BEARING CAPACITY OF SAND REINFORCED WITH WASTE PLASTIC CUPS

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Abstract: *Use of plastic cutlery in our day to day life has increased tremendously. Owing to great adverse environmental impact of the waste plastic cutlery items such as cups, an attempt is made in this research to utilize them as soil reinforcement. A series of laboratory plate load test is performed on prepared sand beds, in a model test tank, by placing layer/s of plastic cups at certain depth below the footing. The test results suggest that multi layers of the waste plastic cups; enhance the load bearing capacity and reduce the settlement of the sand bed significantly. Thus, use of waste plastic cups as soil reinforcement could be a good solution to reduce the problem of their disposal in an effective way.*

Keywords: Soil reinforcement, Waste plastic cups, Bearing capacity, Stress, Settlement, Model test

1. INTRODUCTION

In our daily life, products made from plastic have become a necessity. Worldwide production of plastic items is massive and once used their disposal is a great problem. Recycling and reuse is costly and at the end they are left in the environment causing all sort of pollution. They are not easily degradable. Burning these items release harmful gases that effect to our environment. Soil reinforcement can also be done by the use of waste plastic cups as it provides the confinement to the soil. Geo-synthetics are popularly used in civil engineering construction for resolving the soil related problems.

Waste plastic cups may behave as a geocell. Geocell reinforcement is one of the soil reinforcement techniques. Three-dimensional confinements provided by the geocell membrane increase the load carrying capacity of the soil. Many works on geocell reinforcement through field study and laboratory test were done by researchers, which show the significant potential of this technique. Geosynthetic reinforced (i.e. planer layer, geocell and randomly distributed mesh) sand bed is used to improve the soil strength and reduce settlement Latha and Somwanshi, (2009). The plastic cups are formed using polypropylene plastic materials, items made of polypropylene in the form of fibre are one of the most popular material used in soil reinforcement due to high tensile strength and resistance to biodegradation Rawat et al., (2018.).

The plastic cups confine the sand and act as reinforcement to the sand. The function of soil as a construction material is changed by the soil reinforcement. The reinforcement technique has made engineers to effectively use unsuitable in situ soils as reliable construction materials in a wide range of civil engineering applications to improve strength and stability of soils. This technique is used in soil retaining structures, embankments and pavements.

2. LITERATURE REVIEW

Several investigators have performed study on plastic as a fiber material for soil reinforcement. This literature review gives an insight for the need of soil reinforcement and waste plastic cups as soil reinforcement.

2.1. Necessity of reinforcement

Loose sand without having any reinforcing material collapses at lower range of loads. Due to lack of interlocking between the sand particles the performance in terms of shear strength and bearing capacity reduces significantly as a result the settlement values of sand increases significantly. Thus, there is a need to evaluate the effects of reinforcing material placed in sand.

Reinforced earth introduced by Vidal, (1969) the weak soil reinforced by tensile resisting material such as geosynthetics that helps to reduce the danger of slope stability, improved bearing capacity and reduce lateral deformation.

Hegde and Sitharam, (2014) performed plate load test on clay bed reinforced with geocell which provide cellular reinforcement which increase the load carrying capacity of soil. A natural bamboo cell is also used as alternative but the degradation of bamboo also occurs which suggest that geocell material is good alternative to bamboo material.

Shadmand et al., (2018) revealed that use of geocell made of geotextile thermo welded to form honey comb structure with open at top and bottom and sand reinforcement by geocell and by increasing the number of geocell layers, the bearing pressure increases and footing settlement, surface heave decrease as geocell provide the cellular reinforcement.

Sherin et al., (2017) studied the improvement in load carrying capacity when geocell placed at a certain depth from footing base. And also when the diameter of the opening is reduced, the confinement offered for the sand increases which in turn improve the bearing capacity of the sand.

2.2. Necessity of plastic as soil reinforcement

In the recent years, the major environmental issue in many countries is the plastic waste and for that several researcher reuses the different types of wastes generated with the soil so to improve the strength of soil. In this research paper wastes such as plastic cups which enhance the strength of sand and when the load is applied on it prevents the lateral deformation of the sand

Babu and Chouksey, (2011) had conducted the strength of soil admixed with waste plastic. They showed that the soil reinforced with fiber material can be advantageously employed in improving the strength of the sandy clay. The tests were performed with different size of fibers strips and types of fibers in different proportions and the effects of fiber in enhancing the strength and stability of soil were identified.

Consoli et al., (2002) indicated one of the most promising approach is to use fiber shaped waste of plastic bottle material in the combination with soil and rapid hardening Portland cement to improve the. Engineering behavior of uniform fine sand

Peddaiah et al., (2018) used waste plastic bottle strips in soil reinforcement and observed that plastic content with natural soil increases the strength of silty sand. Thus improving the engineering properties of silty sand.

Murthy et al., (2017) used the granules of waste plastic of 2 mm diameter and 3 mm length, increases the strength of soil and also solves the problem of disposing the waste. The density of soil composite increases with increase in percentage of plastic granule. The strength behavior shows a great influence on percentage of plastic granule.

Li et al., (2019) compare the efficiency of geocell and waste tires as soil reinforcement to analyze the parameter such as distance between the top surface, first layer of reinforcement, distance between reinforcement layer, number of layers and infill density and found that the distance between the first layer is 0.25B (B width of the footing).

Fig- 1: Geocell and Waste tires

In terms of performance, tires provide better alternative to the use of geocell whose tires dimension is diameter 40 cm, thickness 1 cm, length of tread 5 cm and that of geocell is height 5 cm, length of aperture side 40 cm. Fig 1 shows the geocell and waste tire

In this research work effects on bearing capacity of the sand are evaluated using waste plastic cup as soil reinforcement.

3. LABORATORY STUDY

3.1. Formation of plastic cup cell

The plastic cups were bonded with each other with the help of stapler pins that joined them. The plastic cups were laid on the test sand bed to full width of the tank.

Fig- 2: formation of plastic cup cell

The part of arrangement of plastic cups is shown in Fig 2. The same way the plastic cups is laid in the whole tank

3.2. Sand bed preparation

The sides of test tank were coated with polyethylene sheets to avoid the friction from the sides of the tank. Sand bed is prepared through rainfall technique known as pluviation technique in which the sand is kept to fall from height of 1 m from the strainer that is attached with the steel ring. Above the sand bed, the plastic cups reinforcements were placed to the full width of the tank.

To achieve the desired relative density a series of trials were conducted to determine the height of fall of the sand In each trial a small containers with known volume were placed at different location of the tank A calibration chart was prepared by knowing the maximum and minimum void ratios of the sand The plastic reinforcement cells were filled with sand using pluviation technique to maintain a relative density same as that of test sand bed as shown in Fig 3.

Fig-3: sand bed with plastic cup arrangement

3.3. Test procedure

The Laboratory plate load test experiments were conducted in an existing test tank cum loading apparatus. The dimensions of test tank: length 1000 mm; width 1000 mm; and height, 1000 mm and a square-shaped mild steel plate of size length 200 mm; width 200 mm; and thickness 20 mm in size is used for which schematic and photographic view shown in Fig. 4 and Fig 5.

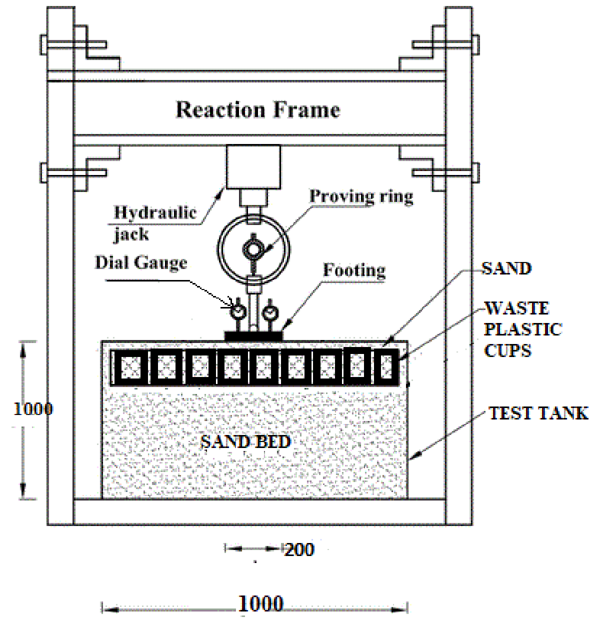

Fig-4: A Schematic view of test setup

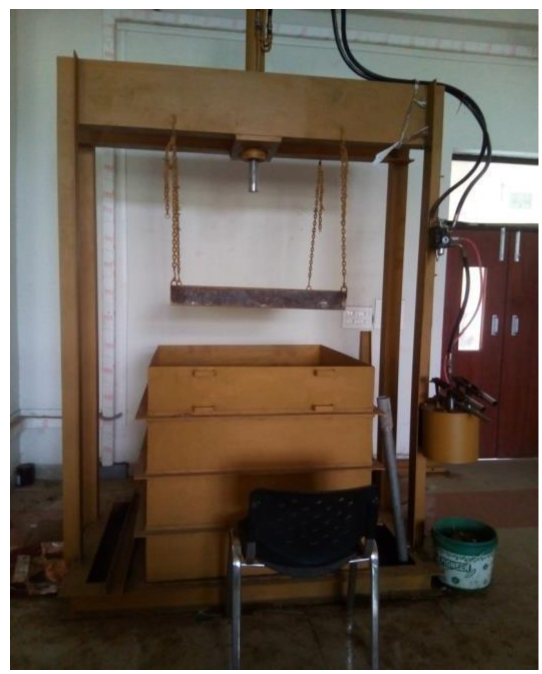

Fig- 5: Photographic view of test setup

The cross section view of plastic reinforcement at different depth and number of layer is shown in Fig 6.. Upon filling the waste plastic cups with the sand, the fill surface was leveled and footing was placed in a predetermined alignment in such a way that the load from the jack would act at the center on the footing.

Table 1 Physical properties of sand

Properties	Values
Coefficient of curvature, Cc	1.12
Coefficient of uniformity, Cu	1.69
Maximum dry density, kN/m^3	18.50
Minimum dry density, kN/m^3	14.80
Specific Gravity, G	2.67
Relative Density	65 %
Moisture content	9%
Internal angle of friction	35°

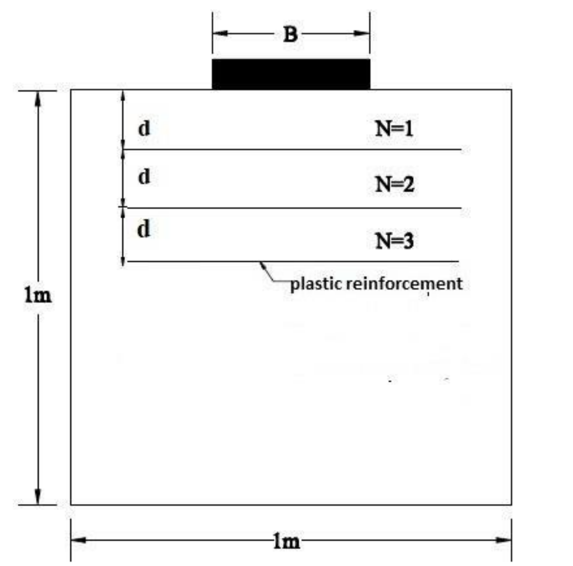

Fig- 6: Cross section view of plastic reinforcement

Footing was loaded with a hand-operated hydraulic jack supported against the self-reacting frame. The load transferred to the footing was measured through pre-calibrated proving ring. Loads were applied in steps with equal load increments in each step. Settlement was recorded with the help of dial gauges. Also throughout the test the relative density is maintained of 65%. The material used in present study is locally available Narmada sand and is classified as poorly graded. Fig 7 shows the particle size distribution curve of the sand used in the experiment.

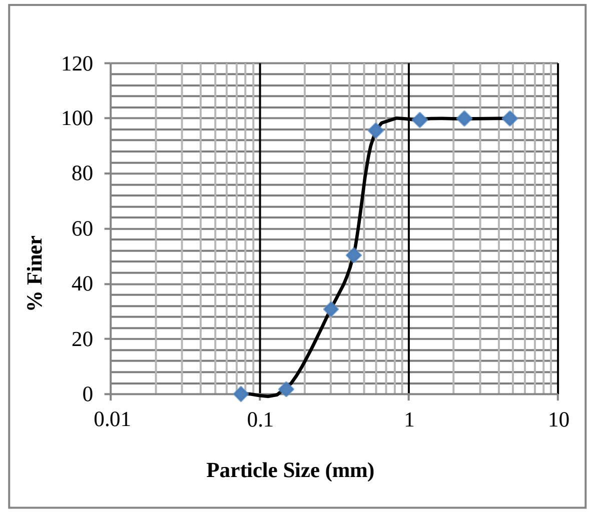

Fig- 7: Grain size distribution of used sand

Waste plastic cups used in the experiment are of size 9 cm in height and 7 cm in diameter and a thickness of 0.4 mm. The plastic cups were arranged in the test tank and test is performed as shown in Fig 8. The load settlement behavior is being observed for different depth of waste plastic cups and number of layers of waste plastic cups. Table 1 list the properties of sand determined in the laboratory.

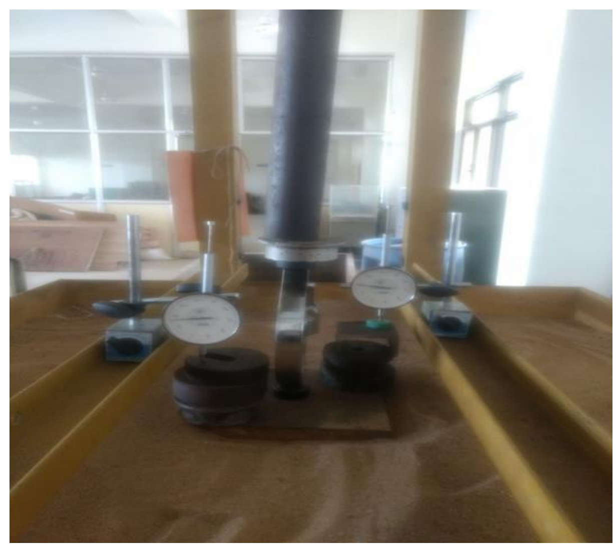

Fig- 8: Plastic cups beneath the test plate arrangement

3.4. Experimental program

The experimental program was developed to compare the bearing capacity of reinforced sand with waste plastic cups to the unreinforced sand. Parameters such as depth of placement of layer and number of layers of waste plastic cups were analyzed (Table 2).

The load applied in increment of 50 kg through hydraulic jack and settlements were recorded with the help of dial gauge. When there is significant settlement in the loading plate then the experiment was terminated. The notations used in this paper are:

B: Width of the testing plate (200 mm)

d: Vertical spacing between the layers of waste plastic cups (5 cm)

N: Number of layers of waste plastic cups s: Settlement of the footing.

u: Depth of placement of waste plastic cups from the bottom of test plate.

Table 2 Configuration and parameters of model tests

Test No.	Reinforcement	u (cm)	Spacing d(cm) between the layer
1	**Variation in depth**		
A	Unreinforced	-	-
B	Plastic cups	0.25B	-
C	Plastic cups	0.5B	-
D	Plastic cups	0.75B	-
E	Plastic cups	1B	-
2	**Variation in number of layer**		
A	Plastic cups	Single layer	
B	Plastic cups	Double layer	5
C	Plastic cup	Triple layer	5

4. TEST RESULTS

4.1. Bearing capacity of sand

The bearing capacity of sand is evaluated for unreinforced sand and sand with waste plastic cups as reinforcement. Effects of variation in depths and layers on bearing capacity are studied and discussed in this section.

The bearing capacity of sand is calculated using double tangent method.

4.1.1. Variation in depth of waste plastic cup

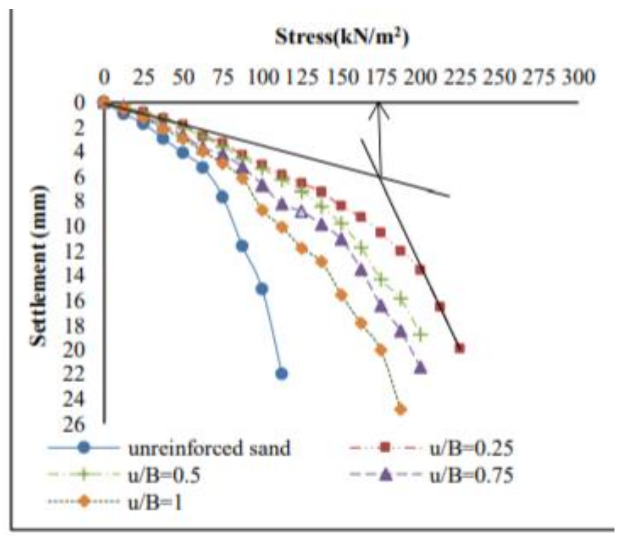

Fig- 9: Effect of depth of reinforcement of waste plastic cups

Fig. 9 shows the stress-settlement curves obtained from test performed on unreinforced sand and the reinforced sand by waste plastic cups at a depth of 5 cm, 10 cm, 15 cm and 20 cm respectively. The effect of depth of waste plastic cups on bearing capacity is evaluated and also the bearing capacity ratio is found out.

Table 3 Bearing Capacity values for variation in depth

S No.	u	Bearing Capacity (kN/m^2)	%increase wrt unreinforced
1	Unreinforced	85	-
2	0.25B	175	106
3	0.5B	160	88
4	0.75B	150	76
5	1.00B	130	53

The bearing capacity of unreinforced sand comes out to be 85 kN/m2 and maximum bearing capacity comes out to be 175 kN/m2 in reinforced sand at depth 0.25B

A better performance is seen when reinforced sand in comparison to the unreinforced sand bed. The test results also show there is an optimum depth of reinforced waste plastic cups: as the depth increases up to 5 cm, the bearing capacity of sand is increases. However, when the depth is increased to 20 cm, the bearing capacity reduces, indicating that the optimum depth is located around 5 cm.

4.1.2. Variation in number of layers of waste plastic cups

A similar behavior can be seen for reinforcement in layers of waste plastic cups. The triple layer of waste plastic cups having vertical spacing of 5 cm shows that the bearing capacity is maximum for triple layer than the single and double layer of waste plastic cups as shown in Fig 10.

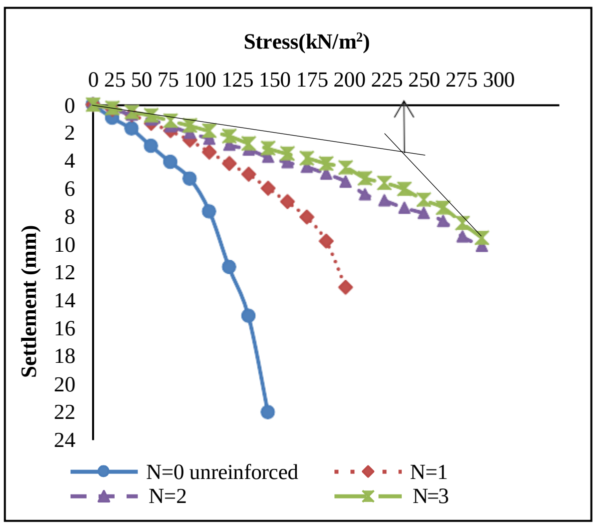

Fig- 10: Effect of number of layer of waste plastic cups

Table 4 Bearing Capacity value for variation in number of layers

S No.	No. of layers	Bearing Capacity (kN/m^2)	%increase wrt unreinforced
1	Unreinforced	85	-
2	Single layer	175	106
3	Double layer	185	118
4	Triple layer	200	135

The bearing capacity of unreinforced sand comes out to be 85 kN/m2 and maximum bearing capacity comes out to be 200 kN/m2 in reinforced sand with triple layer of reinforcement.

From the above graph the bearing capacity of sand increases with increase in number of layer of waste plastic cups. There is increment in bearing capacity of sand for triple layer in comparison to the unreinforced sand. The maximum stress is taken by the three layers as shown in graph. So, the optimum layer for increment in bearing capacity of sand is using three layers of waste plastic cups as soil reinforcement.

4.2. Bearing capacity improvement factor

Effects of variation in depths and layers on bearing capacity improvement factors are studied and discussed in this section

4.2.1. Variation in depth of waste plastic cup

Bearing capacity improvement factor is the ratio of bearing capacity of reinforced sand to the bearing capacity of unreinforced sand. The bearing capacity improvement factor is calculated as shown in Table 5.

Table 5 Bearing capacity Improvement factors for depth variation

		IMPROVEMENT FACTOR				
u(cm)	u/B	s/B				
		1.5%	3%	4.50 %	6%	7.50 %
5	0.25	1.86	1.76	2	2.05	2.1
10	0.5	1.71	1.69	1.71	1.83	1.8
15	0.75	1.57	1.46	1.56	1.72	1.7
20	1	1.42	1.38	1.25	1.38	1.5

For constant u/B, the optimum s/B is 7.5% and if s/B is constant, the optimum u/B ratio is 0.25. Hence from above result it can be concluded that for maximum improvement factor, the optimum depth is 5 cm.

4.2.2. Variation in number of layers of waste plastic cups

The Bearing capacity Improvement factors of the sand reinforced with waste plastic cups in number of layers and settlement to width ratio is shown in Table 6.

Table 6 Bearing capacity Improvement factors for layer variation

	IMPROVEMENT FACTOR		
Number of layer (N)		s/B	
	1.5%	3%	4.50%
1	1.8	1.72	1.81
2	2.48	2.57	2.88
3	2.86	3	3.06

5. CONCLUSIONS

The experiments were performed to analyse the effect of depth and number of layers of waste plastic cups on the bearing capacity of the sand for square footing of size 200 mm, and thickness 20 mm.

- The study presented here has demonstrated that the optimum depth for the waste plastic cups is 0.25B i.e. 5 cm from the bottom of test plate.
- The bearing capacity of reinforced sand at 5 cm depth is 106 % more than the unreinforced sand.
- For constant u/B, the optimum s/B% is 7.5% and if s/B is constant, the optimum u/B ratio is 0.25. Hence from results it can be concluded that for maximum improvement factor, the optimum depth is 5 cm.
- Increasing the number of layer of waste plastic cups increases the bearing capacity of sand maximum for triple layer and minimum for single layer.
- The bearing capacity of reinforced sand for triple layer reinforcement is 135 % more than the unreinforced sand.
- For different s/B% i.e. for s/B 1.5%, 3%, and 4.5%, the improvement factor is maximum for three number of layer of waste plastic cups and minimum for one layer of waste plastic cups.
- When number of layer is constant then the improvement factor is maximum for s/B =4.5%.
- Hence from above results it can be concluded that for maximum improvement factor the optimum number of layer is three and optimum s/B% is 4.5%.
- Waste plastic cups as soil reinforcement may be good alternative to various other costly additives which also degrade the environment.

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REFERENCES

[1]Babu, G.L.S., Chouksey, S.K., 2011. Stress-strain response of plastic waste mixed soil. Waste Management. 31, 481–488.

[2]Consoli, N.C., Montardo, J.P., Prietto, P.D.M., Pasa, G.S., 2002. Engineering Behavior of a Sand Reinforced with Plastic Waste. Journal of geotechnical and geoenvironmental engineering 128, 462–472.

[3]Hegde, A., Sitharam, T.G., 2014. Use of Bamboo in Soft-Ground Engineering and Its Performance Comparison with Geosynthetics: Experimental Studies. Journal of Materials in Civil Engineering 27, 04014256.

[4]Li, L., Cui, F., Ferreira, P., Xiao, H., Jie, H., 2019. Experimental study of embankments with different reinforcement materials and spacing between layers. Geotextiles and . Geomembranes 103453.

[5]Latha, G. M., Somwanshi, A., 2009. Effect of reinforcement form on the bearing capacity of square footings on sand. Geotextiles and . Geomembranes 27, 409–422.

[6]Murthy, G.V.L.N., Krishna, A.V., Rao, V.V.N.P., 2017. An Experimental Study on Partial Replacement of Clayey Soil with an Industrial Effluent: Stabilization of Soil Subgrade 7, 337–348.

[7]Peddaiah, S., Burman, A., Sreedeep, S., 2018. Experimental Study on Effect of Waste Plastic Bottle Strips in Soil Improvement. Geotech. Geol. Eng. 36, 2907–2920.

[8]Rawat, S., Sharma, U., Vikal, V., Sayeed, M., n.d. A study of soil response using polypropylene as reinforcement 4, 125–129.

[9]Shadmand, A., Ghazavi, M., Ganjian, N., 2018. Load-settlement characteristics of large-scale square footing on sand reinforced with opening geocell reinforcement. Geotextiles and Geomembranes 46, 319–326.

[10]Sherin, K.S., Chandrakaran, S., Sankar, N., 2017. Effect of Geocell Geometry and Multi-layer System on the Performance of Geocell Reinforced Sand Under a Square Footing. Int. J. Geosynth. Ground. Eng. 3,

[11]Vidal, H., 1969. The principles of reinforced Earth. Highw. Res Rec 282, 1–16.