Interference of Symmetrical Footings on Bearing Capacity of Soil

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Abstract:
Soil Reinforcement is an effective and reliable technique for improving the strength and stability of soil. The reinforced soil or mechanically stabilized earth is a compacted soil fill, strengthened by the inclusion of tensile elements like geogrids, geotextiles, metal bars and strips. It is now well established in heavy construction industry for the construction of structures like retaining walls, embankments over soft soil, steep slopes etc. In the present study, an attempt has been made to model the settlement behaviour of two footings placed with varying spacing on single layered soil deposit. The study revealed the interference affect the ultimate bearing capacity of adjoining footings. The ultimate bearing capacity was found to be influenced by its spacing. The ultimate bearing capacity of footings increased with decrease in spacing between the footings. The settlement of footings due to interference was found to be increased with decrease in spacing.

Keywords*: Interaction, Footing, Interface, Settlement and Bearing Capacity.*

I. INTRODUCTION

The foundation are designed for transmitting the loads from a structure to soil without causing any shear failure or settlement failure of the foundation[1]. For any project, the choice of a suitable bearing capacity of soil becomes the most important. However, due to scarcity of urban land, it is unavoidable to avoid the existence of nearby structures or footings. These footings when come closer affect the bearing capacity of footing. The interference effect or such footing become more complicated as layered soil exists below footing. The soil below footing exits in layers due to stratification. Its characteristics plays major role in transmitting the stresses. A layered deposit may present as strong layer reposing over the weak layer or weak layer resting on the strong deposit. The theory of elasticity and the finite difference method can be used for the solution. However, with advances in numerical analysis and finite element software solution, understanding the behavior of bearing capacity of two nearby square footings had become easier and correct. In present work, MIDAS3D FEM software had been used for analysis. The variation of bearing capacity of two nearby square footings was studied with respect to the depth of top weak layer and the clear spacing between two footings for vertical load. During the past four decades, innovative methods of improving soil properties have been extended to solve soil problems. These methods are generally regarded as the most economical ways to improve the conditions of undesirable sites compared to traditional construction methods. For example, use of rope fibers, metal strips, tire shreds, metal bars and geotextiles have proved that they improve soil properties such as shear, compression, hydraulic conductivity and density. For soil reinforcement use of stone columns, soil nailing, micro piles and reinforced soil. Also rising land costs and decreasing availability of areas for urban infill have established the situation that previously undeveloped areas are now being considered for the siting of new facilities. However, these undeveloped areas often possess weak underlying foundation materials – a situation that presents interesting design challenges for geotechnical engineers. To avoid the high cost of deep foundations, modification of the foundation soil or the addition of a structural fill is essential. One of the best methods to overcome soil problems is the use of synthetic materials, called as the geosynthetics.

There are many cases where the foundations of structures are subjected to cyclic loading in addition to static loading. Oil reservoir foundations with frequent discharges and filling or road embankments under repeatable traffic loads are examples of such foundations. Although the amplitudes of the cyclic load is usually less than the permissible static load, the concern still exists for the amount of uniform and non-uniform settlement of such structures. The soil under such foundations may be reinforced with geosynthetics to improve their engineering properties.

II. RELATED WORK

The effect of the interference of two footings on geogrid reinforced sand have been studied by various researchers: Khing [3], presented a study regarding some laboratory model test results for the ultimate bearing capacity of an isolated, and two closely-spaced, strip foundation resting on unreinforced sand, and sand reinforced with layers of geogrid. Based on the model test results, the variation of the group efficiency with the center-to center spacing of the foundation has been determined.

Kumar and Saran [4], discussed the results based on a total of 74 tests performed on closely spaced strip and square footings on geogrid reinforced sand. This study was carried out to evaluate the effect of spacing between the footings, size of reinforcement, and the continuous and discontinuous reinforcement layers on bearing capacity and tilt of closely spaced footing.

Kumar and Saran [5], presented an analysis for calculating the pressure of an adjacent rectangular footing resting on reinforced sand for a given settlement. An approximate method has been suggested to compute the ultimate bearing capacity of adjacent footings resting on reinforced earth slab.

Kumar and Walla [6], presented an approximate method to calculate the ultimate bearing capacity of a square footing resting on reinforced layered soil. The soil is reinforced with horizontal layers of reinforcement at the top layer of soil only. An approximate method has been suggested to compute the ultimate bearing capacity of square footing on reinforced layered soil. The predicted values of ultimate bearing capacity are in very good agreement with the experimental results.

Saran and Garg [7], presented a method of analysis for calculating the pressure intensity corresponding to a given settlement for eccentrically and obliquely loaded square and rectangular footings resting on reinforced soil foundation. In their analysis, a method suggested by Agrawal [1] has been used to draw pressure settlement characteristics of eccentrically and obliquely loaded footings on unreinforced soil.

El Sawwaf [8], studied the potential benefits of reinforcing a replaced layer of sand constructed on near a slope crest. Test results indicate that the inclusion of geogrid layers in the replaced sand not only significantly improves the footing performance but also leads to great reduction in the depth of reinforced sand layer required to achieve the allowable settlement. The objective of this research is to investigate the ultimate bearing capacity of two closely spaced strip footings on geogrids reinforced sand.
The finite element method is used to simulate the behaviour of the soil, footings and geogrids layers.

III. DESIGN METHODOLOGY

Foundations are mainly of two types: (i) shallow and (ii) deep foundations. The two different types are explained below:

A. Shallow Foundations

Shallow foundations are used when the soil has sufficient strength within a short depth below the ground level. They need sufficient plan area to transfer the heavy loads to the base soil. These heavy loads are sustained by the reinforced concrete columns or walls (either of bricks or reinforced concrete) of much less areas of cross-section due to high strength of bricks or reinforced concrete when compared to that of soil. The strength of the soil, expressed as the safe bearing capacity of the soil is normally supplied by the geotechnical experts to the structural engineer. Shallow foundations are also designated as footings. The different types of shallow foundations or footings are discussed below.

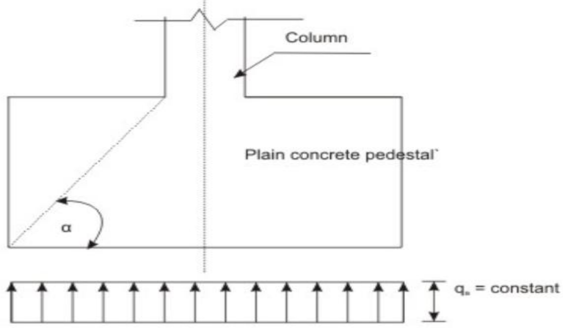


Fig.1 Plain Concrete Pedestal Footings

Plain concrete pedestal footings (Fig.1) are very economical for columns of small loads or pedestals without any longitudinal tension steel. In Fig.1 the angle α between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and the horizontal plane shall be determined.

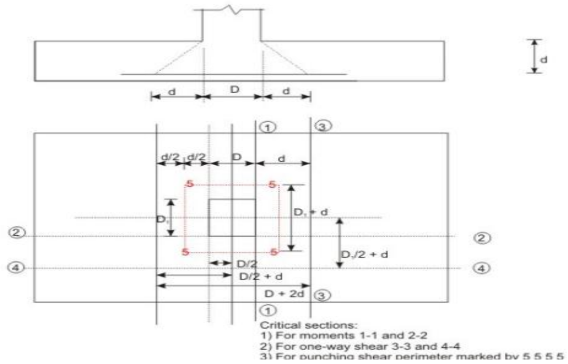


Fig.2 Uniform and Rectangular Footing

These footings are for individual columns having the same plan forms of square, rectangular or circular as that of the column, preferably maintaining the proportions and symmetry so that the resultants of the applied forces and reactions coincide. These footings, shown in Figs.2, consist of a slab of uniform thickness, stepped or sloped.

The work includes plate load test to evaluate the bearing capacity and settlement. The materials used for the work was Kanhan sand and footing of various shapes i.e. square, circular and rectangular made up of cast iron having constant area of $25cm^2$. The assembly for the plate load test setup is as shown in Fig.3 consisting of a tank of size 0.6m x 0.6m x 0.6m with a loading frame. The load is applied with the hydraulic jack and measured with the proving ring. Two dial gauges were placed on each flanges of footing to measure the anticipated settlement.

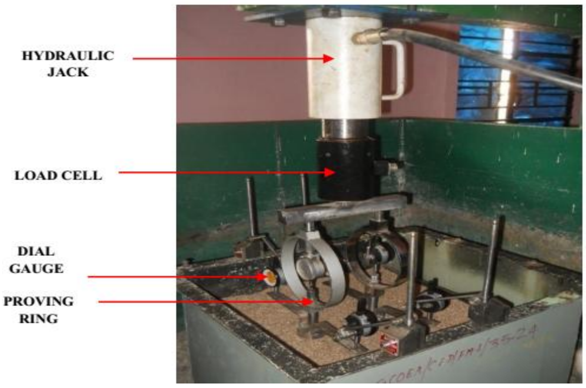


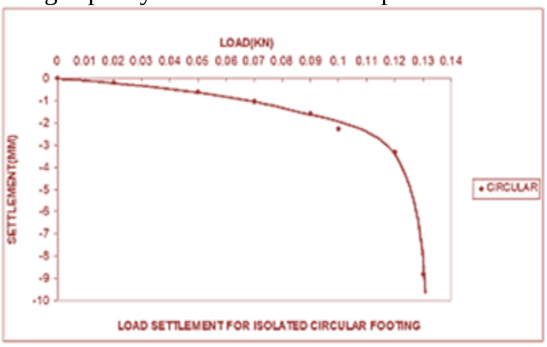
Fig.3 Assembly of Laboratory Plate Load Test

IV. RESULTS AND DISCUSSIONS

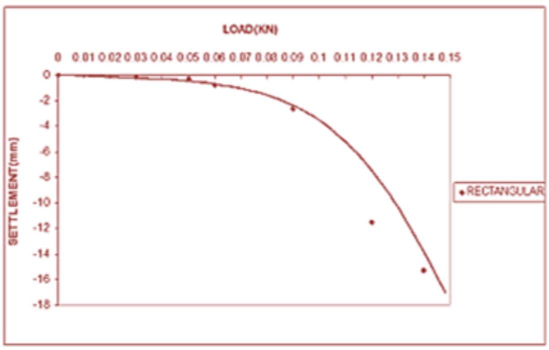
The geotechnical properties of sand were obtained by conducting different tests on [3]. The specific gravity of the sand was found to be 2.81 by pycnometer method. The dry density of sand by rainfall method is found to be 14.63kN/m^3. The angle of internal friction, Φ of the dry sand was found to be 20°. The plate load tests were conducted on square, circular and rectangular footing having same area of 25cm^2. The tests were conducted on isolated footing and twin footing with spacing of 15cm and 20cm. The results of plate load test were plotted and load settlement characteristic was studied.

A. Load Settlement Behaviour of Footings

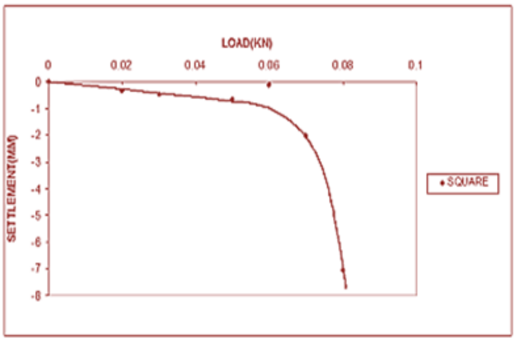
The load settlement curve for circular, square and rectangular isolated footings are shown in Fig.4. The ultimate failure load was determined and ultimate bearing capacity was calculated from plot.



(a) Circular Footing



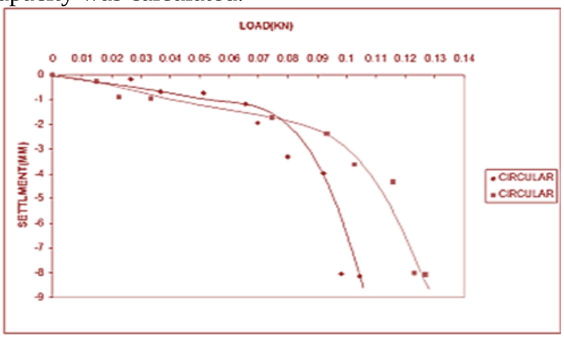
(b) Rectangular Footing



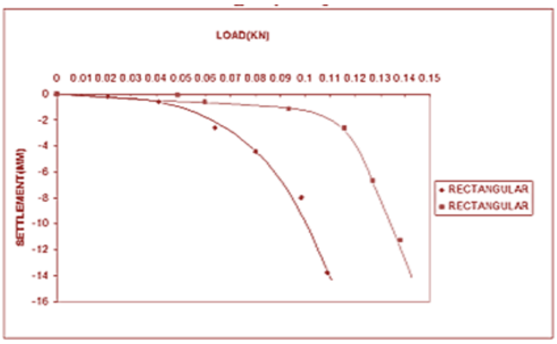
(c) Square Footing

Fig.4 Load Settlement Behaviour of Isolated Footings [10]

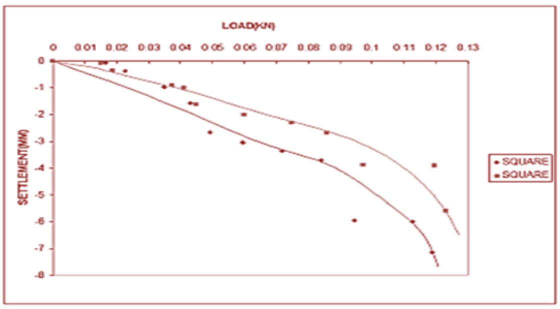
The effect of adjoining footing with 15 cm spacing between them was studied by recording the load on each proving ring and settlement by dial gauges separately. The load settlement curve was plotted as shown in Fig.5 from which the ultimate failure load was determined and ultimate bearing capacity was calculated.



(a) Circular Footing



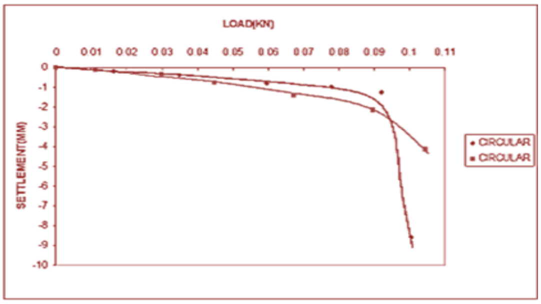
b) Rectangular Footing



(b) Square Footing

Fig.5 Load Settlement Behaviour of Footings Spaced at 15cm [10]

For footings with 20cm spacing, the loads for each proving ring were recorded and settlement by dial gauges. The load settlement curve was plotted as shown in Fig.6 from which the ultimate failure load was determined and ultimate bearing capacity was calculated.



(a) Circular Footing

Fig.6 Load Settlement Behaviour of Ultimate Failure Load [10]

B. Ultimate Bearing Capacities:

The ultimate bearing capacity for various shapes of footings of isolated footing and adjoining footing with different spacing are computed form load settlement plot by tangent method. The efficiency factor ($\xi\gamma$) which is defined as ratio of average pressure on an interfering footing of a given size associated with either an ultimate shear failure or a given magnitude of settlement to the average pressure on an isolated footing of a given size associated again with either an ultimate shear failure or the same magnitude of settlement.

V. CONCLUSIONS

The symmetrical footings interface is more common in present practice of construction. The ultimate bearing capacities of symmetrical shape footings for different shapes of footing and spacing was studied. The study reveals that ultimate bearing capacity of isolated footing was affected by the footing under interference. It was found that the ultimate bearing capacities were reduced irrespective of spacing between two footings due to interference. The settlement was observed to be same in symmetrical footing combinations.

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