Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

Visakhapatnam Chapter

Effect of Submergence on Settlement and Bearing Capacity of Sand Reinforced with Pet Bottle Geocell

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Abstract. In addition to other plastic products, usage of plastic bottles is increasing alarmingly in the world. Most of the single use plastic bottles are made of Polyethylene Terephthalate (PET) and it can be recycled. But the tremendous increase of plastic bottle usage and its unscientific processing is polluting the Earth. This paper evaluates the usefulness of waste PET bottles as geocell mattress for the improvement of submerged sand and thus it's application as mitigation method for liquefaction prone areas. Effect of height of reinforcement, width of geocell and diameter of unit cell on pressure settlement behavior of P-sand under submerged and dry conditions is studied through model load test. Results show that strength of sand is poor under submerged condition. However its strength can be effectively improved by PET bottle geocell by increasing width as well as height of the mattress. Results imply the major role of tensile stiffness of the bottle in increasing the pressure settlement response. This study reveals that plastic waste bottle can be effectively used as stabilizing material so as to solve environmental issues as well as it can be used for stabilizing poor soil which is under submerged condition.

Keywords: waste PET bottles; geocell-mattress; bearing capacity; submergence; model load test

1 Introduction

Natural catastrophes, for example, floods or heavy rain can lift the ground water table up to or past the footing level and cause further settlements of shallow foundations. Under submerged condition, the soil loses its stiffness, and settles more. Unlike in cohesive soils, settlement is quick in cohesion less soil.

Polyethylene terephthalate (PET or PETE) is the material which is used for making most of the single-use plastic bottles, comprising those for water, juices, and soft drinks. A large amount of plastic bottles are disposed of every year worldwide. Landfills or incinerators are the ultimate destination of most of the collected plastic wastes and the remaining is reused. To avoid the disposal issues reuse of plastic is gainful rather than recycling; it is likewise efficient.

Geo-cells have a very significant role in controlling erosion and for stabilization of soil on level ground and steep slopes. Also this cellular system provides channel protection, and structural reinforcement for load support and soil retention. A geocell when in-filled with compacted soil makes another composite element that has improved mechanical and geotechnical properties. Lal and Mandal, (2014) carried out laboratory model load tests using strip footing on fly ash reinforced with cellular reinforcements fabricated using waste PET bottles. They found out that with increase in height and coverage ratio failure surcharge pressure is getting improved. Dutta and Mandal, (2015) conducted laboratory model load tests on fly ash bed overlying soft clay strengthened with cellular reinforcement made using waste PET bottles. A set of model tests were carried out to study the adequacy of cellular mattress in improving the bearing capacity of soft clay. Dutta et al., (2016) carried out laboratory strain controlled compression tests on unit cells formed using waste PET bottles and in filled with compacted fly ash or stone aggregates. The quantitative results showed effectiveness of geocell fabricated using waste PET bottles in load carrying capacity. Choudhary et al., (2019) conducted model load tests by varying different parameters of geocell like the depth of installation of geocell mattress (u - from footing base to the top of geocell mattress) and width of the cellular confinement system (b). Nadaf et al., (2017) studied performance of reinforced fly ash slopes with cellular mattress and strips under strip loading. With the change in edge distances and length of the geocell mattress significant improvement was observed on the settlement of the backfill. Kazi et al., (2015) studied the submergence effect on settlement and load carrying capacity of surface strip footing on sand bed reinforced with geotextiles with and without wrap around ends. The results indicate that the rising of water table level is a reason for significant settlement of the footing for both unreinforced and reinforced cases.

The present study states the possibility of using waste PET bottles for ground improvement purpose by installing geocell mattress. The model load tests were conducted under dry and submerged condition with and without geocell mattress and the effect on settlement and bearing capacity of sand was studied.

2 Materials

2.1 Plastic Bottles

PET bottles were collected locally based on the diameter of PET bottle they were classified as Type A and Type B. Thickness and tensile stiffness (ASTM D5035-11) of the plastic bottles were found and are given in Table 1.

Table 1. Results of wide width tensile strength test

Diameter of PET bottle (mm)	Thickness (μm)	Tensile strength (kN/m)	Tensile stiffness (kN/m)
75 (Type A)	24	25	81
65 (Type B)	18	15	62

2.2 Soil

Soil sample was also collected locally. Dry sieve analysis was conducted and soil is categorized as SP (Poorly graded sand) as per IS 2720. The properties of soil are summarized in Table 2.

Table 2. Properties of soil

Properties	Values
Specific gravity	2.60
Gravel (%)	0.1
Sand (%)	95
Silt and clay (%)	4.9
Uniformity coefficient, C_u	4
Coefficient of curvature, C_C	1
Classification	SP
Max. dry density (kN/m3)	20.10
Min. dry density (kN/m3)	14.49
Cohesion	Nil

3 Laboratory Model Tests

3.1 Test variables

After classifying the soil and finding the properties of plastic bottles used, pressure settlement behavior of sand reinforced with PET bottle geocell was studied under submerged and dry conditions. Effect of footing pressure during footing settlement on sand was found out by varying height and width of geocell mattress. Test variables are shown in Table 3.

Table 3. Test variables for Type A & Type B PET bottles

Width of geocell (b/B)	1.21	1.79	2.52	3.12
Height of geocell, (h/B)	0.25	0.42	0.58	-

3.2 Test setup and procedure

Laboratory model load tests were conducted on sand with and without reinforcement under submerged and dry conditions in a circular tank of inner dimensions as 600 mm diameter and 400 mm height. A 20 mm thick rigid steel plate with a diameter of 120 mm was used as a footing. Vertical loads were exerted to the footing plate using a hand operated mechanical jack of capacity 78.5 kN. The applied load was measured using a proving ring of capacity 30 kN. The settlements were determined using two dial gauges kept diametrically opposite to each other.

For testing under dry condition, the tank was filled in four layers constituting 350 mm thick sand bed. Each layer was compacted uniformly using a rammer to attain a relative density of 45%. For testing the sand under submerged condition, a certain amount of water was filled in the tank, and then the first layer of soil was filled such that level of water should be above the sand layer. Then again water was filled up to certain level and next layer of sand was added. The process was repeated for the next two layers also. At this submerged condition also each layer was compacted uniformly to attain a relative density of 45%.

Fig. 1 shows diagrammatic representation and image of the test setup under dry and submerged conditions.

Fig. 1. Diagrammatic representation and image of the test setup under dry and submerged conditions

Fig. 2 shows photographs of geocell reinforced sand at its preparation stage. The plastic bottles were cut manually using scissors and knife and were connected with plastic cable tie (nylon 66 cables) to make the geocell mattress.

Fig. 2. Preparation of geocell reinforced sand bed

4 Results and Discussion

For analyzing the results the bearing pressure (p) and settlement of the footing (s) are represented in non-dimensional forms so that it can be scaled up to obtain the results in practical cases. Footing pressure (p) is given in terms of bulk unit weight of sand (γ) and footing width (B) as p/γB. The settlement of the footing is given in terms of the footing width (B) as s/B (%).

4.1 Effect of mattress width on pressure settlement response

Width of geocell mattress is a key element which affects the performance of reinforced sand. The mattress width was differed, such that the height of mattress kept constant at h/B=0.58 and the mattress was placed at a constant depth (u/B) = 0.1. Effect of width of mattress was studied under dry and submerged condition. Fig. 3 shows the comparison of results of pressure settlement behavior of sand when width of geocell mattress is varied under dry and submerged conditions at s/B = 10%.

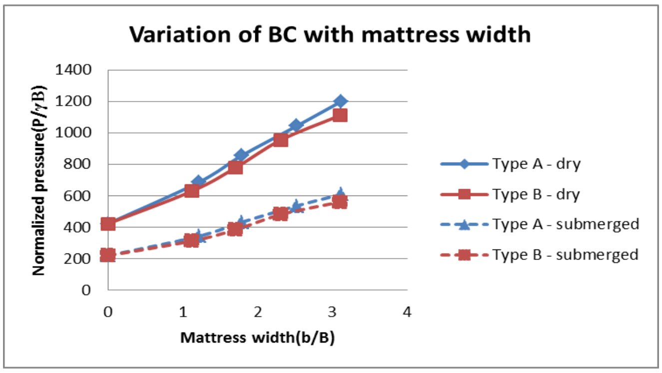

Fig. 3. Variation of bearing capacity with mattress width under dry and submerged condition

The results show that the bearing capacity of sand becomes better when reinforced with a mattress having wider area. From this graph it can be understood that under submerged condition when the sand is reinforced with a geo-cell mattress of width (b/B) =1.21, the BC is 1.56 times the BC of unreinforced sand. When b/B is increased 2.57 times (b/B=3.12), the BC obtained is 2.77 times the BC of unreinforced sand. It implies the BC can be increased 1.78 times if b/B is increased from 1.21 to 3.12.

On comparing load bearing capacity of sand under dry and submerged condition it can be seen that strength of unreinforced submerged sand is 0.52 times the strength of unreinforced dry sand. When the submerged sand is reinforced with mattress of size b/B=1.21 the strength is 0.81 times the strength of unreinforced dry sand. When the submerged sand is reinforced with mattress of greater width (b/B=3.12), the bearing capacity becomes 1.44 times that of unreinforced dry sand, which means that bearing capacity of submerged sand can be improved effectively.

4.2 Effect of mattress height on pressure settlement response

Height of cellular mattress is another important element and its effect on the pressure-settlement response of footing was found out by varying the height for a constant mattress width (b/B) = 3.12 and a constant depth of placement (u/B) = 0.1. Fig.4 shows the comparison of results of pressure settlement behavior of sand when height of geocell mattress is varied under dry and submerged conditions at s/B = 10%.

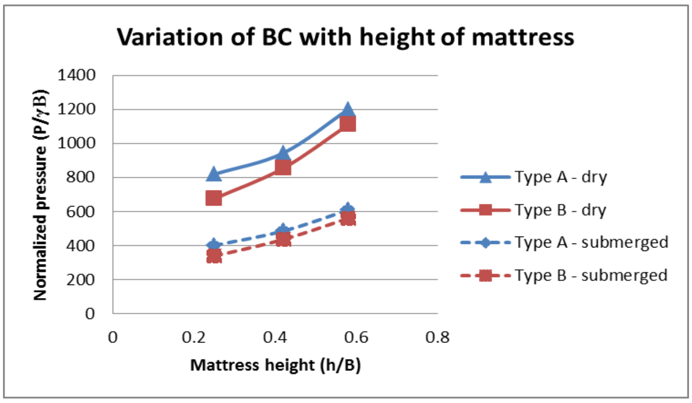

Fig. 4. Variation of bearing capacity with mattress height under dry and submerged condition

From this graph it can be inferred that the more the height of mattress, the more will be the improvement in pressure-settlement response of the sand. Also under submerged condition when the sand is reinforced with a geo-cell mattress of height (h/B)=0.25, the BC is 1.83 times the BC of unreinforced sand. When the height of mattress is increased 2.33 times (h/B=0.58), the BC obtained is 2.77 times the BC of unreinforced sand. It implies the BC can be increased 1.58 times if h/B is increased from 0.25 to 0.58.

When load bearing capacity of sand under dry and submerged condition is compared it can be seen that strength of unreinforced submerged sand is 0.52 times the strength of unreinforced dry sand. When the submerged sand is reinforced with mattress of height h/B=0.25 the strength is 0.94 times the strength of unreinforced dry sand. When the submerged sand is reinforced with mattress of greater height (h/B=0.58), the bearing capacity becomes 1.44 times that of unreinforced dry sand, which means that load carrying capacity of submerged sand can be improved significantly.

5 Conclusions

1. Increment in width of the mattress improved the load carrying capacity of sand significantly. The submerged sand reinforced with mattress of width b/B=3.12 improves the bearing capacity by 1.78 times that of submerged sand reinforced with mattress of width b/B=1.21.

2. Height of mattress also has a significant role in improving the load carrying capacity of sand. Bearing capacity of submerged sand can be improved 1.58 times if h/B is increased from 0.25 to 0.58.
3. As the type A bottle has a diameter 15% higher than that of type B and stiffness 31% higher than that of type B, it carried 10% higher footing pressure compared to type B.
4. Comparison of pressure settlement behavior at s/B=10% shows that
   i. Strength of unreinforced submerged sand can be increased 2.77 times, when the best configuration of reinforcement is chosen
   ii. At this state it is 1.44 times stronger than unreinforced dry sand

The tests were carried out on small scale. To validate the outcomes the tests should be conducted in large scale. Based on the availability, the maximum height of PET bottle used for making the mattress in the present study was limited to h= 70mm (or h/B=0.58). It will be more effective if PET bottles of greater height are used. The type of plastic used is PET (Polyethylene terephthalate), if other sorts of plastics such as PP (Polypropylene), HDPE or LDPE are used, then the improvement in bearing capacity of sand would be different. Only two types of PET bottles were used in the present study. If bottles with higher stiffness are used the load carrying capacity of the soil can be improved further.

References

1. ASTM part 11: "Standard test method for breaking force and elongation of textile fabrics (strip method)." D5035, West Conshohocken, PA (2011).
2. Choudhary, A.K., Jha, J.N., Sujata Fulambarkar.: "Strength and Deformation Characteristics of Bottom-Ash Reinforced with Single Geo-cell Mattress Made of Waste Pet Bottles", Geo-Congress 2019, ACSE, GSP 312, 263-272 (2019).
3. Dutta, S., Mandal, J.N.: "Model Studies on Geocell-Reinforced Fly Ash Bed Overlying Soft Clay", Journal of materials in civil engineering, ASCE, 04015091 1-13 (2015).
4. Dutta, S., Nadaf, M.B., Mandal, J.N.: "An Overview on the Use of Waste Plastic Bottles and Fly Ash in Civil Engineering Applications", Procedia Environmental sciences, Elsevier, 35(2016), 681-691 (2016).
5. Kazi, M., Shukla, S. K., Habibi, D.: "Effect of submergence on settlement and bearing capacity of surface strip footing on geo-textile reinforced sand bed", International journal of geo-synthetics and ground engineering, Springer, (2015) 1:4, 1-11 (2015).
6. Nadaf, M. B. and Mandal, J. N.: "Behavior of reinforced fly ash slopes with cellular mattress and strops under strip loading", Journal of Hazardous, Toxic, and Radioactive Waste Management, ASCE, 21(4) (2017).
7. Ram RathanLal, B. and Mandal, J. N.: "Behavior of cellular-reinforced fly-ash walls under strip loading", Journal of Hazardous, Toxic, and Radioactive Waste Management, ASCE, 18(1), 45-55 (2014).