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Study on Bearing Capacity of Rectangular Footing Resting over Geogrid Reinforced Sand under Eccentric Loading

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ABSTRACT

A number of works have been carried out for the evaluation of a ultimate bearing capacity of shallow foundation, supported by geogrid reinforced sand and subjected to centric load. Few experimental studies have been made on the calculation of bearing capacity of shallow foundation on geogrid-reinforced sand under eccentric loading. However, these studies are for strip footings. The purpose of this research work is to conduct model tests in the laboratory by utilizing rectangular surface foundation resting over the reinforced sand. The model tests have been conducted using rectangular footing with B/L=0.5 & 0.33. The average relative density kept up throughout all the tests is 69%. The sand is reinforced by multiple layers (2, 3 & 4) of geogrid. The eccentricity varies from 0 to 0.15B with an increment of 0.05B. Distance of first layer of geogrid layer from bottom of footing and the distance between two consecutive geogrid layers have been kept constant. The load settlement curve for each tests have been plotted to calculate ultimate bearing capacity. Parametric studies have been made to find the impact of eccentricity on bearing capacity of the foundation. The ultimate bearing capacity of eccentrically loaded square footings can be computed by knowing the ultimate bearing capacity of square footing under central load and a reduction factor (RkR) for reinforced condition.

INTRODUCTION

Foundation is the lower most hidden but very important part of any structure whether it is onshore or offshore structure. It is the part which receive huge amount of load from superstructure and distribute it to ground. So the foundation should be strong enough to sustain the load of superstructure. The performance of a structure mostly depends on the performance of foundation. Since it is a very important part, so it should be designed properly.

Design of foundation consists of two different parts: one is the ultimate bearing capacity of soil below foundation and second is the acceptable settlement that a footing can undergo without any adverse effect on superstructure. Ultimate bearing capacity means the load that the soil under the foundation can sustain before shear failure; while, settlement consideration involves estimation of the settlement caused by load from superstructure which should not exceed the limiting value for the stability and function of the superstructure.

A literature survey on this subject shows that the majority of the bearing capacity theories involve centric vertical load on the rectangular footing. However in some of the cases, footing undergo eccentric loading due to the eccentrically located column on footing or due to the horizontal force along with vertical load acting on the structure. Footing located at property line, machine foundation, portal frame buildings are some examples where the foundations experience eccentric loading.

LITERATURE REVIEW

After going through the literature, it has been found that several researchers worked on foundation problem. Some researchers worked on unreinforced sand bed while some worked on reinforce sand bed. At the same time, some researchers based their study on the results of prototype laboratory model testing while some researchers used theories based on finite element and numerical analysis to develop formulas to predict ultimate bearing capacity. Results that are available is related to the enhancement of load bearing capacity of shallow foundation supported by sand reinforced with metal strip, metal bar, rope fibers, geotextile and geogrid. Some of these tests were conducted using model square foundation while others using model strip foundation.

Terzaghi (1943) was first to proposed a theory to calculate the ultimate bearing capacity of shallow foundation. The foundation having depth less than or equal to width is considered as shallow foundation as per this theory. This theory assumed the foundation as strip foundation with rough base. The soil above the bottom of foundation is considered as the surcharge $q = \gamma Df$. The failure zone under the foundation is distinguish into three part i.e. one triangular zone just below the foundation, two radial shear zone and two Rankine passive zone. Using the equilibrium analysis

Meyerhof (1953) extended the bearing capacity theory of foundation under the central vertical load to eccentric and inclined load and gave a theory which is referred as effective area method. Analysis result of eccentric vertical loads on horizontal foundation is correlated with the result of model footing test on clay and sand. Further the theory is extended to central inclined loads on horizontal and inclined foundation and compared with model test result of footing on clay and sand.

Meyerhof (1963) proposed a generalized equation for ultimate bearing capacity of any shape of foundation (strip, rectangular or square) since Terzaghi (1943) do not report the case of rectangular footing and also do not consider the shearing resistance across the failure surface in soil above the bottom of foundation.

Huang and Tatsuoka (1990) performed a number of plane strain model test on a strip footing. The effect of length, the arrangements, the rigidity and the breaking strength of reinforcement were scrutinized systematically. The strain field in sand, the tensile force in reinforcement and the distribution of contact pressure on footing were measured. Based on the test result, a method of stability analysis by the limit equilibrium method was developed, taking into account the effect of the arrangement and properties of reinforcement and the failure mode of reinforced sand. The test result shows that the bearing capacity in sand can increase largely by reinforcing the zone immediately beneath the footing with stiff short reinforcement layer having only a length equal to the footing width.

Das and Omar (1994) performed laboratory model test to calculate the ultimate bearing capacity of surface strip foundation on geogrid reinforced sand and unreinforced sand. Effect of width of foundation and relative density of sand bed were also observed by changing these parameter. Model test result shows that BCR of given sand geogrid system decreases with increase in foundation width and reached to a practically constant value when width of foundation is equals or greater than about 130-140mm.

EQUIMENTS AND MATERIALS

General

The basic aim of this research is to discover the bearing capacity of reinforced sand bed. So the sand is the basic material which is used in this research work. Tensar Biaxial geogrid is used to reinforcing the sand. Hydraulic static loading machine is used to apply the concentrated load on the mild steel footing which is transferred to sand bed in form of distributed load. Test tank of dimension 1 X 0.504 X 0.655 m is used to prepare the sand bed.

Material Used

Sand

Sample Collection

The sand used in research work is collected from nearby Koel river. The sand is washed to make it free from soil, grass roots, and other organic materials and then the washed sample is dried in oven. The oven dried sample is first sieved on 710µ IS sieve and then the sand passing through 710µ IS sieve is again sieved on 300µ IS sieve. The sand sample retained by 300µ IS sieve is used for research work.

Static Loading Unit

A hydraulically operated static loading unit is used to apply the load on the foundation during test. The whole loading unit consist of one electrical panel, one power pack and one loading frame with shaft. Power pack consist of one oil tank filled with oil which is used to develop hydraulic pressure and it also consist of several valves to control the flow of oil to loading unit and hence control the movement of shaft. The shaft is supported by a horizontal beam which provide the reaction to the shaft during application of load.

Model Test And Methodology

General

To study the bearing capacity of eccentrically loaded foundation, laboratory model test has been performed on rectangular footing resting on sand bed reinforced with multilayered geogrid. Model test is performed on sand remolded at one density, footing with eccentricity varied from 0 to 0.15B and number of reinforcements varied as 0, 2, 3 & 4. Footing is resting on the surface of reinforced sand bed i.e. depth of embedment is zero in the test. Metallic ball is used as load transferring medium between shaft and model footing.

Sample Preparation

Placement Of Sand

Internal dimension of the test tank is measured and weight of sand to fill the tank upto a specified height is calculated using working density of 1.46gm/cc. Now sever trials are made to discover the height of fall of sand by allowing the sand to fall from different height to filling the tank up to desired height. After filling the tank upto desired height using raining technique, density of sand filled in tank for different trials is calculated. Height of fall for which the density is same as working density is taken for sample preparation. After finding out the height of fall, weight of sand require for 2.5cm thick layer to maintain the working density is taken and poured into the tank from specified height of fall using sand raining technique. Each layer is levelled using level plate to check whether the density is maintained properly or not. For the preparation of reinforced sand sample, geogrid is placed at desired depth from bottom of footing after levelling the surface to make it horizontal.

Model Test Procedure

Theoretical bearing capacity of the sand bed is calculated using Meyerhof's bearing capacity formula. Now this ultimate load is applied on the footing in 8 steps. Load to be applied in one steps is calculate by dividing the ultimate load by number of steps and then load in one step is again dividing by least count of proving ring used during the test to calculate the number of division in each step. Since the test is stress controlled, the load calculated in one step is applied on the footing and corresponding settlement is measured by taking average reading of both dial gauge fitted at two diagonally opposite corner of footing.

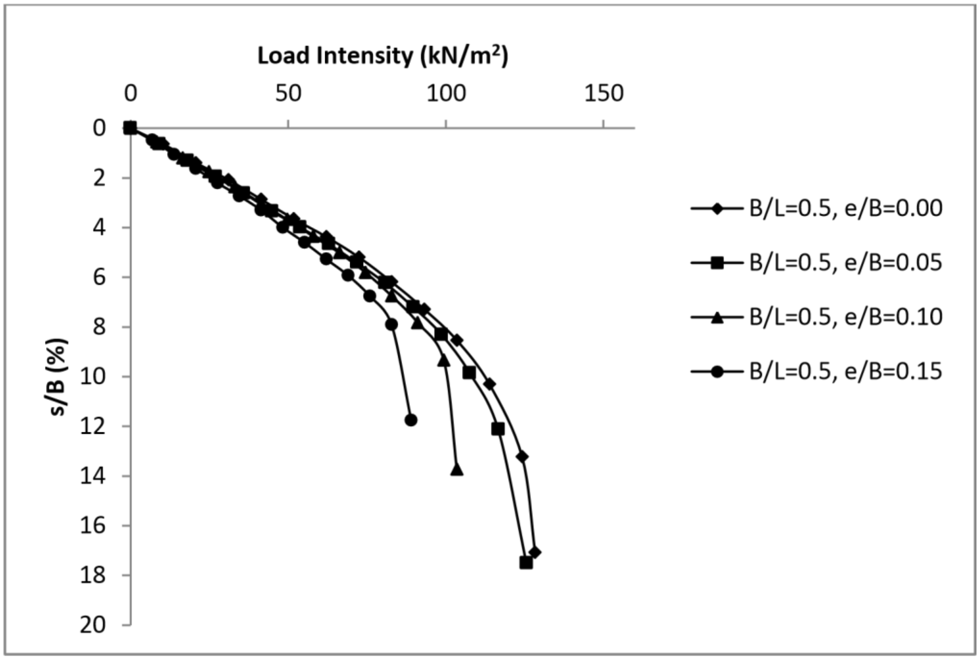
RESULTS AND ANALYSIS

Load tests have been performed on model rectangular footings of size 10cm 20cm and 10cm 30cm resting over unreinforced as well as reinforced sand bed with eccentricity varying from 0.0 to 0.15B. For preparing reinforced sand bed, multiple number (2, 3, 4) of geogrid (SS20) layers have been introduced. Settlement corresponding to each load increment is noted and the test result is plotted in term of load-settlement curve. Ultimate bearing capacity for each test is determined from load- settlement curve using tangent intersection method. Bearing capacity result is then analyzed to develop mathematical relationship for reduction factor (R_{KR}) which is the function of eccentricity width ratio (e/B) and the ratio of depth of reinforcement layer and width of footing (d_f/B).

Bearing Capacity Of Unreinforced Sand

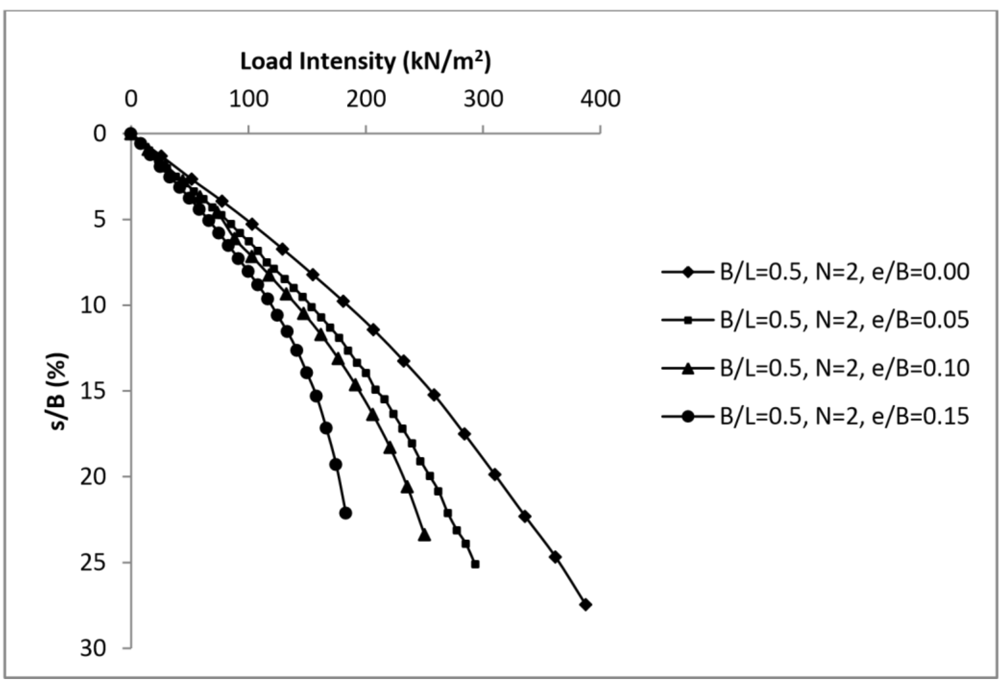
Model Test Result

Results of load test have been plotted in term of load-settlement curve as shown in Figure 5.1 & 5.2 for footing size 10 20cm (B/L = 0.5) and 10 30cm (B/L = 0.33) respectively. From the graph, it is observed that ultimate bearing capacity decreases as eccentricity width ratio (e/B) increases and also the total settlement at failure load decreases as eccentricity width ratio (e/B) increases. By comparing the graph shown in Figure 5.1 and Figure 5.2, it can also be concluded that as the width to length ratio (B/L) decreases, load carrying capacity of footing increases.



MODEL TEST RESULT

Laboratory model tests have been performed using rectangular footing with B/L=0.5 & 0.33 resting over the geogrid reinforced sand. The sand is reinforced by placing multilayer (N=2, 3, 4) geogrids with d_f/B ratio equals to 0.6, 0.85 & 1.1, where d_f is the depth of lower most geogrid layer from bottom of footing and B is the width of footing. The load is applied centrally as well as eccentrically on the model footing using static loading machine. Settlement corresponding to each load increment has been noted down and load settlement curve has been plotted. The ultimate bearing capacity has been found from load-settlement curve using tangent intersection method. Load settlement curve shown in Figure 5.10 to 5.15 is showing the effect of eccentricity on the load bearing capacity of footing on reinforced sand. From the graph it can be observed that load bearing capacity decreases with the increase in eccentricity.



RESULTS AND SCOPE OF FUTURE WORK

A number of laboratory model tests have been conducted to determine the ultimate load bearing capacity of rectangular model footings resting over geogrid reinforced sand and subjected to vertical eccentric load. All the tests have been conducted for footing resting on the surface.

Following are the summarized results of present research work.
The ultimate bearing capacity of the foundation for un-reinforced and reinforced soil decreases with the increase in eccentricity ratio i.e. e/B.

The ultimate bearing capacity of the foundation increases with the increase in number of reinforcement layer. Reduction factor for the footing with B/L=0.5 & 0.33 has been derived separately and then combined to get a simple generalized equation of reduction factor for rectangular footing as shown in Equation 5.11.

A comparison of the experiment and predicted ultimate bearing capacity for rectangular footings on reinforced sand bed by using concept of reduction factor is calculated using the derived relation and presented in Table 5.9. The maximum deviation of experimental from predicted is 7.14%.

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