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Performance of Plastic Bottle Reinforced Soil

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***Abstract*– Use of plastic products such as polythene bags, bottles, containers and packing strips etc. is increasing day by day creating the disposal problem for the society. Attempts are therefore being made to utilize waste plastic bottles as geotechnical material to solve both geotechnical and environmental problem. This paper presents the results of detailed experimental study on the possible use of waste plastic bottles as soil reinforcement for bearing capacity improvement. Bearing capacity of square footing on sandy soil reinforced with waste plastic water bottles is evaluated and the effect of parameters like width of reinforcement (L/B ratio), number of layers of reinforcement (N) and spacing between reinforcing layers is studied through model plate load tests. Results show that there is considerable increase in bearing capacity value with the provision of plastic bottles as reinforcement.**

***Keywords* – Waste Plastic Bottles, Geotechnical Material, Bearing Capacity.**

I. Introduction

Bearing capacity is one of the most important subject of Soil Engineering. Reinforced earth is relatively new construction material which has only been used commercially for past 40 years or so for bearing capacity improvement. The introduction of the soil reinforcing techniques has enabled engineers to effectively use unsuitable in-situ soils as reliable construction materials in a wide range of Civil Engineering applications. Reinforced soil construction is an efficient and reliable technique for improving the strength and stability of soils. Reinforced soil has found wide use in different areas of Civil Engineering, such as foundation slabs, dams, sea walls, bridge abutment and retaining walls. The speciality of reinforcement is its flexibility, which enables construction on poor foundation soil, rapid construction and low cost.

Use of geosynthetics as reinforcement for improving the performance of shallow foundations has been studied by engineers over the past two decades. But most developed and developing countries all over the world have huge resources of waste materials. Despite the ban, the use of plastic products, such as polythene bags, bottles, containers, and packaging strips, is increasing by leaps and bounds. As a result, open waste dumps are continuously filling up leading to various environmental concerns. The work reported in this paper consists of results from laboratory model plate load tests on square footings resting on sand beds reinforced with model plastic bottles. Parameters that are varied to establish the response of footing on reinforced soil bed are number of layers of reinforcement, width of reinforcement and spacing between the layers. The relations between load-settlement are brought through laboratory model tests.

II. Literature Review

Much research has been carried out to understand the beneficial effects of using planar forms of reinforcement in soil such as geotextile and geogrid. More recently soil reinforcement in the form of cellular structure such as geocell has been successfully used in many areas of geotechnical engineering such as bearing capacity improvement under footing, roads/ pavements, embankments and in retaining walls. Benson and Khire [1] used cut pieces of HDPE waste milk jugs and showed that there is an increase in strength, CBR, and secant modulus of sand. They also found that the friction angle increase is as large as 18°. Bueno [2] conducted a laboratory study on mechanically stabilized soils with short, thin plastic strips of different lengths and contents, and reported enhanced strength and load bearing capacity. Anas Ashraf [3] studied on the possible use of waste plastic bottles for soil stabilisation. The analysis was done by conducting plate load tests on soil reinforced with layers of plastic bottles filled with sand and bottles cut to halves placed at middle and one-third positions of tank. The test results showed that cut bottles placed at middle position were the most efficient in increasing strength of soil.

III. Experimental Investigation

The experimental investigations discuss about the materials used for model foundation system, procedure adopted for model tests and the details of testing program.

A. Materials

Materials used for model plate load tests were as follows:

a. Sand

The sand used in this study was dry sand of SP type as per IS classification. The properties of soil determined from laboratory tests are tabulated in Table 1.

b. Reinforcement

The type of reinforcement used in the experiments is plastic straws of diameter 6 mm and 20 mm height representing plastic water bottles and arranged in staggered pattern as shown in Fig. 1. The diameter and height of model water bottles is selected corresponding to a scale ratio of 1:10 with respect to original dimensions of mineral water bottles of 1 litre capacity available in market (diameter 60 mm and height 270 mm). A layer of reinforcement is formed by pasting their bottom to a thin plastic sheet, thus closing the bottom ends of the straws and simulating them as plastic bottle. The numbers of model plastic bottles in a layer are varied depending upon L/B ratio of the reinforcement.

Table 1: Properties of sand

S.No.	Tests	Values
1	Specific gravity	2.58
2	γ_{max}	17.01 kN/m^3
3	γ_{min}	14.7 kN/m^3
4	Relative density (%)	60
5	Angle of internal friction	40^0
6	Average grain size (D_{50})	0.46 mm
7	Effective grain size (D_{10})	0.3 mm
8	Coefficient of uniformity (C_u)	1.67
9	Coefficient of curvature (C_c)	0.91
10	I. S. Classification	Medium sand, SP grade

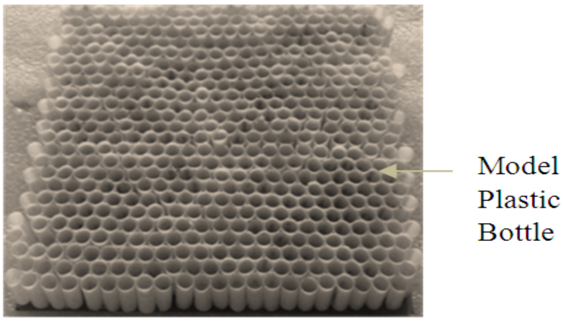

Fig.1. Structure of reinforcement

B. Test Setup

The apparatus used for the model tests consists of a steel tank of size 500 mm (length) x 500 mm (width) x 500 mm (height), a loading frame, a hydraulic jack, a pumping unit, proving ring for measuring applied load and dial gauges for measuring settlement of footing. Test tank was made rigid to avoid volume change of tank while preparing test bed as well as during the load test. Dimensions of model footing used for model tests was square footing of size 100 mm x 100 mm made of thick steel plate. Sand rainfall technique was adopted to achieve the required unit weight of sand in the tank. The load was applied by means of hydraulic jack, which was supported centrally by the steel beam made of channel sections.

Settlements were recorded by two dial gauges placed diagonally opposite on the plate. The complete test setup is as shown in Fig. 2.

C. Test Details

One model test was conducted on square footing resting on unreinforced sand bed. After that the different series of plate load tests were conducted on reinforced soil bed by varying the parameters like numbers of layers of

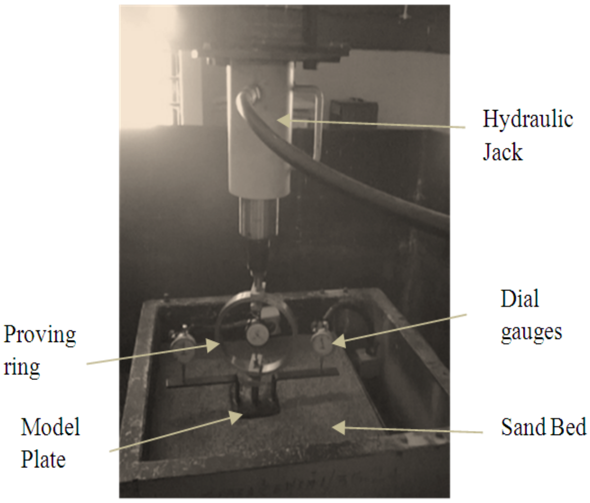

Fig.2. Complete Test setup

reinforcement (N), width of reinforcement (L) and spacing between the reinforcing layers (S). The layout and configuration of reinforcement used in the study is as shown in Fig. 3. Placement of reinforcement in the sand with different L/B is as shown in Fig. 4. The depth of top most layer of reinforcement from the footing was kept constant equals to one-fourth the width of footing in all tests. The layers of reinforcement were kept in touch in each other without any spacing between them. After each layer of reinforcement kept in position, the soil bed was prepared in the same way as in case of unreinforced soil bed taking care that model plastic bottles are completely filled with sand.

In another set of experiments, the spacing was introduced between the reinforcing layers, for L/B = 4. The spacing provided was equal to one-eight, one-fourth and half the width of footing. The testing program is as presented in Table 2.

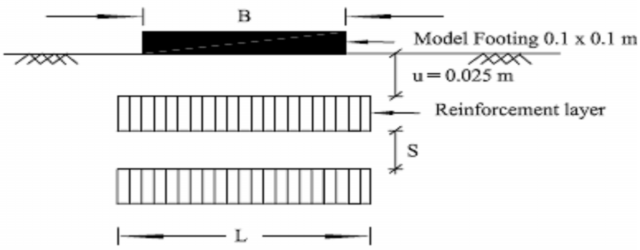

Fig.3. Layout and configuration of reinforcement layers in the model test

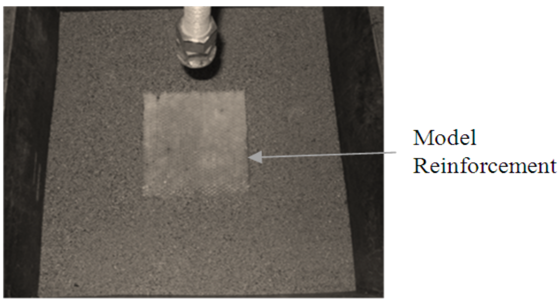

Fig.4. Placement of reinforcement in sand bed

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Table 2: Testing Program

Case No.	L/B	N	Spacing (S)
1	Unreinforced Sand		
2	1.25	1, 2, 3	0
3	1.5		
4	2		
5	3		
6	4		
7	4	2, 3	B/8
8			B/4
9			B/2

IV. Experimental Results and Discussions

The performance of plastic reinforced bottle bed was studied using various conditions on 100 x 100 mm plate. Each plate load test results were plotted and the ultimate bearing capacity was obtained by tangent method. In some cases, the load-settlement curve was observed to be straight without any change of slope. In such case, the failure of footing was considered corresponding to settlement equal to 20% of width of footing. Typical load-settlement curves for case 1 and case 2 are as shown in Fig.5.

The ultimate bearing capacities for all the cases studied are tabulated in Table 3. The bearing capacity ratio (BCR) was then determined for each case, which is defined as the ratio of the ultimate bearing capacity of the footing on reinforced sand to that of footing on unreinforced sand.

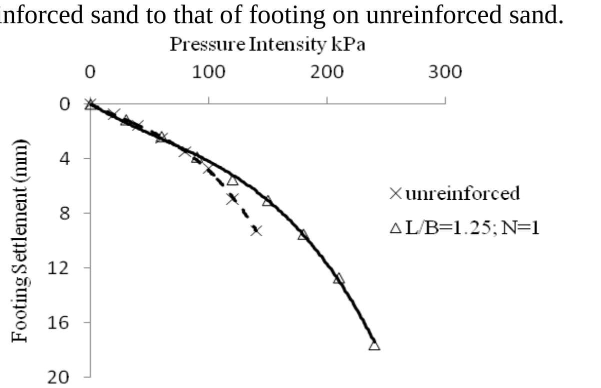

Fig.5. Load-settlement curve for unreinforced sand condition

Table 3: BCR values for various cases

Case No.	L/B	N	UBC kN/m^2	BCR
1	Unreinforced Sand Test		100	-
2	1.25	1	120	1.2
		2	170	1.7
		3	200	2
3	1.5	1	160	1.6
		2	200	2
		3	280	2.8
4	2	1	220	2.2
		2	260	2.6
		3	300	3
5	3	1	240	2.4
		2	260	2.6
		3	320	3.2
6	4	1	290	2.9
		2	300	3
		3	400	4
7	4 & S=B/8	2	540	5.4
		3	600	6
8	4 & S=B/4	2	510	5.1
		3	540	5.4
9	4 & S=B/2	2	320	3.2
		3	420	4.2

A. Effect of width of Reinforcement (L)

In this series, tests were conducted to investigate the effect of width of reinforcement (L) in the improvement in load carrying capacity of square footing. The width of reinforcement (L) of 1.25B, 1.5B, 2B, 3B and 4B are used to reinforce the sand bed at a depth of u = 0.25B. There is considerable increase in BCR values of sandy soil when reinforced with model plastic bottles as reinforcement. However it is found that the optimum width of reinforcement is only 2B, beyond which there is only a marginal increase in the BCR value. Fig. 6 shows variation in BCR values with L/B ratio corresponding to different number of layers.

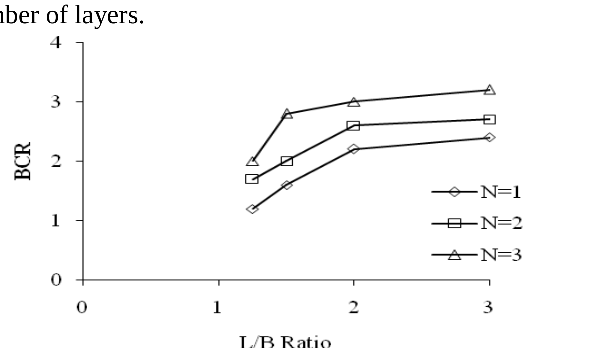

Fig.6. Variation in BCR values with L/B ratio

B. Effect of number of layers of Reinforcement (N)

In this series, the layers were kept close to each other so that there was no spacing between them. Fig. 7 shows the variation in BCR with respect to number of layers for different L/B ratio.

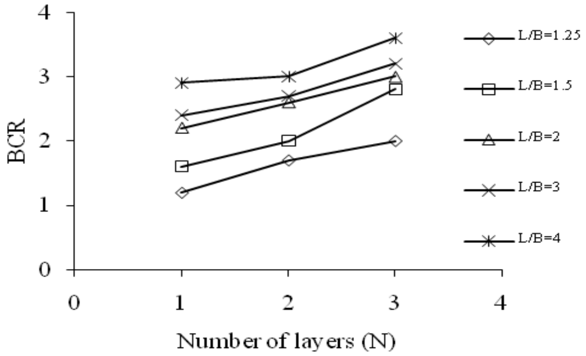

Fig.7. Variation in BCR-N for different L/B ratio

In all cases, the maximum BCR is obtained for N = 3. The increase in ultimate bearing capacity of sandy soil reinforced with plastic bottles may be due to the confining effect in the zone of shear failure below footing and making the foundation bed stiffer as compared to the unreinforced soil foundation bed. The plastic bottles form a 3D cellular structure similar to that in case of 'Geocell Mattress'.

B. Effect of spacing in Reinforcement (S)

In this series, tests are carried out to study the effect of spacing in between the reinforcing layers. Spacing of B/8, B/4 & B/2 were provided for L/B = 4 to determine BCR values. Depth of top most layer of reinforcement was kept same as in earlier test. Fig. 8 shows the variation of BCR with spacing between the layers for L/B = 4.

It is found that the BCR increase for a spacing of B/8 between the layers. However for greater spacing, the BCR value decrease indicating that maximum benefits can be obtained by providing space of B/8.

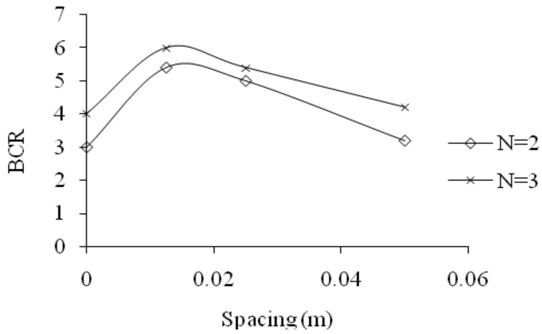

Fig.8. Variation of BCR with spacing for L/B = 4

V. Conclusions

The improvements in bearing capacity of sandy soil reinforced with model plastic water bottle were investigated through model plate load tests in laboratory. The study shows that the ultimate bearing capacity of the footing increases with the introduction of layers of plastic bottles as reinforcement. The increase in bearing capacity may be due to the additional confinement to the soil in the vicinity of footing similar to that in case of Geocell. The bearing capacity increases with the increase in width of reinforcement and number of layers. Optimum benefit can be obtained by providing three reinforcing layers with L/B ratio of 2 and spacing between them equal to B/8.

Use of waste plastic bottles as reinforcement is recommended to reduce the quantities of plastic waste, which creates the disposal problem.

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