Bearing Capacity of Rectangular Footing Resting Over Geo-grid Reinforced Sand under Eccentric Loading

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Abstract- A number of works have been carried out for the evaluation of an ultimate bearing capacity of shallow foundation, supported by geo-grid reinforced sand and subjected to centric load. Few experimental studies have been made on the calculation of bearing capacity of shallow foundation on geo-grid-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 geo-grid. The eccentricity varies from 0 to 0.15B with an increment of 0.05B. Distance of first layer of geo-grid layer from bottom of footing and the distance between two consecutive geo-grid 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 (R_{kR}) for reinforced condition. The reduction factor is developed based on the results of laboratory model tests on geo-grid reinforced soil. The ultimate bearing capacity of eccentrically loaded rectangular footing resting over geo-grid reinforced sand can be calculated by knowing the ultimate bearing capacity of rectangular footing resting over reinforced sand bed and subjected to central vertical load by using reduction factor (R_{kR}). An equation for reduction factor for rectangular footing resting over geo-grid reinforced sand is developed based on laboratory model test results.

Keyword: Ultimate Bearing Capacity, Reinforced Sand Bed, Eccentric Loading

I. 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.

Ultimate bearing capacity problem can be solved with the help of either analytical solution or experimental study. First one can be studied using theory of plasticity or finite element method, while the second is reached through performing laboratory model test.

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.

II. PREVIOUS WORK

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. Finally both results are combined for the analysis of foundation with eccentric inclined load.

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.

Khing et. al. (1993) performed laboratory model test for bearing capacity of strip foundation supported by sand reinforced with a number of geogrid. Based on the model test result, BCR based on ultimate bearing capacity and at level of limited settlement of the foundation has been determined. The BCR calculated on the basis of limited settlement appears to be about 60-70% of the ultimate BCR.

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.

III. METHODOLOGY

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.

Figure 1: Equipment Setup

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. After taking the reading on proving ring and dial gauge, load applied is calculated by multiplying the number of division on proving ring by it's least count and corresponding settlement is calculated by multiplying the dial gauge reading by it's least count i.e. 0.01. Now the load-settlement curve is drawn and using double tangent method, experimental bearing capacity is extracted.

IV. RESULTS AND ANALYSIS

Load tests have been performed on model rectangular footings of size 10*cm by* 20*cm* and 10*cm by* 30*cm* resting over unreinforced as well as reinforced sand bed with eccentricity varying from 0.0 to 0.15*B*. 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).

Results of load test have been plotted in term of load-settlement curve as shown in Figure 2 & for footing size 10 x 20*cm* (B/L = 0.5) and 10cm x 30*cm* (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 2 and Figure 3, it can also be concluded that as the width to length ratio (*B/L*) decreases, load carrying capacity of footing increases.

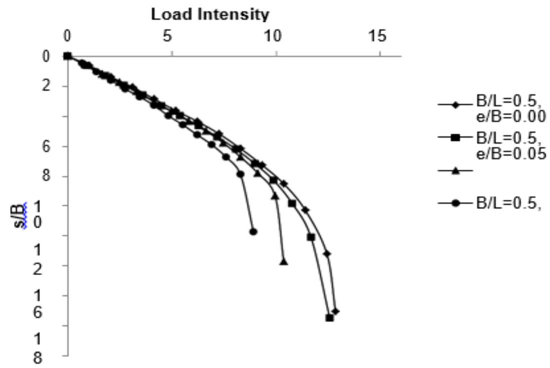

Figure 2: Load-settlement curve of unreinforced sand bed (B/L=0.5)

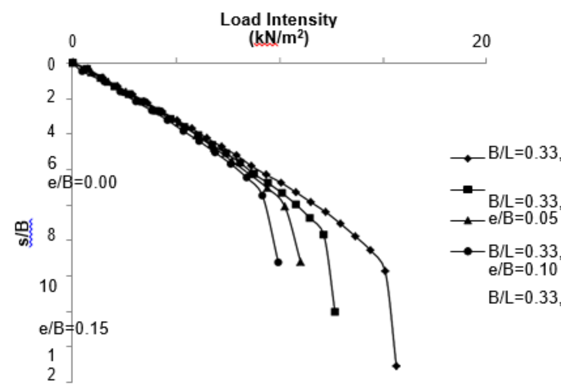

Figure 3: Load-settlement curve of unreinforced sand bed (B/L=0.33)

V. CONCLUSIONS

Following are the summarized results of present research work.

A. The ultimate bearing capacity of the foundation for un-reinforced and reinforced soil decreases with the increase in eccentricity ratio i.e. *e/*B.

B. The ultimate bearing capacity of the foundation increases with the increase in number of reinforcement layer.

C. 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.

- 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. The present research work is related to bearing capacity of eccentrically loaded rectangular footing with B/L

= 0.5 & 0.33 resting over reinforced sand bed. Due to time constraint, other aspects related to shallow foundations could not be studied. The future work should consider the below mentioned points:

1. The present work can be extended for footing with different B/L ratio and the result can be correlated with the result of present work.
2. A generalized equation for ultimate bearing capacity of reinforced sand bed can be derived for any shape (i.e. square, rectangular and strip) of footing.

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