Interference effect on the load-settlement behavior of Closely Spaced Axisymmetric Footings on Sand

Salini Patra[1] M. Ramakoteiah[1]

[1]Department of Civil Engineering, College of Engineering Bhubaneswar, India

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Abstract - Because to large loads, limitations in structure, and a lack of suitable construction locations, engineers frequently have to install footings closely spaced apart. The bearing capacity and load-settling behavior of these footings are influenced by one another. Generally, ring footings are used to support walls or columns in axisymmetric constructions, which typically have circular floor plans. It serves as the basis for many structures, including oil storage facilities, silos, chimneys, television antennas, and water and electricity transmission towers. This study used experiments to examine the load-bearing capacity of nearby circular and ring footings on sandy soil. This study aims to assess the interference effect on neighboring circular and ring footings' load-settlement behaviour. This study examines the influence of interference of footings as well as the impact of the distance between footing centers. Laboratory circular and ring footing models were employed to accomplish these goals. According to experimental findings, the load-carrying capability of two closely spaced circular and ring footings diminishes with increasing spacing to footing diameter ratio (S/D) and is maximum when they stand immediately next to one another. It is discovered that each adjacent footing's load carrying capacity is nearly equal to that of a single footing for S/D > 5. This indicates that no discernible interference effect was seen at center-to-center spacings larger than 5D, and each footing behaved almost independently, much like a single footing.

Keywords— *Interference, settlement, Circular footing, Ring footing, Interference factor*

1. INTRODUCTION

The bearing capacity of shallow foundations besides the parameters and conditions of the soil below the foundation depends on the shape of the foundation. Ring footings are generally used to support columns or walls of axisymmetricstructures which are normally circular in plan. It is used as foundation for water towers, transmission towers, television antennas, silos, chimneys and oil storage because it provides a more suitable and cost effective design. The use of ring footing decreases the amount of materials used and it is more economical.Due to heavy loads, structural restrictions and shortage of suitable sites for construction of structures, engineers are often required to place foundations at close spacing. Therefore, the foundations in the field generally interfere with each other to some extent and are rarely isolated. Interference of foundations can cause changes in bearing capacity and load-settlement behavior, when compared to isolated foundations. 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 variationcan be studied by varying the spacing between centres of the footings. Such an influence of closeness of footings in bearing capacity values is defined as the effect of interference of footings.

The goal of this study is to evaluate the interference effect on the load-settlement behavior of adjacent circular and ring footings. To investigate this, in this paper, the results of a series of laboratory tests on closely spaced model circular and ring footings on sand are presented. The experimental results of circular and ring footings are then compared and conclusions are made.

2. OBJECTIVES

The project aims at achieving the following objectives:

- To investigate the effect of spacing on the load settlement behavior of two closely spaced circular footings resting on sand.
- To investigate the effect of spacing on the load settlement behavior of two closely spaced ring footings resting on sand.
- To compare the interfering effect of two circular and ring footings using interference factor.

3. MATERIAL USED

Sand was chosen for the study and it was river sand obtained from Pattambi region, Palakkad. The sand was air dried for conducting all the laboratory tests. The properties of sand is determined as per IS specifications and Table 1 shows the basic properties of the sample.

Table -1: BASIC PROPERTIES OF SAND

Properties	Values
Specific gravity	2.65
Uniformity coefficient, C_u	2.4
Coefficient of curvature, C_c	0.77
Gradation of sand	SP
Max. dry density (g/cc)	1.819
Min. dry density (g/cc)	1.777
Soil friction angle	33°
Permeability (cm/s)	7.24×10^{-4}

4. LABORATORY MODEL TESTS

4.1 Model Tank and Footings

The experimental model tests were conducted in a test tank that had dimensions 1m×1m in plan and 0.6m in depth. The tank was made of steel. The load was applied by means of a hydraulic jack over which proving ring is connected in order to measure the applied load. A dial gauge is provided for the measurement of corresponding settlements.

Model ring footing made of mild steel with an outer diameter of 100mm and inner diameter of 40mm.Model circular footing having diameter same as the outer diameter of ring footing was made from mild steel. The inner to outer diameter ratio of the ring was 0.4. The thickness of model circular and ring footing was 15mm. The base of footings was made to have a rough surface by gluing a thin layer of sand using epoxy glue. The loading system was a hydraulic jack and the load was transformed equally to both of the footings using a rigid steel beam.

4.2 Test Setup

An experimental program was carried out to study the behavior of circular footings and ring footings resting on sand. A relative density of 50% was chosen for the soil medium, to carry out the tests, based on which the density of soil medium was determined. Density corresponds to 50 % relative density is obtained as 1.789g/cc. To achieve reasonably homogeneous sand beds of reproducible packing, fixed density method was used to deposit sand in to model tank. In this method, sand is filled in the tank with layers of equal thickness, 100 mm. Total depth of complete sand mass was kept equal to 50 cm. For each layer, mass of sand required to achieve the density was calculated. That total mass in each layer was filled by applying proper compaction. Footings were placed over leveled sand surface in the tank. It was placed at proper locations using plump bob and leveled using spirit level to avoid eccentric loading. Hydraulic jack was placed vertically between footings and reaction beam. Vertical loading shaft was installed between footings and proving ring to transfer the load properly. A horizontal loading beam was placed above the footings in order to transfer the load symmetrically. Load was applied using hand operated hydraulic pumping system. A proving ring of 100kN capacity was placed between the hydraulic jack and footings to monitor the applied load. Two dial gauges of 25mm capacity were used to monitor the settlement of footings during loading. The experimental setup is shown in the Fig. 1 given below.

Fig. 1 Experimental set up and loading arrangement

5. RESULTS AND DISCUSSIONS

5.1 Effect of Spacing on the Load Settlement Behavavior of Two Circular Footings

From the load settlement graph, it is clear that load carrying capacity of interfering circular footings is greater than that of isolated footings. At a centre-to-centre spacing of 1D the load and

Laboratory tests were conducted on a single circular footing and two circular footings placed centre-to-centre spacing, S. Spacing between centres of the footings were varied as 1D, 2D, 3D, 4D and 5D where D is the diameter of footing. Load settlement behavior of circular footings at various spacing is shown in the Fig. 2.

settlement of interfering circular footings is maximum. Ultimate load and settlement of interfering circular footings shows a similar trend that is decreases with increase in spacing. At a spacing of 5D the ultimate load and settlement is more or less similar to that of isolated footing. Therefore interference effect is negligible when the spacing between centres of the footings is greater than five times the footing size. For single circular footing the ultimate load at failure is 4.240 kN and at spacing 1D the ultimate load increased to 6.361 kN. That around 50% increases in ultimate load at failure as compared to isolated footing. In case of settlement, settlement increased by 16.24% at a spacing of 1D as compared to isolated footing. Since ultimate load and settlement is maximum at spacing 1D, so spacing 1D can be considered as critical spacing between centres of the footings. Load and settlement shows a similar trend, which increases with decreasing the spacing between centres of the footings, this occur due to the phenomena called blocking.Laboratory tests were conducted on a single circular footing and two circular footings placed centre-to-centre spacing, S. Spacing between centres of the footings were varied as 1D, 2D, 3D, 4D and 5D where D is the diameter of footing. Load settlement behavior of circular footings at various spacing is shown in the Fig. 2.

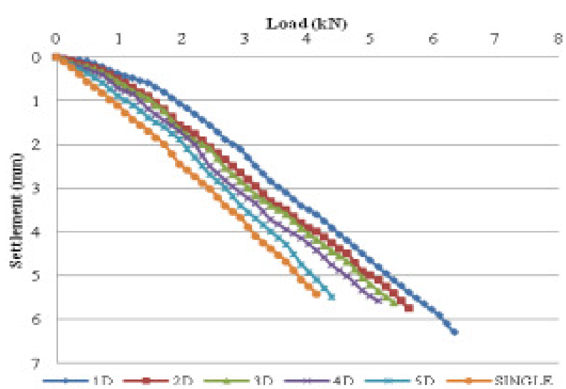

Fig. 2 Load settlement behavior of interfering circular footings

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From the load settlement graph, it is clear that when it reaches the spacing 5D the load carrying capacity is same as that of isolated footing. That is at spacing 5D the two ring footings will be acting as an individual footings. As spacing decreases the bearing capacity and settlement increases. At spacing 1D it attains a maximum value where as the spacing increases the load carrying capacity is decreasing. For single ring footing the ultimate load was about 4.687 kN and at spacing 1D the ultimate load increased to 6.807 kN. That around 45.23% increases in bearing capacity as compared to isolated footing. In case of settlement, settlement increased by 19.33% at spacing of 1D as compared to isolated footing. So spacing 1D can be considered as critical spacing between centres of the footings. Bearing capacity and settlement shows a similar trend, which increases with decreasing the spacing between centres of the footings, this occur due to the phenomena called blocking which is similar to the case of two circular footings..

5.2. Effect of Spacing on the Load Settlement Behavior of Two Ring Footings

Laboratory tests were conducted on a single ring footing and two ring footings placed centre-to-centre spacing, S. Spacing between centres of the footings were varied as 1D, 2D, 3D, 4D and 5D where D is the diameter of footing. Load settlement behavior of ring footings at various spacing is shown in the Fig. 3.

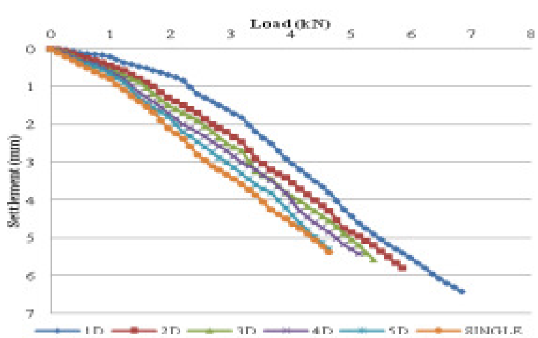

Fig. 3 Load settlement behavior of interfering ring footings

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5.3. Interference factor on load carrying capacity of interfering circular and ring footings

Interference factor (IF) on load carrying is the ratio of ultimate bearing capacity of interfering footing to the ultimate bearing capacity of the single footing, it is given bythe equation

$$IF = \frac{\text{Ultimate bearing capacity of interfering footings}}{\text{Ultimate bearing capacity of single footing}}$$

Interference factor will be always higher than 1 for an interfering footing. Fig. 4 shows the variation of the interference factor at various S/D ratios.

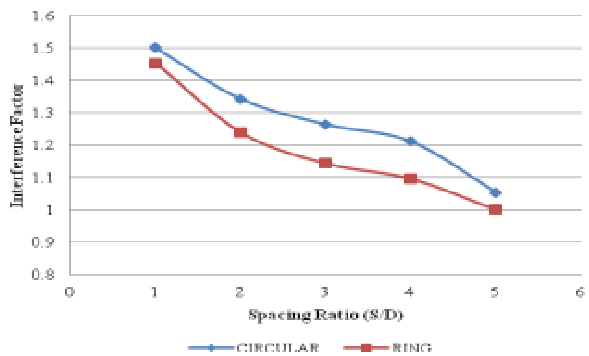

Fig. 4 Interference factor at failure of interfering circular and ring footings at various S/D ratios

For circular and ring footings at spacing between centres of the footing 1D the interference factor attains a maximum value <1.4. At spacing 5D interference factor of circular footing is greater than 1 hence at spacing 5D there is interference effect but in case of ring footing at spacing 5Dthere is no interference effect. Since the interference factorfor ring footings at spacing 5D =1.

6. CONCLUSION

In this study a number of laboratory model tests were performed to determine the interference effect of closely spaced circular and ring footings resting on sand. Based on the results of model tests, the following conclusions are drawn:

- Load settlement behavior of interfering footing depends on the spacing between centres of the footings.
- Due to interference effect load carrying capacity of interfering footings is always higher than that of single isolated footing.
- Bearing capacity and settlement of interfering circular and ring footings follows a similar trend, which decreases with increasing in spacing.
- At spacing of 1D, load carrying capacity of interfering circular and ring footings attains a peakvalue.
- Load carrying capacity increased by 50% and 45.23% for both circular and ring footings respectively as compared to isolated footing at spacing 1D.
- Settlement at failure increased by 16.24% and 19.33% for both circular and ring footings respectively as compared to isolated footing at spacing 1D.
- Magnitude of interference factor of interfering footing at failure is always higher than 1 and it is attains a maximum value at a centre to centre spacing of 1D for both circular and ring footing.
- At spacing 5D, there is no interference effect for ring footing, that is the two footings will be acting as individual footings.

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