AN EXPERIMENTAL INVESTIGATION ON EFFECT OF INTERFERENCE ON BEARING CAPACITY OF ADJACENT FOOTINGS IN SAND

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Abstract - *Due to rapid urbanization, the space available for construction is getting reduced. This leads to a situation in which individual footings come closer to each other causing an interfering effect. This significantly influences the bearing capacity. Here two individual footings are selected to study the effect of interference between them. This is done by obtaining a relation between Bearing Capacity Ratio (BCR) and Spacing to Width ratio(S/B) of footings. The parameter studied here is the influence of footing depth on load capacity of soil at different spacings. The model tests are conducted for S/B ratios (0.5, 1, 1.5 and 2) at D/B ratios 0, 0.1 and 0.2 respectively. Medium dense sand is selected for the experiment. The study is conducted for both unreinforced and reinforced conditions. Geogrid sheets are used for reinforcing purpose. Results show that as the depth of footing increases the bearing capacity value also increases. In addition to this it is found that the maximum value of BCR is for S/B ratio 1 which is the critical spacing for all the depth variations.*

Key Words: **Bearing capacity ratio, Geogrid, Spacing to width ratio, Square footing, Model study**

1.INTRODUCTION

As population and urbanization flourish, there occurs a situation of scarcity of good construction sites. As a result buildings are to be constructed more close to each other. We know that the load transfer in soil follows a proper pattern. So if two different footings come closer, there occurs a quiet different condition that the bearing capacity of each footing may change. This variation can be studied by varying the spacing between the footings. Such an influence of closeness of footings in bearing capacity values is defined as the effect of interference of footings.

Also, the builders are forced to construct structures in sites that are not much good for construction. Since the sites are not much good, in order to improve its load carrying capacity, there are many methods adopted. Out of this, one of the most effective methods is the provision of reinforcing layers in soil. The provision of reinforcements at proper depth and dimensions can reduce the settlements and improve the bearing capacities of soil to a great extend. There are different materials available for reinforcement. Each type is selected based on the requirement.

Here the effect of interference of two footings in terms of bearing capacity ratio, at different footing embedment depths (Depth to width of footing ratios D/B = 0, 0.1 and 0.2) are studied. Here four spacings (spacing to width of footing ratios S/B = 0.5, 1, 1.5 and 2) are adopted.

2. LITERATURE REVIEW

Arvind Kumar and Swami Saran[1] studied the effect of spacing, reinforcement size and layers on bearing capacity and tilt of footings resting in sand. They found that the results are much comparable with that of single footing and the bearing capacity values are improved.

Elif Cicek, Erol Guler,Mand Temel Yetimoglu[2] investigated about the comparison of experimental and theoretical studies of pressure distribution below two adjacent strip footings in sand. They used pressure sensors at different depths to measure the values and found that the results are satisfying with westergaard's load distribution mechanism.

Jyant Kumar and Manas Kumar Bhoi[3] investigated interference phenomenon of two strip footings on sand by conducting model tests. They varied the spacing of footings and found that at some critical spacing, the bearing capacity attains a maximum value. They also found that the bearing capacity values are similar to previous suggested theories.

L. S. Nainegali and P. K. Basudhar[4] conducted a finite element analysis of interference between two footings in sand. They varied parameters like spacing, width, length to width ratio, modulus of elasticity and found that these parameters greatly influence the load settlement behaviour of footings. They also found that settlement increases with decrease in spacing and reduces with improvement in slope angle.

Arash Alimardani Lavasan, Mahmoud Ghazavi, and Tom Schanz[5] studied the bearing capacity, settlement and failure kinematics of two circular footings in reinforced soil. They proposed a nonlinear elastic-plastic constitutive model to understand the behavior. They found that the bearing capacity increased 40% to 95% for a two layer reinforcement layer and the settlement increases up to 40% to that of single footing.

A. B. Cerato, A.M. and A. J. Lutenegger[6] studied the bearing capacity of footings in uniform sand layer with a rigid base at some depth. They used three different densities of sand and five different thicknesses. By conducting large scale model tests, they proposed modified bearing capacity factors.

Temel Yetimoglu, Jonathan T. H. Wu et al.[7] studied the strengthening of sand with reinforcements. They understood that the load carrying capacity of soil has an optimum value at some particular reinforcement embedding depth for both one layer and multi layer reinforcing systems. They also studied the effect of reinforcement number, size and stiffness.

G. Madhavi Latha, Amit Somwanshi[8] experimented the variation of loading behavior of two square footings using different reinforcing materials and at different embedment depth. The experimental values are compared with numerical results. They understood that bearing capacity does not much rely on tensile strength of reinforcement layer and also found that there is a critical position of reinforcement for providing maximum bearing capacity.

Mohamed I. Ramadan and Mohammed H. Hussien[9] studied the effect of loading in a two layered soil with sand overlying clay at different cases using experimental and numerical methods. They also explained the modes of failure in each case. Here the layered condition of soil is selected for the study.

3. MATERIALS

The materials selected for the experiment are river sand and geogrid sheet. The details regarding the materials are given below.

3.1 River sand

Fig -1: Sand collected

The sand is collected form Thodupuzha river. The sample is properly air dried for conducting the test. The properties of sand is determined as per IS specifications.

3.1.1 Tests on materials

The tests conducted on sand are as follows:
1. Specific gravity test
2. Grain size analysis
3. Relative density.

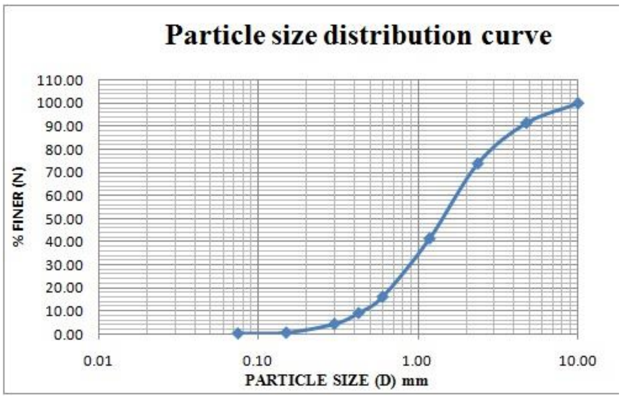

Chart -1: Grain size analysis for sand

Table -1: Properties of sand

Properties	Values
Specific gravity	2.61
Uniformity coefficient, Cu	4.1
Curvature coefficient, Cc	1.2
Angle of internal friction	37 °
Relative density	50%
IS classification	SP

3.2 Geogrid sheet

There are different types of materials available in market which are used as soil reinforcements. Here, a biaxial polypropylene geogrid sheet is used as a reinforcing material. The inclusion of soil reinforcements can increase the bearing capacity of soil to a great extend and is very useful in case of weak soil and slopes. The mass per unit area is 160 g/m^2. The tensile strength is 22 kN/m. The geogrid is shown in fig-2.

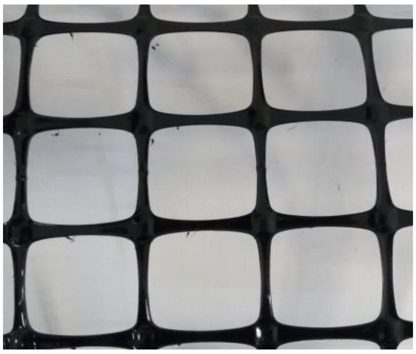

Fig -2: Biaxial geogrid sheet

4. METHODOLOGY

In this study we consider the load response of two square footings. The effect of spacing to width (S/B) ratio on Bearing Capacity Ratio is studied by varying the depth to width (D/B) ratio of footing. The conditions are tested for both unreinforced and reinforced cases and are compared. Footings of required scaled down dimensions are made which consist of square footings of 10cm x 10 cm size.

Fig -3: Sand filled in the tank

Tank was modeled for a dimension of 60 cm x 60 cm x 55 cm. Basic properties of sand was determined. The sand is filled in the tank in medium dense condition upto a depth of 50 cm (fig-3). The footings are placed on sand and tested by using a manual loading mechanism. The parameter varied here is the depth of footing and the tests are repeated for reinforced condition with two layers of reinforcements at a spacing of 3 cm from the base of footing (0.3B). The test results of both unreinforced and reinforced conditions are compared.

4.1 Preparation of sand bed

The sand was collected from river and it was dried completely. Based on the result of relative density test, the tank was filled in a medium density condition (50%). The sand was allowed to fall from a height of 27 cm inorder to achieve required density. It was filled upto a height of 50 cm. For reinforced sand case, two reinforcing sheets are provided at 3 cm gap below the footing base of each footing.

5. EXPERIMENTAL MODEL TEST

In order to apply the load, a frame is constructed and fixed on the top of the tank using proper fixing mechanisms. A proving ring is also attached to it, so as to measure the applied load (fig-4). A handle is provided to apply load manually by rotating it at a constant loading rate. The applied load is distributed equally to both the adjacent footings and settlement corresponding to each load is noted. The settlement is measured by means of dial gauges of least count 0.01 mm. In order to maintain a constant loading result, the footings are loaded to a settlement value equal to 10% of footing width, as per ASTM D1194. Here the footing width is 100 mm. So the maximum settlement value measured here is 10 mm.

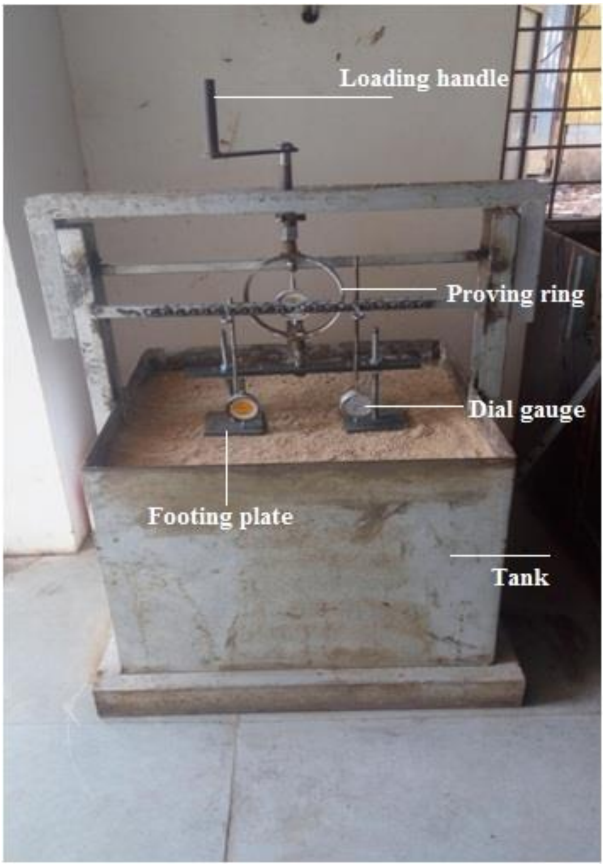

Fig -4: Manual loading arrangement

6. RESULTS AND DISCUSSIONS

The footings are tested for the above described conditions and the intensity of load versus settlement curves are plotted. From this it is clear that for all loading cases, the reinforced condition gives maximum bearing capacity as compared to that of unreinforced case. Also when interference occurs, the value of load capacity of footing plates reaches a peak value at a critical spacing and then decreases. Also, when the footing depth is considered, it is seen that as the depth of foundation increases, the bearing pressure on sand also increases in both reinforced and unreinforced cases. The variations are plotted below.

In order to understand the variation of bearing capacity, a dimensionless term has been used here. It is known as Bearing Capacity Ratio (BCR).

BCR = Bearing capacity of soil in case of adjacent Footings / Bearing capacity of single footing

Inorder to calculate the BCR, the load capacity of single footing is also required. For that, a plate load test is conducted for single footing (fig-5).

Fig -5: Loading arrangement of single footing

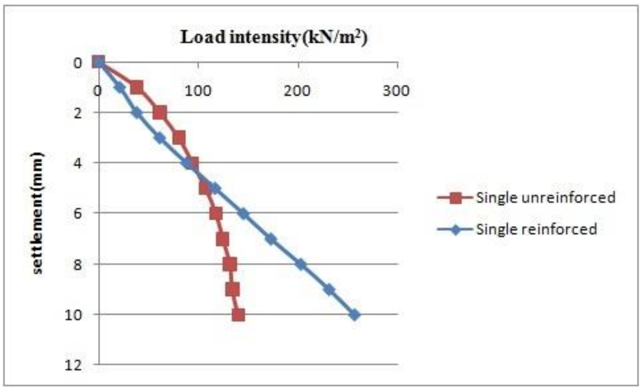

Chart -2: Variation of load intensity of single footing for unreinforced and reinforced cases

Based on the above test results, the Bearing Capacity Ratio (BCR) values for both unreinforced and reinforced cases are calculated (chart 2) and they are plotted against S/B ratio for the varying footing depths. For that, load capacity of individual footing is determined. The load intensity versus settlement curve is plotted for both unreinforced and reinforced conditions.

6.1 Loading behavior of two isolated footings

Here two isolated footings are loaded simultaneously, by varying their spacings (0.5B, 1B, 1.5B and 2B) at three different depths (0B, 0.1B and 0.2B) respectively. The intensity of load to settlement curves are plotted below. It gives a clear idea about how the loading condition changes as two individual footings come closer as compared to the load response of single footings separated far apart. The tests are repeated for reinforced soil also.

The variation of load intensity versus settlement corresponding to D/B ratios 0, 0.1 and 0.2 for unreinforced case are plotted and are shown in charts 3, 4, 5 and that for reinforced case are given in charts 6, 7 and 8 respectively. Also the variation of bearing capacity corresponding to S/B ratio are also plotted and the variations are well shown in charts 9 and 10 respectively.

Fig -6: Loading arrangement of two individual footings

In all the cases, load intensity up to 10 mm is measured and the bearing capacity value is selected based on this. According to ASTM D1994, termination of loading test can be done for a settlement of minimum 10% of footing width.

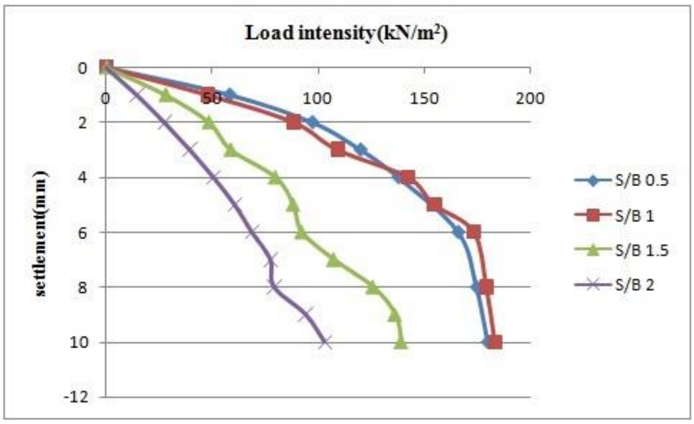

Chart -3: Load intensity versus settlement curve for D/B ratio = 0 (Unreinforced)

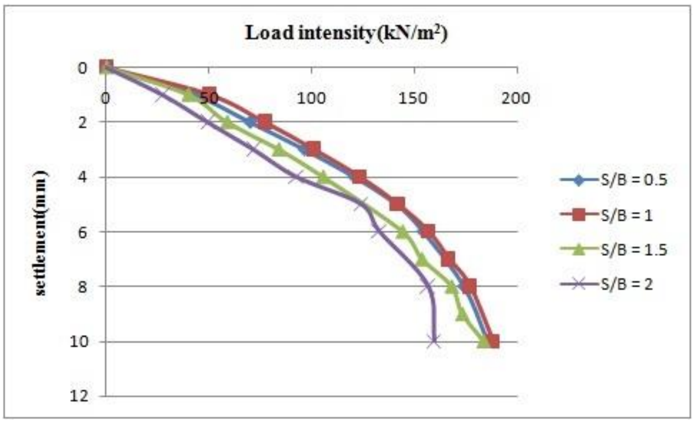

Chart -4: Load intensity versus settlement curve for D/B ratio = 0.1 (Unreinforced)

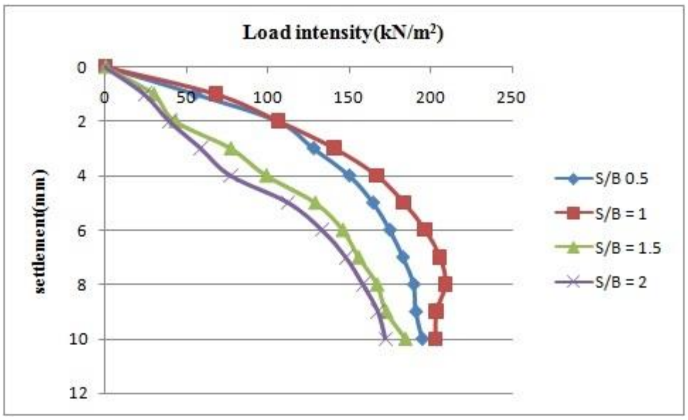

Chart -5: Load intensity versus settlement curve for D/B ratio = 0.2 (Unreinforced)

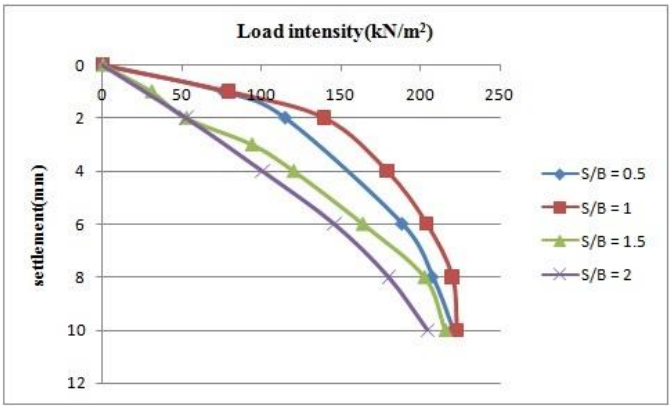

Chart -6: Load intensity versus settlement curve for D/B ratio = 0 (Reinforced)

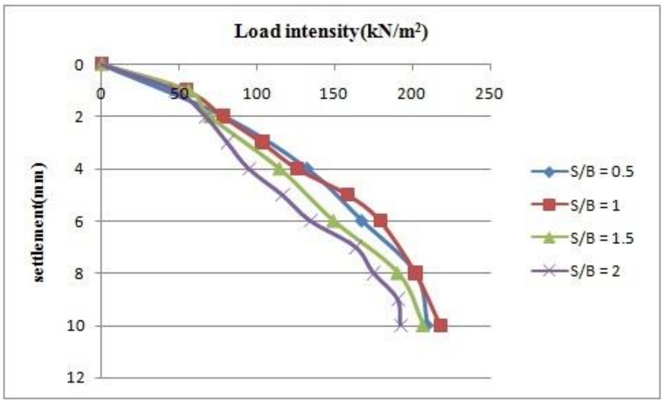

Chart -7: Load intensity versus settlement curve for D/B ratio = 0.1 (Reinforced)

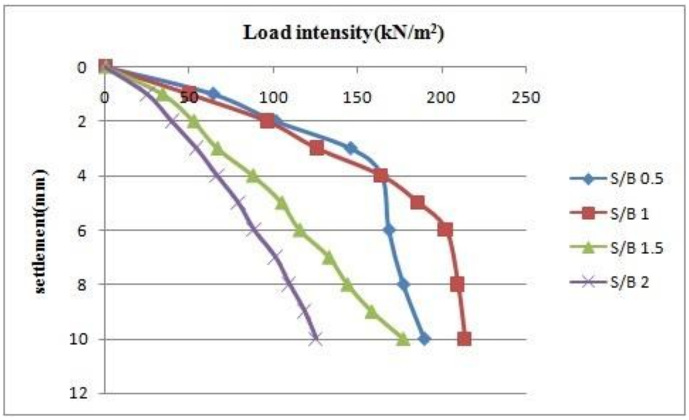

Chart -8: Load intensity versus settlement curve for D/B ratio = 0.2 (Reinforced)

From the curves plotted above the bearing capacity at different spacing conditions can be obtained.

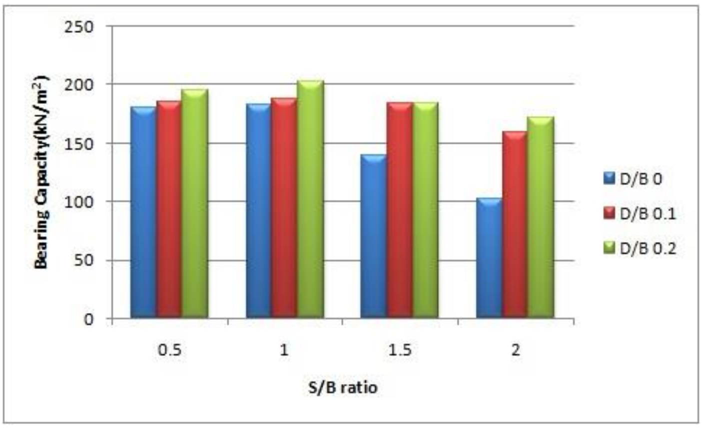

Chart -14: Variation of bearing capacity for unreinforced case

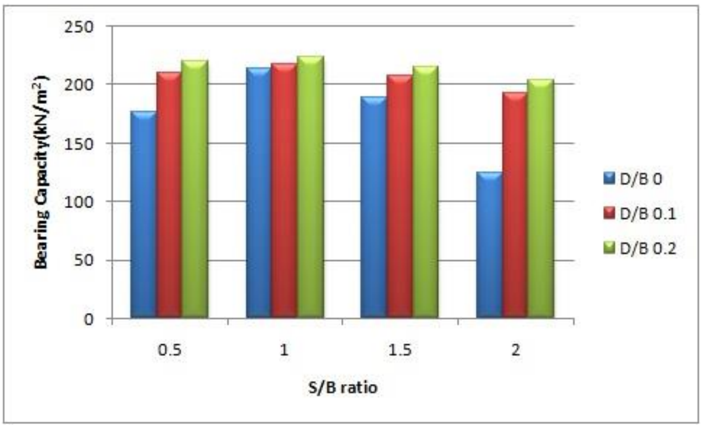

Chart -15: Variation of bearing capacity for reinforced case

In order to understand the comparison, the bearing capacity values are tabulated. The charts give a picture that when spacing between footings are changed, there occurs a different situation that bearing capacity increases, then reaches a maximum at critical spacing and then reduces.

Table -2: Variation of bearing capacity at different footing depth

Loading cases	BC (unreinforced) (kPa)	BC (reinforced) (kPa)
Single footing	140.4	256.7
For S/B 0.5 and D/B 0	136.5	176.3
For S/B 1.0 and D/B 0	183.2	213
For S/B 1.5 and D/B 0	179	189
For S/B 2.0 and D/B 0	102.7	124.7
For S/B 0.5 and D/B 0.1	185.5	209.5
For S/B 1.0 and D/B 0.1	185.8	218.1
For S/B 1.5 and D/B 0.1	183.5	209.2
For S/B 2.0 and D/B 0.1	159.6	202.1
For S/B 0.5 and D/B 0.2	205.3	220.4
For S/B 1.0 and D/B 0.2	210	223
For S/B 1.5 and D/B 0.2	190.9	215
For S/B 2.0 and D/B 0.2	172.2	204.2

Based on the above results, variations of BCR with S/B ratio are plotted (chart 17 and 18). The plot shows that, at depth equals 0.2B, the maximum value of bearing capacity ratio is achieved. The results thus obtained are given below.

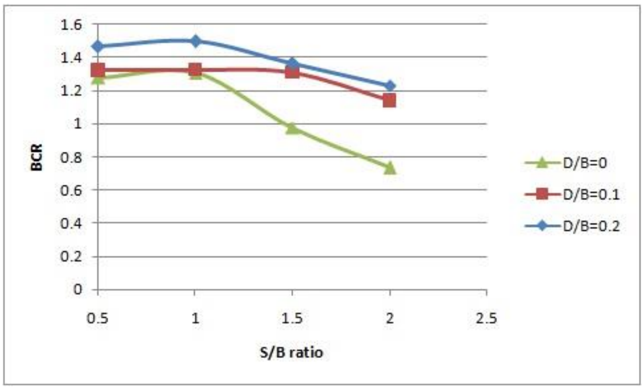

Chart -17: Variation of BCR for unreinforced condition

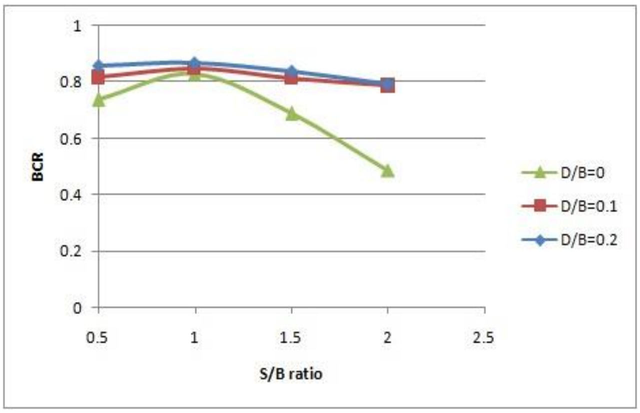

Chart -18: Variation of BCR for reinforced condition

6. CONCLUSIONS

- As the depth of footing increases, the value of bearing capacity also increases.
- The value of load capacity of soil first increases and reaches a peak value at a critical spacing, which is S/B = 1 and further decreases.
- This peak value occurs due to the effect of blocking and the value so obtained will be higher than that when the footings placed at zero spacing.
- The value of bearing capacity ratio (BCR) is higher for the D/B value 0.2.
- The reinforced soil gives a higher value of bearing capacity compared to unreinforced condition in all the depth variations (0B, 0.1B and 0.2B) respectively.
- The provision of geogrid reduces settlement.

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