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# Behaviour of strip footing resting on sand bed reinforced with plastic bottle geocells

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**ABSTRACT**

*For long different methods have been used for enhancing bearing capacity of soil. This study aims at providing an economic and efficient method of reinforcement for sand by using waste plastic bottle geocells in sand as reinforcement. Attempts were made for observing strip footing behaviour emplaced on sand bed and in which emplacement of geocell made from waste bottles of plastic is done. Various parameters namely, geocell heights, geocell emplacement depth beneath the footing, vertical distance of second geocell from single geocell. Results indicated that enhancement was noticed by incorporation of geocells. Also, using different heights had positive effects but beyond h/B=0.1, not much effect was observed. When geocell was emplaced at u/B=0.25, a rise is seen in ultimate bearing capacity. Beyond u/B=0.25, there is downfall noticed in ultimate bearing capacity. Also, when second geocell was emplaced at v/B=0.25, a rise is seen in ultimate bearing capacity. Beyond v/B=0.25, there is downfall noticed in ultimate bearing capacity*

## 1. Introduction

The biggest problem faced by the human race in the present era is dealing with the waste materials being generated at an alarming rate. Due to its production at an alarming rate, it has become headache for mankind. The major waste material being used is waste plastic bottles. Their disposal is such a huge mess that it has become very difficult to find a solution. Different techniques are being used for finding a solution. The present study aims to provide a solution for this problem by using waste bottles of plastic for making geocells which are emplaced in sand. Strip footing behaviour is closely seen in this study by putting geocells of waste bottles in the sand. Geocells are confining materials which are three dimensional structures in the form of a web.

Different experimental inspections have been performed by researchers for improving sand performance, Dash et al. (2001) observed the effects on the bearing capacity of strip footing emplaced on sand bed by addition of geocell reinforcement. Investigation of efficiency of the geocell as a reinforcement was done. Great effects were witnessed by emplacement of geocell as displacement reduced drastically. Cicek et al. (2015) performed the experimental investigation to study the impact of reinforcement length on sand characteristics. The rise in length resulted in improvement of bearing capacity due to larger area for transmitting load. Dutta and Mandal (2016) observed the impact and effectiveness of geocell mattress made of waste plastic bottles as reinforcement with flue ash as an infill material which was emplaced the soft clay. Due to cellular confinement, improvement was reported by addition of geocell. Kargar and Hosseini (2016) studied the impact of the stiffness and strength of the geocell emplaced in the sand. Positive effects were seen by emplacement of geocell.

The present study aims at providing an easily assessable, cheap and effective material for reinforcing the sand and making it suitable for use. Also, the use of geocells as reinforcement materials is also encouraged by means of this study. Moreover, this study aims at providing a solution for both environmental as well as geotechnical problem.

## 2. Testing materials

### *2.1 Sand*

Dry density having an average value of 16.04kN/m$^3$ was achieved when sand was poured from a height of 60cm. This height was fixed after completion of trials where sand was poured in a container. Geotechnical properties of sand are mentioned below:-

Table-1
Geotechnical properties of sand.

| S.No. | Property | Value |
|---|---|---|
| 1 | UCS Classification | SP( poorly graded sand) |
| 2 | Coefficient of uniformity ( $C_u$ ) | 1.90 |
| 3 | Coefficient of curvature ( $C_c$ ) | 1.17 |
| 4 | Effective Grain Size, $D_{10}$ (mm) | 0.11 |
| 5 | $D_{30}$ (mm) | 0.165 |
| 6 | $D_{60}$ (mm) | 0.21 |
| 7 | Maximum Dry Density | 17.97 kN/m$^3$ |
| 8 | Minimum Dry Density | 13.40 kN/m$^3$ |
| 9 | Relative Density | 64.6 % |
| 10 | Specific Gravity | 2.66 |

Fig.1 showcases the particle size distribution curve and Fig.2 showcases the dry density when sand was poured from multiple heights and Fig. 3 showcases the relative density when sand is poured from varying heights.

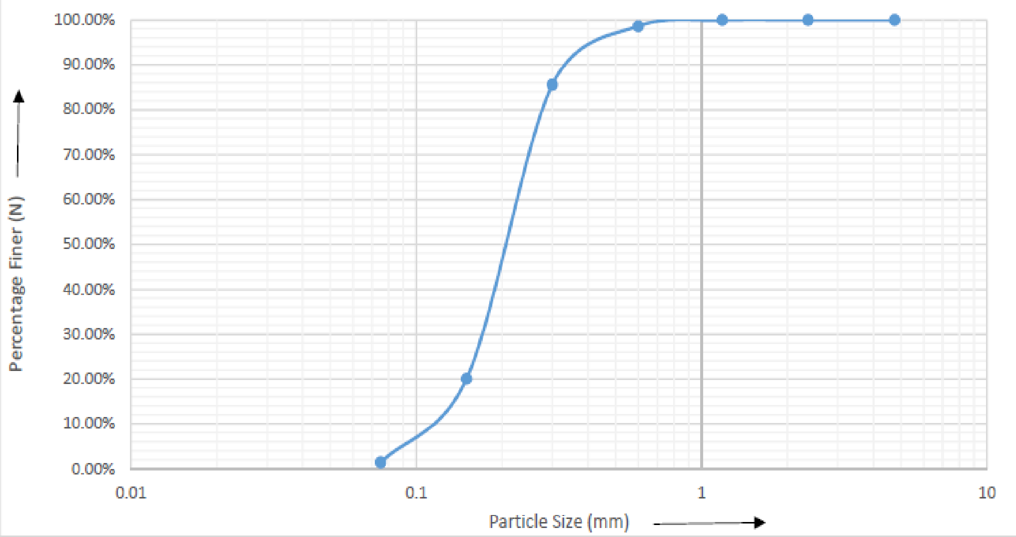


Fig. 1 Particle Size Distribution Curve.

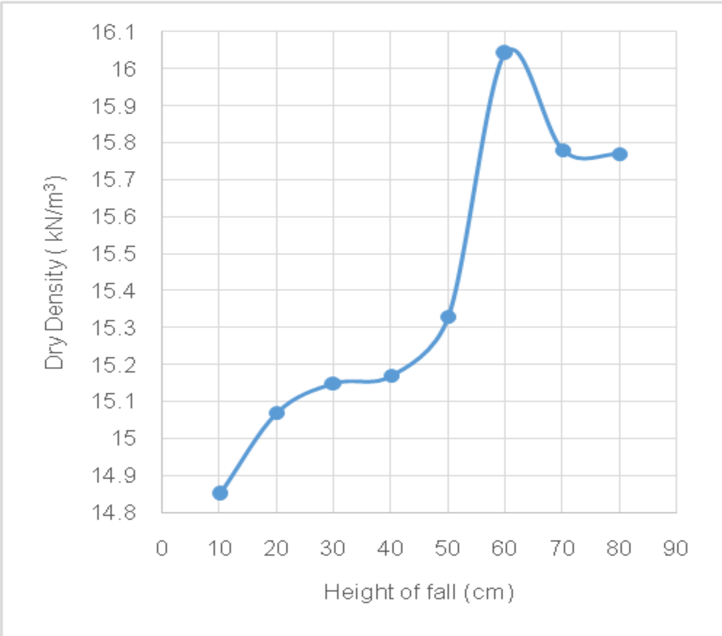


Fig. 2 Dry density when sand is poured from multiple heights.

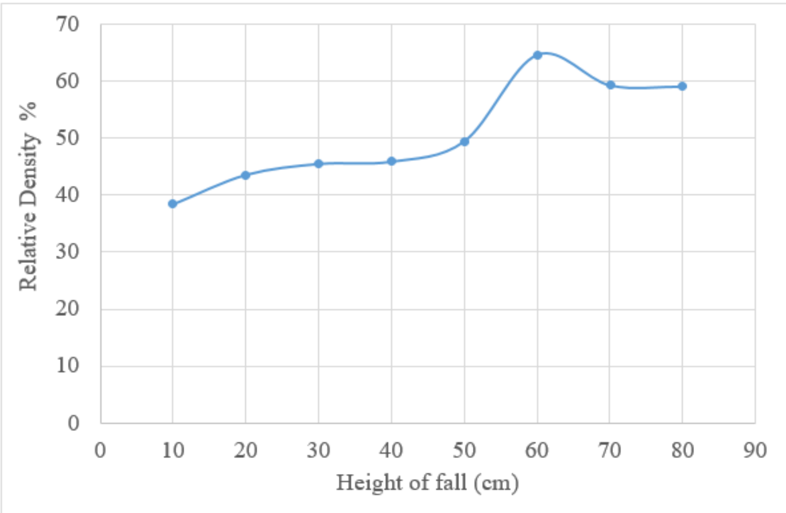


Fig. 3 Relative density when sand is poured from varying heights.

 

### *2.2 Geocells*

Geocells made from waste plastic bottles were used in this study. Plastic bottles were cut into cells of different heights. The plastic cells were having a diameter of 60mm. These cells were joined with the help of nylon 66 ties.

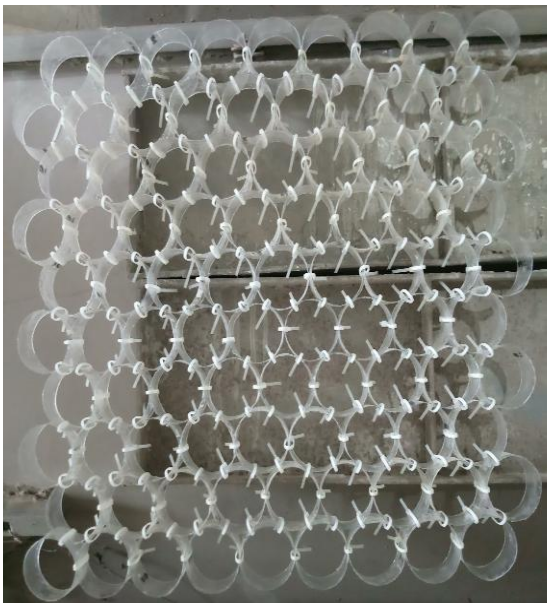

Fig. 4 Geocell made of waste plastic bottles.

## 3. Methodology

### *3.1 Testing setup*

The testing box was rectangular in shape having measurements of 1.5m length, 0.6m width and 0.8m height. It was braced properly to avoid bulging due to load application. Transparent perspex sheet was used for making longitudinal walls of test box for observing failure of sand. Strip footing having dimensions of 598mm length, 100 mm width and 25 mm thickness was used. Gap of 1mm was kept between the sides of box and the footing for maintaining plain strain conditions. Load application was done by manual hydraulic jack of 750kN capacity. The capacity of load cell employed for measuring the loads was 300kN. Two dial gauges were used for displacement measurement of footing.

### *3.2 Preparation of sand beds*

Sand bed preparation in testing box was done by sand rainfall technique. For this, sand was poured from different heights and the height which had the maximum value of dry density was fixed as the height from which sand will be poured throughout the testing. Maximum value of dry density of 16.04kN/m$^3$ was achieved at a height of 60cm having relative density of 64.6%. Mechanical hopper was used for preparation of sand beds in large testing box. Preparation of sand bed was done with the layers of thickness 4cm after which the sand layer was levelled. By following this procedure, relative density of 64±2% was accomplished.

Fig. 5 Model plate load test being done.

### *3.3 Parameters varied for testing*

The present study consists of 13 tests which were performed for carrying out the experimental investigations. The different parameters varied are mentioned below in tabular form. Representation of testing is showcased in Fig. 6.

**Table-2**
**Varied parameters for testing.**

| Tests Performed | Constant Parameters | Parameters Varied | No. Of Tests Performed |
|---|---|---|---|
| Unreinforced | - | - | 1 |
| Sand reinforced with single geocell layer. | u/B= 0.5, d/B= 0.6, b/B=5.53,ID=64.6% | h/B= 0.1, 0.2, 0.3, 0.4 | 4 |
| Sand reinforced with single geocell layer. | h/B= 0.1, d/B= 0.6, b/B=5.53,ID=64.6% | u/B= 0.25, 0.5, 0.75, 1.0 | 4 |
| Sand reinforced with two geocell layers. | h/B= 0.1, d/B= 0.6, b/B=5.53,ID=64.6% | v/B= 0.25, 0.5, 0.75, 1.0 | 4 |

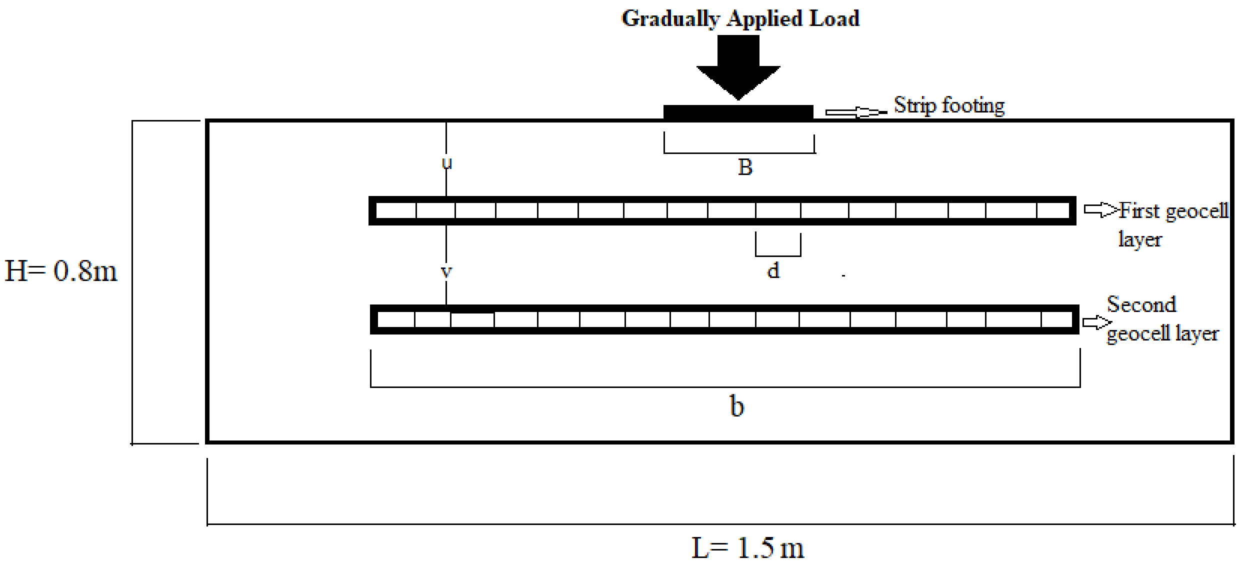


Fig. 6 Representation of testing.

## 4. Results and Discussions

Total 13 laboratory tests were performed in the experimental investigation. Loads were varied gradually and applied on the centre of footing. The first test series consisted of varying the height of geocell and is displayed below in Fig. 7

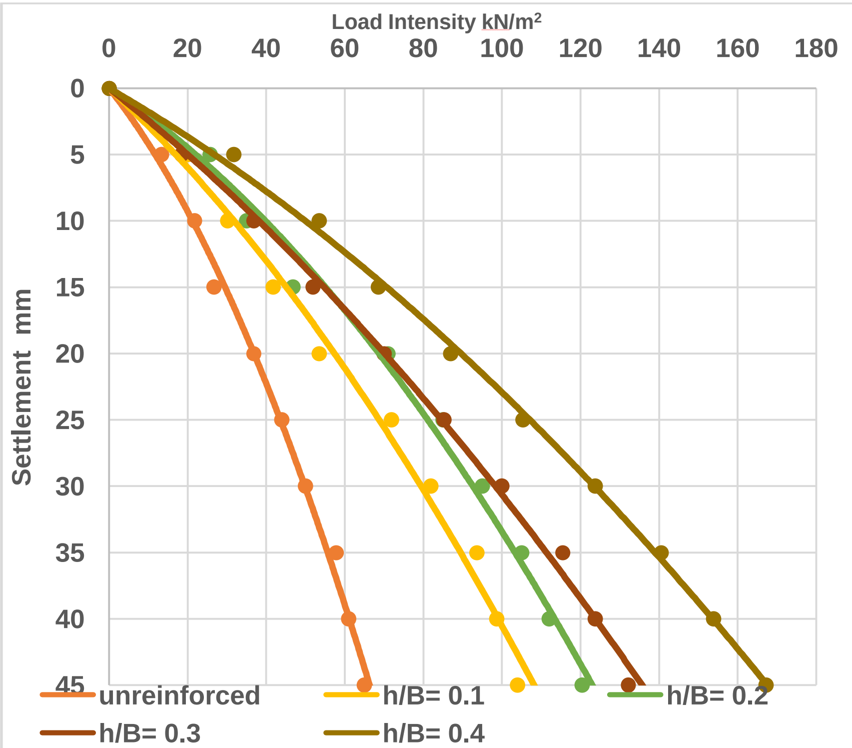


Fig. 7 Impact of varying heights for geocell.

Change in heights of geocell shows rise in ultimate bearing capacity. As greater height for geocell is selected, ultimate bearing capacity for sand rises. This is due to the presence of larger are for the expansion of pressures generated in sand due to load application. Cellular confinement also becomes greater with rise in height. But beyond h/B=0.1, this rise becomes marginal.

Second test series consisted of impact of changing depths for emplacement of geocell and is displayed in Fig. 8 below.

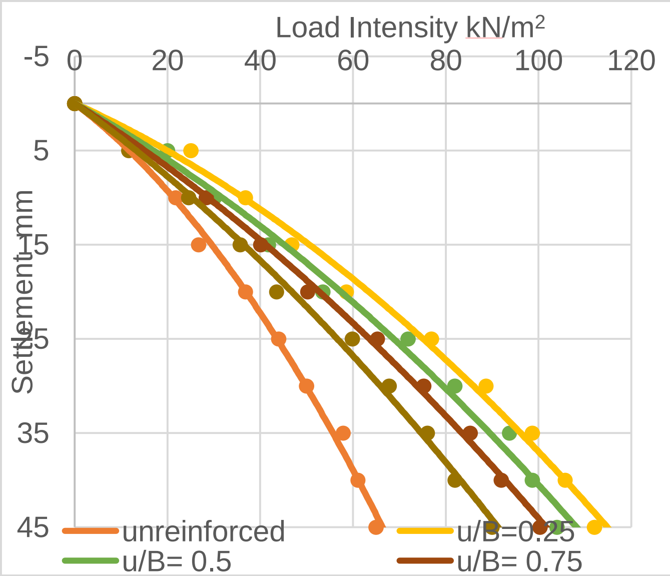

Fig. 8 Impact of changing depths for emplacement of geocell.

When emplacement of geocell is done at lower depth, a fall is seen in ultimate bearing capacity. This can be due to the fact that at lower depth, the effect of load becomes small. Also, at a greater depth, geocell is emplaced away from zone of influence of the load. Greatest impact is seen when the depth for emplacement of geocell is u/B=0.25.

Third test series shows the impact when vertical distance (v/B) of second geocell layer is varied beneath first layer (u/B) and is showcased in the Fig. 9 below.

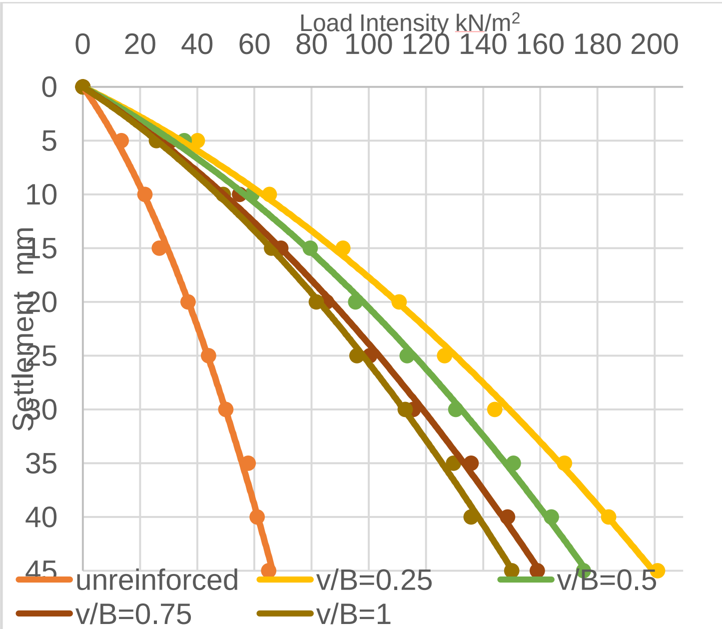

Fig. 9 Impact when vertical distance (v/B) of second geocell layer is varied.

When emplacement depth for second geocell is changed, a great rise is seen in ultimate bearing capacity for v/B=0.25. This is due to increase in area for distribution of load due to emplacement of second geocell. Beyond v/B=0.25, it is seen that as the emplacement of second geocell is done at a greater depth, there is a fall in ultimate bearing capacity. This is attributed to the fact that at greater depth, impact of load is small as it is away from zone of influence of load.

**5. Conclusions**

Total 13 tests were performed for studying the behaviour of strip footing after emplacement of geocells made from waste bottles. The conclusions from the tests are mentioned below:-

1. As the height goes beyond h=0.1B, ultimate bearing capacity rise is marginal. The relative rise in ultimate bearing capacity for h/B= 0.1 is 65.5%, for h/B= 0.2 is 8.46%, for h/B= 0.3 is 13.75% and for h/B= 0.4 is 7.28%. So, it is clear that h=0.1B is the optimum height for geocell.
2. As the depth for emplacement of geocell goes beyond u/B=0.25, ultimate bearing capacity decreases considerably. The relative rise in ultimate bearing capacity for u/B= 0.25 is 74.85%, for u/B= 0.5 is 65.5%, for u/B= 0.75 is 35.1% and for u/B= 1.0

 

is 35.1%. So, it is clear that u/B=0.25 is the optimum depth for geocell.

3. As the depth for emplacement of second geocell goes beyond v/B=0.25, ultimate bearing capacity decreases considerably. The relative rise in ultimate bearing capacity for v/B= 0.25 is 161.40%, for v/B= 0.5 is 140.30%, for v/B= 0.75 is 121.60% and for v/B= 1.0 is 112.3%. So, it is clear that v/B=0.25 is the optimum depth for geocell.

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