Effects of Utilization of Waste Plastic Bottles Cell on CBR Values of Poor Cohesive Subgrade Soil

Barsha Supriya and Siddharth G. Shah

February 27, 2023

Proceedings of Eighth Indian Young
Geotechnical Engineers Conference 2021,
October 21-23, 2021

Effects of utilization of waste plastic bottles cell on CBR values of poor cohesive subgrade soil (MU Rajkot 2021)

Barsha Supriya [1], Siddharth G. Shah[0000-0003-4021-4153]

[1]Department of Civil Engineering, Post Graduate Student,Geotechnical Engineering, Marwadi University, Rajkot- 360003, Gujrat, India, E-mail address: supriyabarsha2014@gmail.com

[2]Department of Civil Engineering, Professor & Head, PG Programs, Marwadi University, Rajkot-360003, Gujarat, India, E-mail address: siddharth.shah@marwadieducation.edu.in

Abstract: India is developing with an increase in traffic but more than 20 % of the soil has less California Bearing Ratio (CBR) value which is not able to bear the proposed traffic load. On other hand sustainable development is the need of the day where waste utilization is essential. Thus, to improve the engineering properties of soil utilization of such waste is the need of the day. Furthermore, the use of plastic beverages and food items has increased exponentially and the packaging material used for all of these items is polyethylene which has the same material properties as geosynthetics. Anticipating the current circumstances of lifestyle complete prescription on the High density polyethylene (HDPE) and Low density polyethylene (LDPE) plastic waste i.e polyethylene cannot be put, albeit these hazardous wastes taking the face of the devil for the existing and subsequent generation. Subsequently, in the existing exploration, an endeavor has been made to demonstrate the potential of claim-backed Polyethylene terephthalate (PET) waste plastic bottles as geocell soil reinforcement for improving the subgrade soils inappropriate ways. Geocell derived from waste plastic bottles are accommodated at top, 1cm, 2cm and 3cm profundity individually. CBR tests are carried out by utilizing aggregates as infill in a mat. The Test results show that the CBR value of soil was escalated by with inclusion of PET bottle mat geocell with aggregate as infill material. Further, as the depth increases it doesn't show any significant changes but the top placement shows better improvement than the middle and bottom positions. Therefore, plastic waste bottles are effective in improving the CBR values of the soft-cohesive soil subgrade.

Keywords: Black cotton soil , Sand, Wasted plastic PET bottle cell, CBR, subgrade, soft soil

Paper No: 250
Theme : Transportation Geotechnics

1. Introduction

In today's era, plastic containers made primarily of HDPE and LDPE are increasingly used to store, promote, and market many processed foods and beverages. Most of this packaging is mainly for one-time use, has a short shelf life, and is discarded, immediately after use; However, in many places, HDPE and LDPE are collected for reuse or recycling; the secondary market for HDPE and LDPE is no longer developed as a trade-in program. Therefore, the amount of HDPE and LDPE currently being reused or modified is better than a small part of the total annual production, and the rest is either dumped in landfills or randomly discarded on the ground. Some plastic waste cannot be decomposed, while others take 450 years to decompose, which can cause major problems in the disposal and disposal of solid waste, which can lead to environmental problems.

Waste management is an urgent issue in the modern world. Among all types of plastics, the production of PET products is growing rapidly worldwide. Their consumption of landfill will increase the pollution of the plastic industry to the environment. Due to its "disposable culture", plastic waste is currently regarded as an environmental and ecological risk. Eliminating plastic waste without biological hazards exacerbates the real problems of the existing environment. People don't know the benefits of recycling, which is the most economically useful plastic. Therefore, used PET bottles are an economical and reasonable solution to some civil engineering problems related to the lack of acceptable high-quality soil for road construction, canal lining, slope protection, and the growth of plants and vegetation.

2. Literature Review

Husna Humayoon, Binil Gopinat (2016) used waste plastic mats to replace geocells of different thicknesses in the CBR experimental device and found that the value of CBR increased to a certain depth. Successfully used, the use of sand can increase the strength of the soil with low resistance. Siddharth Shah, Yogesh Alwani and Morvin N. Solanki (2018-2019) Compared with the reference standards of CBR and Plate load test, the results of samples based entirely on geocells appear pale, indicating that the use of geocells in plastic trash bottles to repair potholes increases the load-bearing capacity. The capacity and strength provided during greater repairs and the CBR increased by 21%. Datta and Mandal (2016) used computer hardware to perform laboratory compression tests on various composite cells wrapped in jute geotextiles to prevent fine fillers such as fly ash and angular aggregates from leaking from the holes. Provide strong evidence/minimum at a constant displacement rate of 1.2 mm/min. The test results confirmed the high load-bearing capacity of the fly ash composite cell. Studies have shown that correctly filled plastic bottles can be used as excellent extruders.

A.K. Choudhary, J.N Jha, and K.S. Gill (2010) studied the performance of CBR behavior with the aid of different proportions of plastic strips with the floor was increased by three times compared with the unreinforced floor. Peddaiah, A. Burman, S. Sreedeep (2018) According to research, the strip size (15mm * 9.15mm) can improve the performance of silt with a plastic content of 0.4%. Sanat K Pokharel, Meisam Norouzi, Ian Martin, and Marc Breault (2016) The modulus and strength of the reinforced composite and toughness of the heavy volume traffic road construction by definitely lessening the necessary amount of total aggregate material make it more cost-effective with the use of Geocell as a reinforcing material. K Rajagopal, A. Veeragavan, and S. Chandramouli (2012) had a research report that analyzes asphalt pavement structures the improvement of the resistance and stiffness of the base layer in the flexible pavement reinforced by using geocells. A. Emersleben (2008) There was an improvement in the bearing capacity of gravel bases in avenue structures utilizing geocell at the building site and therefore increasing the stiffness and behavior of the soil under loading and deformation. S.K. Pokharel, J. Han, R.L. Parsons, and Y. Qian, D. Leshchinsky, and I. Halahmi (2009) conducted pressure tests on laboratory plates to analyze the performance of geocells: constructed under static and repeated loads with sand and quarry debris from the Kansas River as a filling material. The test result shows that the application of a single geocell can increase the load-sustaining capacity, stiffness, and percentage of elastic deformation per cycle, and reduce permanent deformation. Sireesh Saride, M. ASCE, Suraj Vedpathak, S.M. ASCE, Vijay Rayabharapu and S.M. ASCE (2014) A large-scale plate load test sequence was performed on the jute geocell reinforced sand of small roads to verify elastic behavior and found that CPD improves performance in terms of mileage, TBR, overall plastic deformation and is better suited to weaker floor areas than to harder floors. Compared with the unreinforced subterranean soil, the settlement ratio is reduced due to the increased degree of reinforcement.

3. Objective of Study

The broad objectives of the present investigation are firstly, to assess the strength of the soft grade soil with/without PET squanders as a geosynthetic stabilization by experimental investigations. Secondly, To determine the optimum depth of PET bottle cellular mat lying regarding max CBR value.

4. Materials

4. 1 PET Squander Bottles for Geocell

In this study, 250 ml of disposed PET containers/bottles of the same brand utilized for soft drinks are cut into the required shape of diameter 55mm and height of 55mm of an aspect ratio of 1. Then they are punctured with the assistance of a heating rod having a width of 10 mm (perforation was made at 10mm c//c dispersing). Further, it was stitched together to form mat-like structure as in **Fig. 1(a-d).**

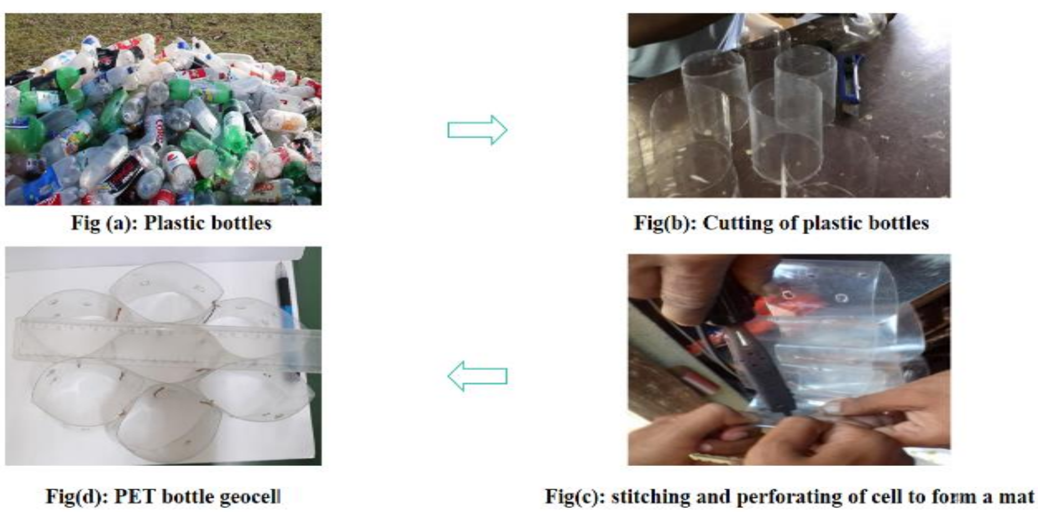

Fig. 1(a-d). Manufacturing of PET bottle cell

4. 2 Black Cotton Soil

The black/regur cotton soil wielding in this investigation was collected from a site at the Marwadi University in Gujarat, India. The properties of which are presented in **table. 1.**

4. 3 Infill material

Since our main concern was to improve the load-carrying capacity and find the effectiveness of the geocell in the soft black cotton soil, the aggregate passing through 20mm sieve and sand passing through 4.75mm sieve were selected as filler material as they can withstand the greatest amount of compressive strength and provide the good result. From the old literature, the infill aggregates are selected. The specific reason behind selecting the aggregates of particle size range limited to 4.75mm to 20mm size is that to get a better density and good interlock of the confined aggregate within the geocell.

5. Test Setup

Laboratory California bearing ratio tests were conducted at the geotechnical laboratory at the Department of Civil Engineering at the Marwadi University, Rajkot. The test was performed on samples of plastic bottle mat at different depths of CBR mould. Altogether five CBR Tests were done on the cohesive soil along with the PET bottle mattress accommodated at a different height from the top of aspect ratio 1. The PET cell mattress was filled with an infill material i.e aggregate and sand passing through IS Sieve 20 mm and 4.75 mm respectively. Separate tests were performed on seven PET cells (each with a diameter of 55 mm and a height of 55 mm) to form a mat with a depth of about Top, 1 cm, 2 cm, and 3 cm from the top.

Fig. 2. PET bottle cell with infill material installation in CBR mould. **Fig. 3.** California Bearing Ratio Test Set up.

6. Result and Discussion

Table. 1. Engineering properties of Virgin Black cotton soil.

Test	**Result**
Specific gravity	2.415
Classification	CH
Liquid Limit	77 %
Plastic Limit	37.18 %
Plasticity Index	39.81 %
Optimum Moisture Content	23.94 %
Maximum Dry Density	1.51 gm/cc
CBR	1.824

A Typical Load-settlement response of the waste PET bottles cells-geocell reinforced cohesive black cotton soil under CBR Test is shown in Figures . It can be observed that the effect of laying depth was studied by keeping the dimension and the infill parameter of PET cell as a constant. The virgin soil specimen is accommodated with PET mattress of aspect ratio 1 at various laying depth (i.e Top, 1cm, 2cm and 3cm). The CBR Test is performed on all these alternative aspects and the test analysis are shown below. **Figs 5, 6, 7,** and **8** show the load Vs settlement antiphon of cells compacted with stone aggregates and sand.

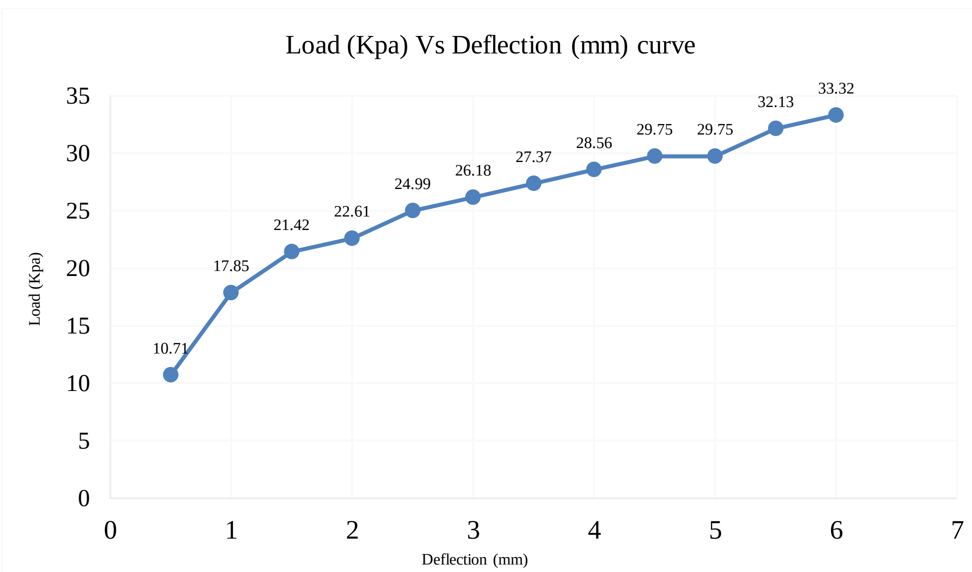

Fig. 4. Load vs Deflection Curve of Unreinforced BCS

Calculation

CBR rate at 2.5mm = $\frac{\text{Corrected load at 2.5 mm}}{\text{Standard Stone load at 2.5}}$* 100 = $\frac{24.99}{1370}$ * 100 = 1.824

CBR rate at 5.0mm = $\frac{\text{Corrected load at 5.0 mm}}{\text{Standard Stone load at 5.0}}$* 100 = $\frac{29.75}{2055}$ *100 = 1.44

As CBR test value (2.5mm) > CBR test value (5.0mm) . Hence, the CBR test analysis for saturated state of this virgin soil specimen is 1.824.

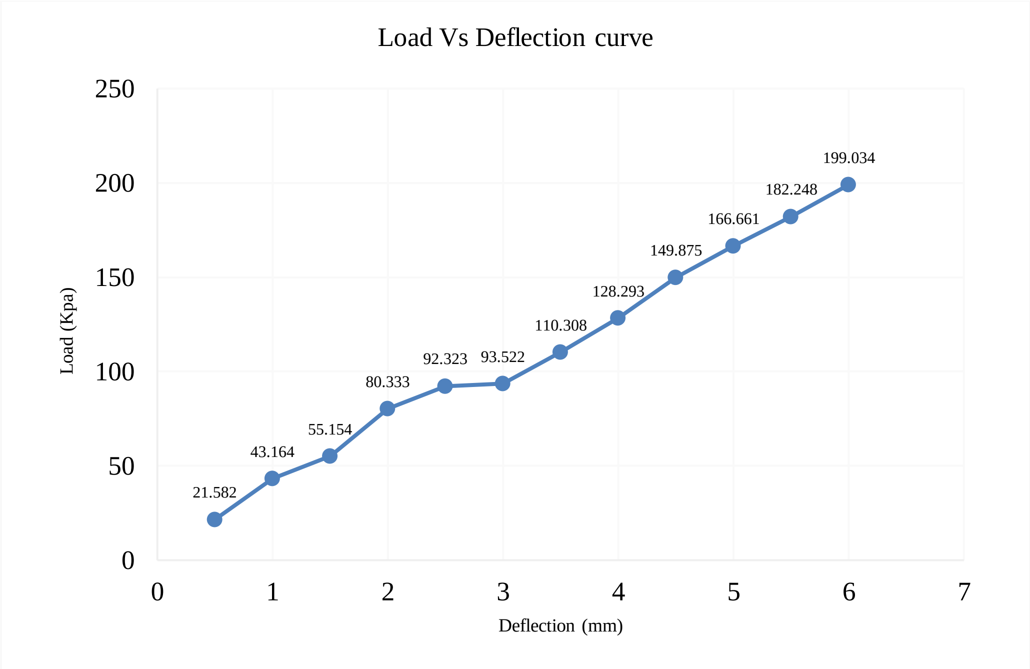

Fig. 5. Load vs Deflection Curve of reinforced BCS with PET mat at Top Surface of mould.

CBR at 2.5 mm =$\frac{Corrected\ Load\ at\ 2.5\ mm}{Standard\ Load\ at\ 2.5\ mm}$*100 = $\frac{92.323}{1370}$ * 100 = 6.738 %

CBR at 5.0 mm=$\frac{Corrected\ Load\ at\ 5.0\ mm}{Standard\ Load\ at\ 5.0\ mm}$*100 = $\frac{166.661}{2055}$ * 100 = 8.110 %

As CBR (5.0) mm is pronounced compared to CBR (2.5) mm. So, that the CBR test value of a soil along with PET mat is 8.110 %.

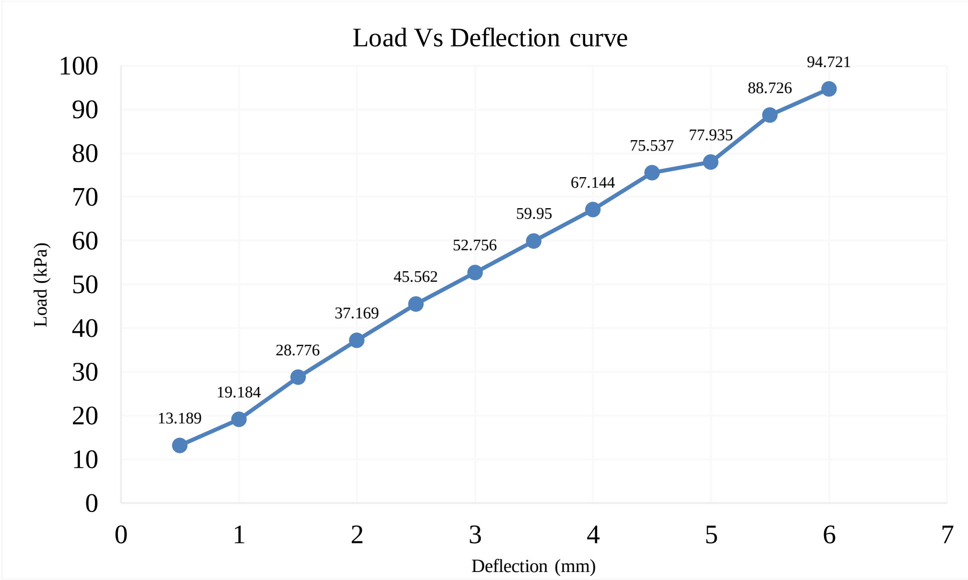

Fig. 6. Load vs Deflection Curve of reinforced BCS with PET mat at 1cm depth from Top Surface of mould.

Calculation

CBR at 2.5mm = $\frac{\text{Corrected Load at 2.5 mm}}{\text{Standard Load at 2.5 mm}}$ *100 = $\frac{45.562}{1370}$ * 100 = 3.3256 %

CBR at 5.0 mm = $\frac{\text{Corrected Load at 5.0 mm}}{\text{Standard Load at 5.0 mm}}$ * 100 = $\frac{77.935}{2055}$ * 100 = 3.792 %

As CBR (5.0) mm is greater compared to CBR (2.5) mm. So, that the CBR value of a soil along with PET mat at 1cm depth from top is 3.792 %.

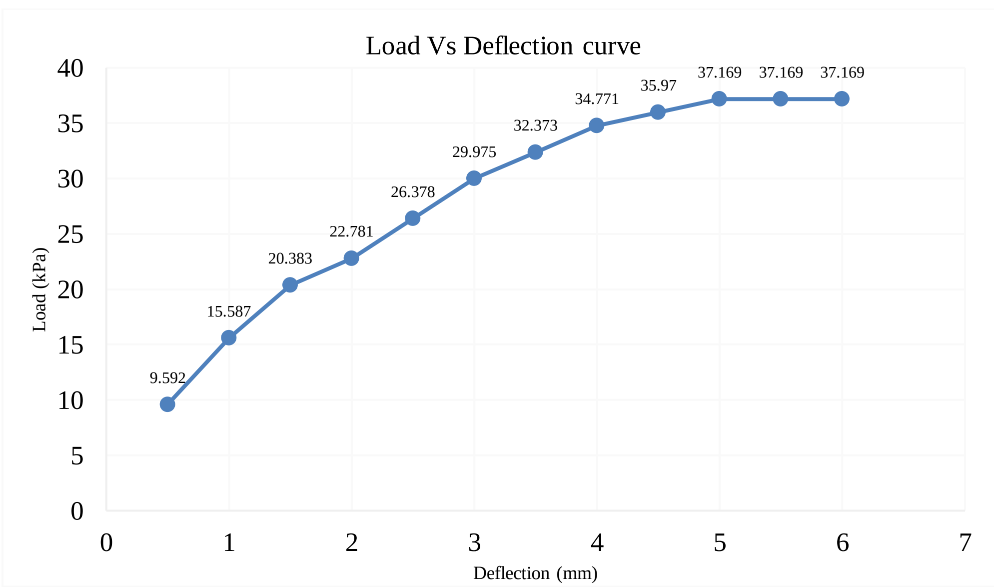

Fig. 7. Load vs Deflection Curve of reinforced BCS with PET mat at 2cm depth from Top Surface of mould.

Calculation

CBR at 2.5 mm = $\frac{Corrected\ Load\ at\ 2.5\ mm}{Standard\ Load\ at\ 2.5\ mm}$ * 100 = $\frac{26.378}{1370}$ * 100 = 1.925 %

CBR at 5.0 mm = $\frac{Corrected\ Load\ at\ 5.0\ mm}{Standard\ Load\ at\ 5.0\ mm}$ * 100 = $\frac{37.169}{2055}$ * 100 = 1.808 %

As CBR (2.5) mm is pronounced than CBR (5.0) mm. So, that the CBR test result of a soil along with PET mat at 2cm depth from top is 1.925 %.

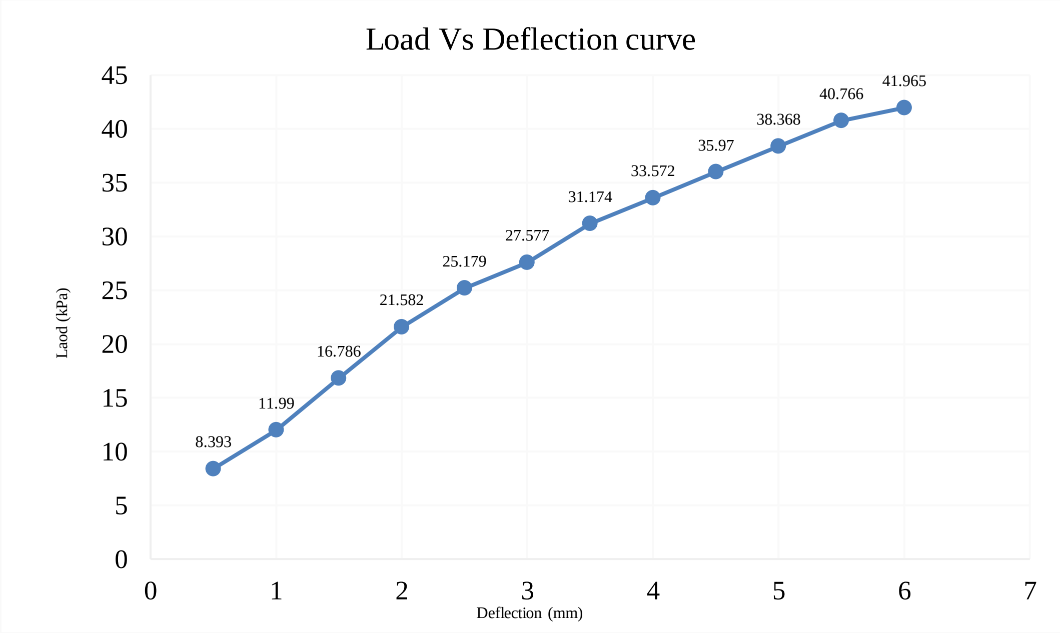

Fig. 8. Load vs Deflection Curve of reinforced BCS with PET mat at 3cm depth from Top Surface of mould.

Calculation

CBR at 2.5 mm = $\frac{Corrected\ Load\ at\ 2.5\ mm}{Standard\ Load\ at\ 2.5\ mm}$ * 100 = $\frac{25.179}{1370}$ * 100 = 1.837 %

CBR at 5.0 mm = $\frac{Corrected\ Load\ at\ 5.0\ mm}{Standard\ Load\ at\ 5.0\ mm}$ * 100 = $\frac{38.368}{2055}$ * 100 = 1.867 %

As CBR (5.0) mm is greater than CBR (2.5) mm. So, that the CBR analysis of a soil along with PET mat at 3cm depth from top is 1.867 %.

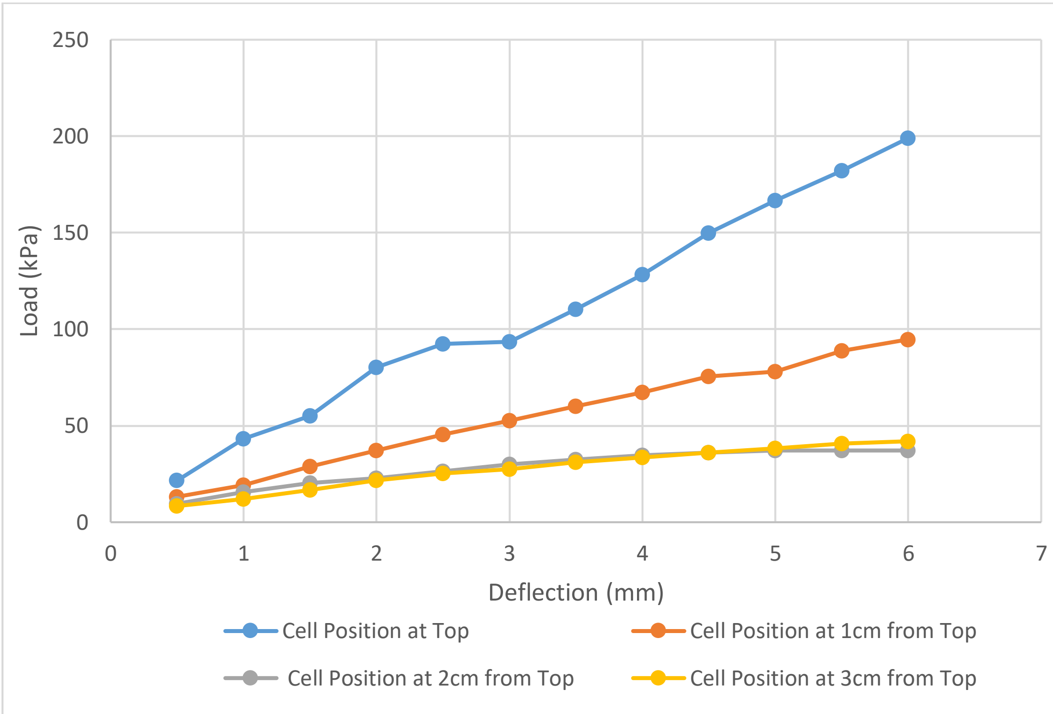

Fig. 9. Graph between load vs displacement curve of Comparison of Laying depth of PET mat accommodated in Black cotton soil specimen.

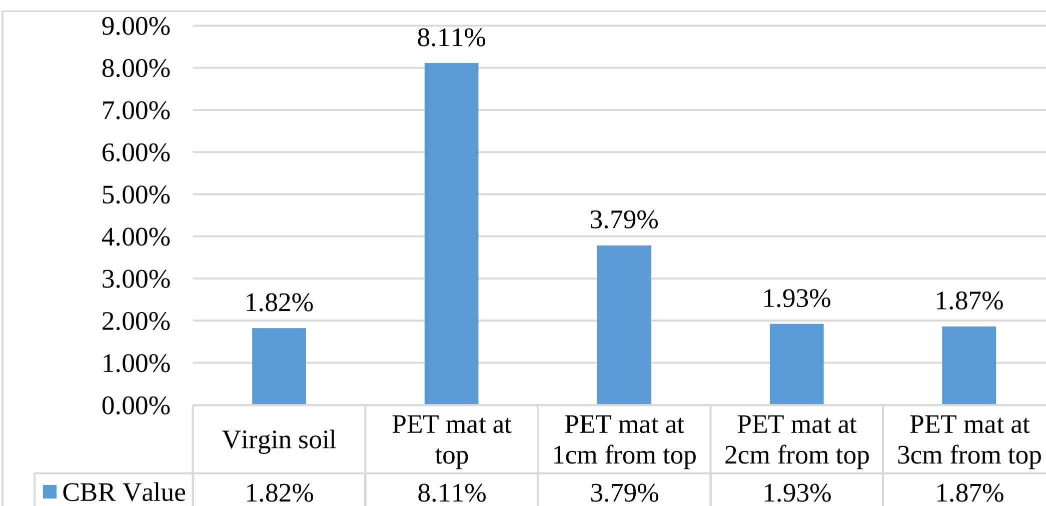

Fig. 10. Comparison graph between reinforced and unreinforced CBR

It can be seen from the graph (**Fig, 10.**) that all among all four possibilities, there is a decrease in bearing capacity with an escalation in the laying depth of the mat from the ground level. As from the figure above it was perceived that CBR value decreases with increment in the depth of the laying of PET mat in the CBR (i.e 8.110 % at top, 3.792 % at 1cm, 1.925 % at 2cm and 1.867 % at 3cm of depth from surface) . So, it is advised to keep the PET mat at the ground level along with the infill materials as it increased the CBR value by 3.446 % than the Virgin soil.

Discussion

In soft soil without inclusion of geocell, the CBR value was very less and with inclusion of Geocell as a reinforcing material, the CBR value is increasing because of the load dispersion is within the range of geocell confinement which is shown in **Fig. 11**. As we can see that the PET mat at the top position shows a higher increment in CBR value, this is because the load dispersion of CBR plunger is within the perview of geocell confinement and the gecell confinement is taking the load. Hence, the CBR value is higher. Further, when the geocell is placed at larger depth then this plunger load dispersion is not within the geocell area. Therefore, as we go deeper the load dispersion is less hence CBR values are not increased and is low.

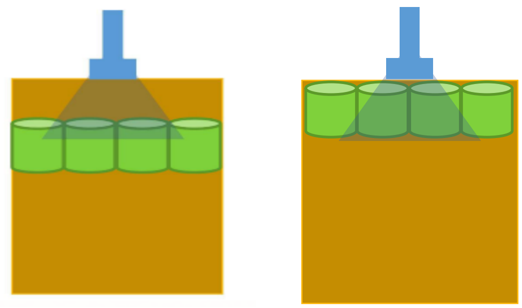

Fig. 11. Load Dispersion of CBR plunger on Waste PET bottle cell at different positions.

7.Conclusion

A sequence of five California bearing ratio (CBR) experiments were conducted to scrutinize the response of soft black cotton soil braced on unreinforced/ reinforced soft soil with sustainable geocell made up of squander PET bottles. Based on the result obtained by experimental evaluation following conclusion can be drawn.

- The CBR value of soil was increased siginificnatly approximately by three folds with the inclusion of PET bottle mat geocell with aggregate as infill material.
- The effect of geocell placement depth is also significant on its CBR values. The cell accommodated a shorter depth from the top surface shows more effect than the cell accommodated at greater depth.
- By comparing previous literature of actual geocell used in soft soil with present PET bottle geocell used in soft soil shows the similar effect. Through which it can be conclude that sustainable geocell made from PET squander bottles infilled with aggregates can be used as as geocell is found effective.

References

1. Husna Humayoon, Binil Gopinath, A Study on the Improvement of CBR using squander Plastic Mat as Geocell , International Journal of Engineering Research & Technology (IJERT),vol 5, 2016.
2. A.K. Choudhary, J.N. Jha and K.S.Gill , A Study on CBR behaviour of squander plastic strip reinforced soil, Emirates Journal for Engineering Research, 15 (1), 2010.
3. Sanat K Pokharel, Meisam Norouzi, Ian Martin & Marc Breault, Sustainable road construction for heavy traffic using high strength polymeric geocells, Resilient Infrastructure, (2016).
4. Rajagopal , A. Veeragavan , and S. Chandramouli, Studie on the geocell reinforced road pavement structure, Geosynthetics Asia, 5th Asian Regional Conference on Geosynthetics, 2012.
5. S.K. Pokharel, J. Han, R.L. Parsons & Y. Qian, D. Leshchinsky and I. Halahmi (2009), Experimental study on bearing capacity of geocell-reinforced base, Bearing Capacity of Roads, Railways and Airfields – Tutumluer & Al-Qadi (eds) © 2009 Taylor & Francis Group, London, ISBN 978-0-415-87199-0, 2009.
6. Sireesh Saride , M. ASCE, Suraj Vedpathak , S.M. ASCE, Vijay Rayabharapu and S.M. ASCE (2014), Elasto - plastic behaviour of Jute - Geocell reinforced sand subgrade ,Geo-Congress 2014 Technical Papers, GSP 234 © ASCE, 2014.
7. Siddharth Shah, Yogesh Alwani & Morvin N. Solanki , Study the Potential of Plastic Waste Bottles as Geo-Cells for Maintenance of Pot-Holes in Flexible Pavement , Proceedings of the Indian Geotechnical Conference 2019 https://doi.org/10.1007/978-981-33-6370-0, Springer Singapore
8. A. Emersleben & Norbert Meyer, “the use of geocells in road constructions over soft soil: vertical stress and falling weight deflectometer measurements”,EuroGeo4 Paper number 132.
9. Peddaiah, A. Burman, S. Sreedeep(2018): Experimental Study on Effect of squander Plastic Bottle Strips in Soil Improvement .
10. Sushovan Dutta, M. B. Nadaf, J. N. Mandal. (2016). An Overview on the Use of squander Plastic Bottles and Fly Ash in Environmental Sciences 35, pp 681-691.
11. Rajagopal, K., Krishnaswamy, N.R. and Latha, G.M.(1999). “Behaviour of sand confined with single and multiple geocells.”Geotextiles and Geomembranes 17.3, 171184.

Compliance Sheet

1. The justification for the derivation of Geocell from plastic waste bottles with fig. 1(a-d). showing the preparation has shown in page 3 under heading Material required.
2. The heading in 1.1 Waste plastic bottles has been removed from introduction and included in section 4 materials as PET Squander Bottles for Geocell.
3. As there is no any recent new papers found related to our research so addition of new paper was not done.
4. For the justification of choosing the aggregates particle size limited in the range of 4.75mm to 20mm size is to get better density and good interlock of the confined aggregate within the Geocell. Similar aggreages are used in the old literature [2,5,6,7,9],
5. For mentioning the reason behind chossing the position of mat, according to the papers [2,7], it was learned that the geocell is not effective at the bottom position. So, at the top position it is workable and in top at which positions are ground level, 1cm, 2cm or 3cm was selected.
6. The CBR graph was corrected in page 9 in fig. 9 .
7. Remaining graph from Fig. 4. to Fig. 8 was revised with its units of axis titles in page 5-9.
8. PET at top position shows a higher increment in CBR value is explained in discussion topic in page no 10.
9. The conclusion has been made specific to the objectives.
10. For the overall discussion of the test result, it has been found that soft soil without geocell has less CBR value while with inclusion of Geocell as a reinforcing material the CBR value is increased because of the load dispersion is within the Geocell confinement as explained in page 10 in discussion heading.