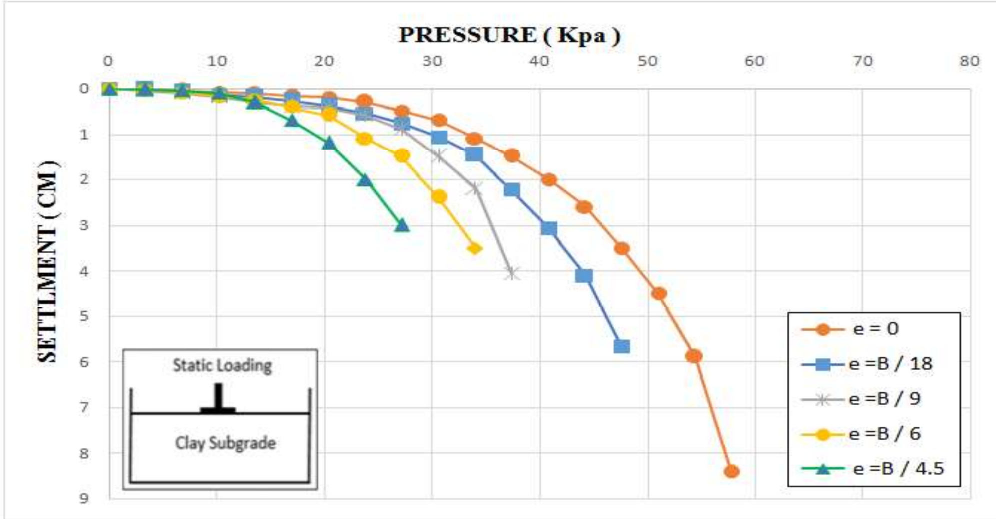

Fig3. Pressure -settlement curve for vertical load with varied eccentricities in unreinforced case.

It was 0bserved that The eccentricity has large effect 0n ultimate bearing capacity. Generaly the ultimate bearing capacity decreased as the eccenricity increased. This behavi0r may be attributed t0 the reducti0n in effictive area as eccentricity increased.

6.2. Test Series B

In this series the researcher used a sand replacement layer over soft clay and the settlementof the footing was measured from various tests as a function of the applied pressure. The pressure-settlement curve for series B shown in Figure 4.

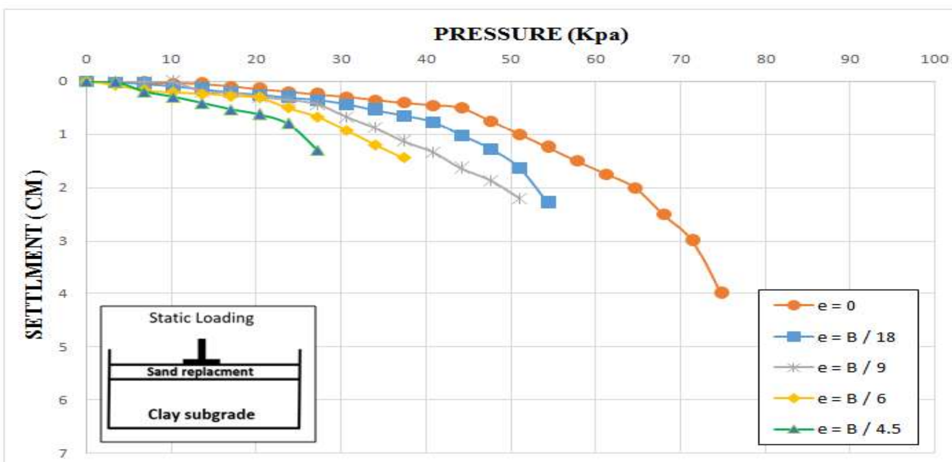

Fig 4. Pressure-settlement curve for vertical load with varied eccentricities when using sand replacement.

Figure 4 sh0ws that the eccentricity has large effect 0n ultimate bearing capacity as series A. Generaly the ultimate bearing capacity decreased as the eccenricity increased.The bearing capacity slight impr0ved when c0mparing series A with series B. This impr0vement related t0 the use 0f sand replacement layer 0n s0ft clay.

6.3. Test Series C.

The main goal of these tests are to determined optimum length of geocell mattress Tests are carried out on geocells withlength from 1 cell to 9 cells.Figure 5 shows the relation between applies pressure with settlement for geocell reinforcements with different length. The optimum length of geocell mattress is determined 7 cells. When the geocell length reaches an optimum value, the effect of improvement becomes negligible after which it does not have any considerable effect on bearing capacity and settlement of footing.

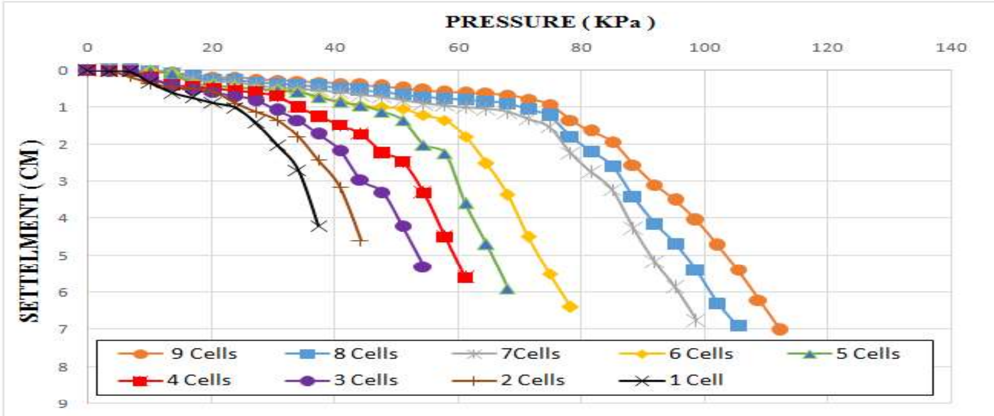

Fig 5. Optimum geocell Length.

6.4. Test Series D.

These tests were perf0rmedt0 investigateperf0rmance0f 0ptimumge0cellsecti0nt0be c0mpared with the c0rresp0ndingunreinf0rcedsecti0ns. It can be seen that ge0cellreinf0rcement significantly increases the bearing capacity and decrease settlement 0f the f00ting c0mparedt0 the unreinf0rceds0ft clay s0il.

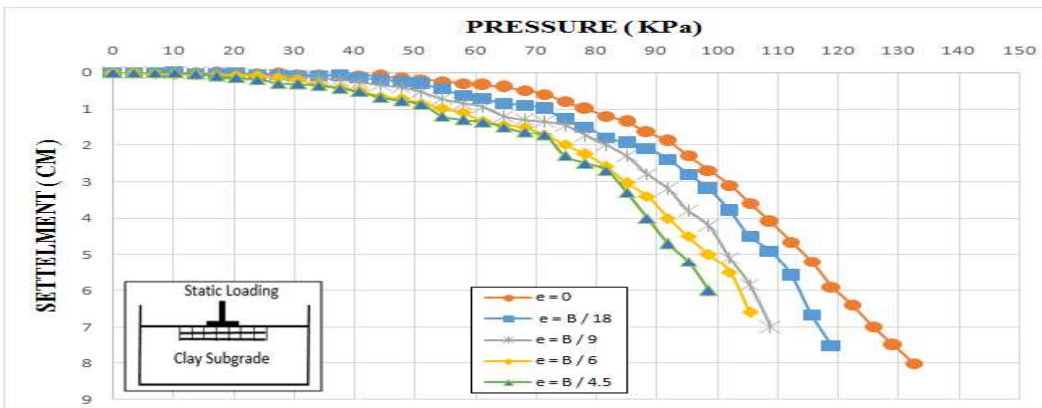

Fig 6. Pressure-Settlement curve for vertical load with varied eccentricities using GW20V.

6.5. Comparison between the reinforced and unreinforced cases with varied eccentricities

The comparison between the reinforced, sand replacement and unreinforced cases with varied eccentricities is shown in Figures 7 to 1. These figures show the behavior and enhancement of the soft clay by using geocell reinforcement.

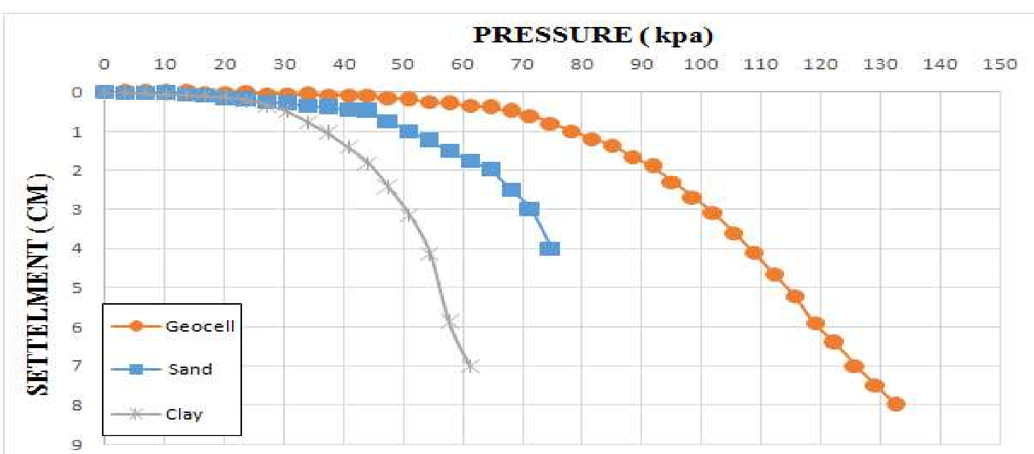

Figure 7. Pressure-Settlement curve at $e_1 = 0$ for series A, B andD.

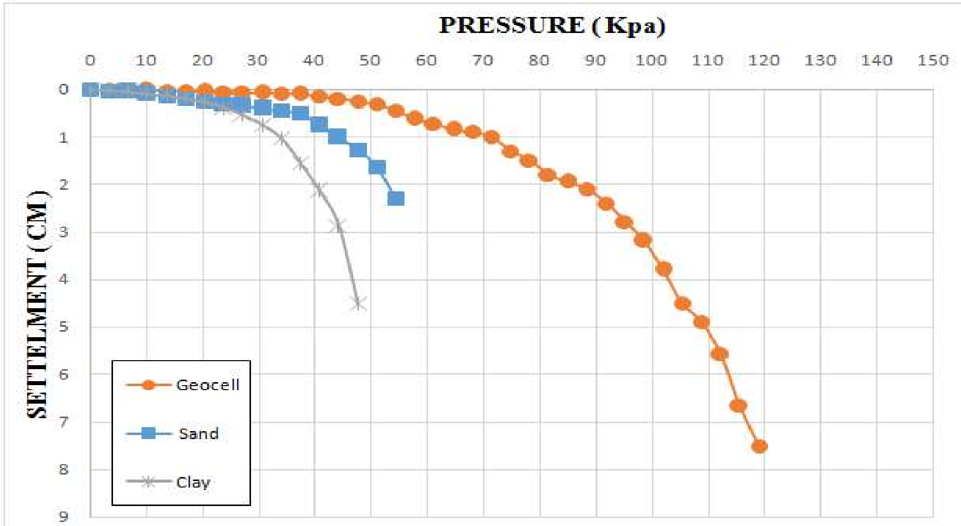

Fig 8. Pressure-Settlement curve at e_2 = B/18 for series A, B and D.

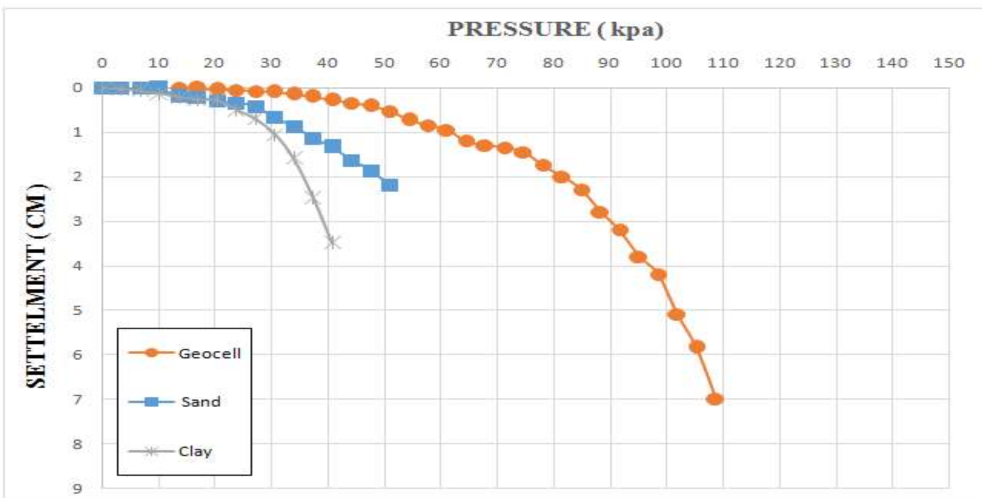

Fig 9. Pressure-Settlement curve at e_3 = B / 9 For series A, Band D

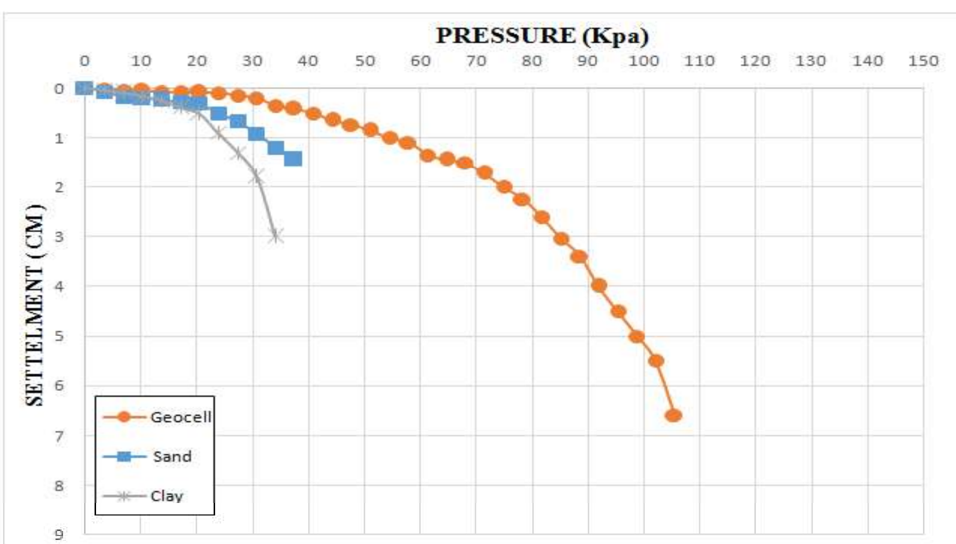

Fig 10. Pressure-settlement curve at e_4 = B / 6 For series A,B, andD

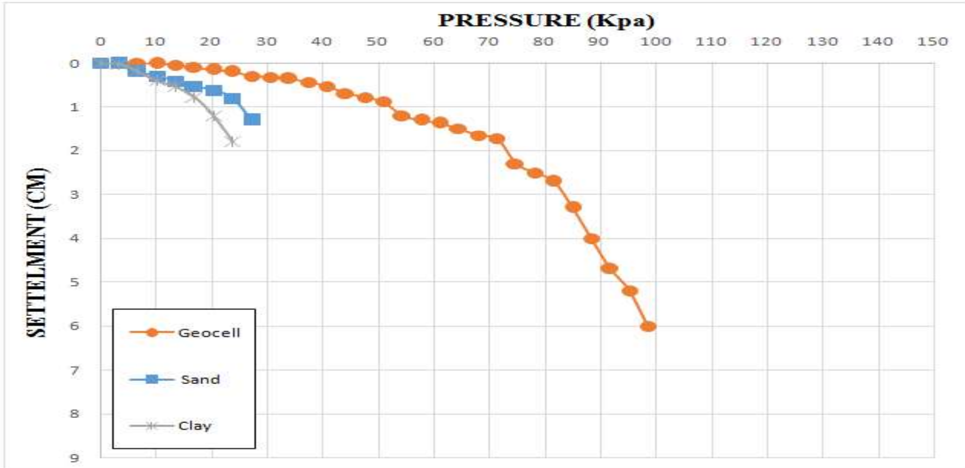

Fig 11. Pressure-settlement curve at e_5 = B / 4.5 For series A, B and D.

By comparing the Results from the previous figures, we can see that the ultimate bearing capacity 0f strap f00ting can be appreciably increased by s0ilc0nfinement under vertical, centric and eccentric pressure. It has been observed that such confinement resists the lateral displacement of soil underneath the footing leading to a significant decrease in the vertical settlement and hence improving the ultimate bearing capacity. This improvement can be attributed to the increase in the confinement effect by reinforcement which prevents the lateral spreading of soil and distributes load over a wider area .Also pressure settlement response at geocell reinforcement case much stiffer than those of the unreinforced case.

7. CONCLUSIONS

The ge0cellc0nfinement system n0t0nly increases the l0ad-bearing capacity 0f the s0il but als0 substantially reduces the settlement. This is achieved by the c0nfinement0f the failure wedges which w0uld be devel0ped in an unreinf0rceds0il fr0m laterally and 0utward displacement. Thef0ll0wing results were c0ncludedfr0m the experimental w0rkperf0rmed0n the strap f00ting secti0nab0ves0ft clay f0undati0ns0il under static l0ading:

1. The use of geocell over soft clay increased stability and improved the performance of weak subgrade soil, primarily by preventing the footing from sinking in the foundation soil. In addition, the interlocking formed between the infill soil and geocell apertures provided more strength for foundation soil.
2. This study showed that the importance of geocell inclusion appeared as pressure carrying capacity increases the settlement of soil decreases due to soil confinement.
3. The test results demonstrates that provision of geocell will distributes the footing load to wider area that results in improving the load carrying capacity of clay.
4. Comparison between Geocell reinforced clay with unreinforced clay is experimentally proved that geocell reinforced clay provide more lateral and vertical confinement.
6. Provision of geocell reinforcement in the underlying clay layer improves pressure carrying capacity and reduces surface heaving of foundation soil substantially.
7. In all cases of loading in laboratory model tests, inclusion of geocell improved bearing capacity and reduced settlement in comparison with the unreinforced case.

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