

# Behavior of Eccentrically Loaded Ring Footing on Sand

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**ABSTRACT:** Ring foundations are often adopted for large and tall structures to resist lateral loads and to increase the stability against overturning. They have been used worldwide under various structures, including telecommunication towers, liquid storage tanks, bridges and offshore structures. The performance of a structure mostly depends on the performance of foundation. However, the behavior of these foundations has not been well understood. Since it is a very important part, it should be designed properly. 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. This paper presents the behavior of ring footing under eccentric loading on sand. The effects of ring radii ratio and load eccentricity have been investigated by means of experimental investigation.

**KEYWORDS:** Foundation, lateral loads, ultimate bearing capacity, eccentric loading

## I. INTRODUCTION

Ring footings are generally used to support columns or walls of axi-symmetrical structures, which are normally circular in plan. They have been applied worldwide for various structures, including foundation for water towers, transmission towers, television antennas, silos, chimneys, and oil storage. The use of ring footing decreases the amount of material used and it is more economical.

The bearing capacity of soil is a main concern in foundation design. In case where ring footings are constructed on relatively extensive layers of cohesion less soil, the bearing capacity will be reduced and the settlement will be increased. This leads to a great increase in footing size or the use of deep foundation which makes the design uneconomical. By using ring footing with suitable radius ratio, bearing capacity can be increased.

This paper is organized as follows. Section II describes previous similar work done by various researchers. The material used for the test and the test procedure is given in Section III. Section IV presents experimental results. Finally, Section V presents conclusions.

## II. RELATED WORK

Several experimental, analytical and numerical analyses were performed on eccentrically loaded footing resting on soil which is unreinforced by various authors.

Zhu (1998)<sup>1</sup> conducted a centrifuge modelling and numerical analysis of bearing capacity of ring foundations on sand to investigate the bearing capacity of ring footings on a dense sand under vertical loads. It was found that for eccentrically loaded ring footings, the bearing capacity decreases with increase in load eccentricity.

Mehrjardi (2008)<sup>2</sup> studied on Bearing Capacity and settlement of ring footings. The behavior of ring footing with circular footing are compared and presented its design method.

Albusoda and Hussein (2013)<sup>3</sup> presents an experimental study to determine Bearing Capacity of Eccentrically Loaded Square Foundation on Compacted Reinforced Dune Sand over Gypseous Soil. It was found that Bearing capacity

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Vol. 5, Issue 4, April 2016

increases to 2.5 to 3.0 times after replacement and reinforcement of gypseous soil. For eccentric loads, the load carrying capacity decreases with the increase of eccentricity value.

Atalaret.al (2013)<sup>4</sup> presented the paper on Bearing capacity of shallow foundation under eccentrically inclined load. The results of a number of laboratory model tests conducted to determine the ultimate bearing capacity of a strip foundation supported by sand and subjected to an eccentrically inclined load with an embedment ratio varying from zero to one have been reported.

Dharet al. (2013)<sup>5</sup> conducted a study on Behaviour of Rigid Footing under Inclined and Eccentric loading. It was found that with increase of eccentricity of applied loading whether vertical or inclined, load carrying capacity also decrease. Irrespective of eccentricity the load carrying capacity of footing decreases with increase in the angle of inclination of loading.

Algin (2014)<sup>6</sup> conducted the study on Elastic Settlement under Eccentrically Loaded Rectangular Surface Footings on Sand Deposits. The analytical closed form solutions and the resulting influence factors were presented for estimating the elastic settlement under eccentrically loaded footing. The equations are also developed for the theoretical cases where the location of incompressible soil layer is infinitely deep.

### III. METHODOLOGY

The main objective of experiment is to study the behavior of eccentrically loaded small-scale ring footings resting on reinforced soil.

#### 1. Test Material and their Properties

- Test sand

For the model tests, cohesionless, washed, dried, and sorted by particle size was used as the foundation material. It was composed of rounded to sub-rounded particles, as shown in fig.1. The geotechnical and engineering properties of sand such as specific gravity, density, angle of internal friction, etc., were determined by conducting various lab test. The values of these properties are given in table1



Figure 1: Sand

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Table 1 : Properties of sand

Sr. No.	Properties	Value
1	Specific Gravity	2.69
2	$V_{max}$	16.254 kN/m <sup>3</sup>
3	$V_{min}$	15.76 kN/m <sup>3</sup>
4	Bulk Density (kN/m <sup>3</sup> )	15.953 kN/m <sup>3</sup>
5	Height of Fall (cm)	30 cm
6	Angle of Internal Friction	32°
7	Coefficient of Uniformity $C_u$	2.234
8	Coefficient of Curvature $C_c$	1.021
9	Effective Size $D_{10}$	0.47
10	I.S. Classification	Medium sand, SP grade

- Model Footing

The model ring was fabricated by using mild steel plate. Model footing consists of 100mm diameter of circular footing and for ring footing 100 mm outer diameter and different inner diameters was considered. The inner diameters 20mm, 40 mm, 60 mm were considered.

## 2. Procedure for Test Setup

The detailed test procedure adopted for experimental investigation is explained below-

- Preparation of Sand Bed

The tank of 600 mm x 600 mm x 450 mm was filled with the dry sand of 2mm passing and retaining on 450 $\mu$  sieve up to a depth of 100 mm tank by using the sand raining technique (hopper method). Prior to that, the side walls of the tank was made smooth by coating with a lubricating gel to reduce the boundary effects. Whenever the sand was deposited up to the location of the desired layer the top surface of the sand was levelled. Figure 2 shows the test arrangement.



Figure 2: Test Arrangement

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

### Model Plate Load Test Procedure

For the experimental work, the model plate load tests were conducted on sand as per IS 15284 (Part 1): 2003 to evaluate the bearing capacity and settlement. After preparation of sand bed, the model footing was placed at the centre of the tank. Then two dial gauges were placed on the flanges of the footing. The load was applied on the footing with the help of a screw jack in increments. Each load increment was approximately equal to 1/5<sup>th</sup> of the expected ultimate load. The load transferred to the footing was measured through a proving ring placed between the footing and screw jack. Footing settlements were measured through two dial gauges placed on either side of the centre line of the footing. The footing settlement was reported as the average value of the readings taken at the two different points. The experimental test setup is shown in Figure 3.

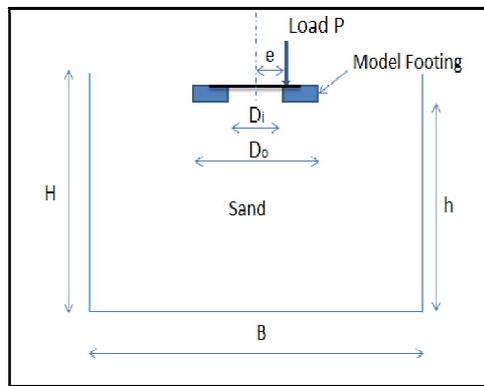


Figure 3: Equipment Setup

- where,  $e$  = Eccentricity  
 $P$  = Load intensity  
 $D_i$  = Inner diameter of footing  
 $D_o$  = Outer diameter of footing  
 $h$  = Depth of sand  
 $B$  = Width of tank  
 $H$  = Height of tank  
 $D_i/D_o$  = Inner to outer diameter ratio (Ring radii ratio)  
 $e/D_o$  = Eccentricity to outer diameter ratio.

### IV. EXPERIMENTAL RESULTS

The various parameters for study include inner to outer diameter ratio, and eccentricity of loading. The details of parameters study are given in table 3.

Table 3: Details of Size of Model Footing

Sr. No.	Outer Diameter ( $D_o$ )	Inner Diameter ( $D_i$ )
1	100mm	20mm
2	100mm	40 mm
3	100mm	60mm
4	100 mm	80 mm

The test was conducted at various  $e/D_o$  ratios for circular footing and ring footing. The results obtained for circular footing at various  $e/D_o = 0, 0.05, 0.1, 0.15$  are shown in fig. 4.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

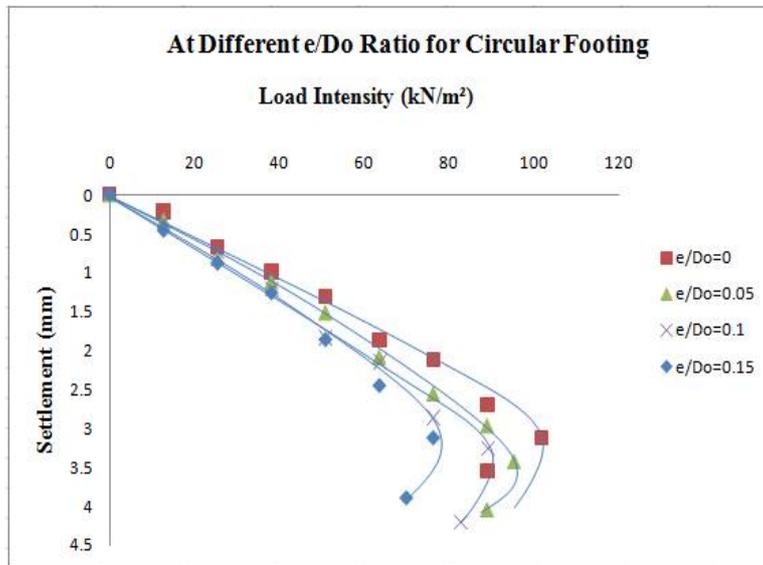


Figure 4: Load-Settlement curves of different e/Do ratio for Circular Footing

Ring footing of different ring radii ratios ( $D_i/D_o$ ) 0.2, 0.4, 0.6 was used with different ratio of eccentricity  $e/D_o = 0, 0.05, 0.1, 0.15$  on sand. The corresponding load settlement graph is drawn. The load settlement graph at different  $e/D_o$  ratio for  $D_i/D_o=0.2$  is shown in figure 5.

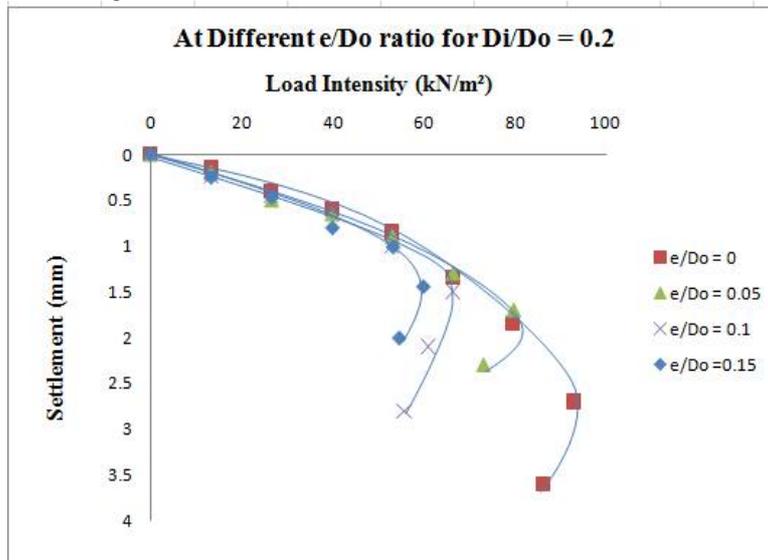


Figure 5: Load-Settlement curves of different e/Do ratio for ring footing of  $D_i/D_o=0.2$

The load settlement graph at different  $e/D_o = 0, 0.05, 0.1, 0.15$  for ring footing of  $D_i/D_o=0.4$  is shown in figure 6.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

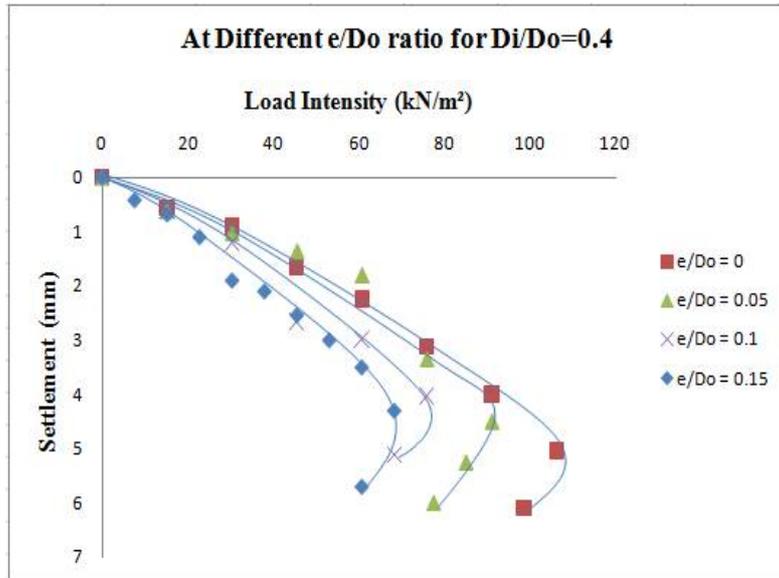


Figure 6: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.4

The load settlement graph at different e/Do = 0, 0.05, 0.1, 0.15 for ring footing of Di/Do=0.6 is shown in figure7.

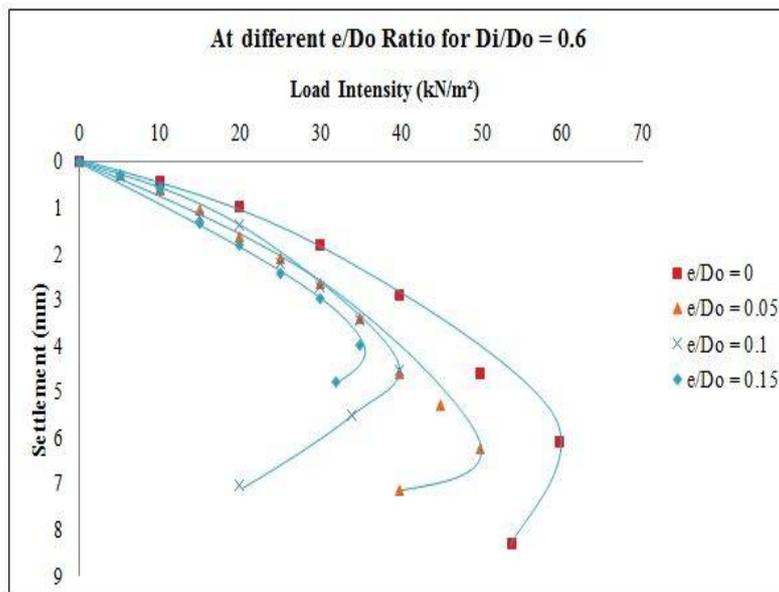


Figure 7: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.6

The load settlement graph at different e/Do = 0, 0.05, 0.1, 0.15 for ring footing of Di/Do=0.8 is shown in figure 8. From the result it is observed that the ring footing having ring radii ratio of 0.8 gives minimum bearing capacity.

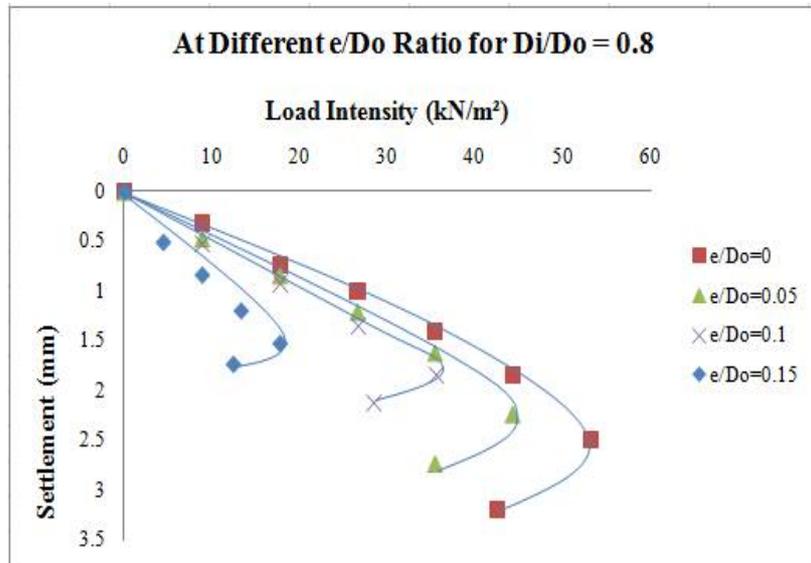


Figure 8: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.8

Fig. 9 shows the comparison between ring footing with different ring radii ratio (0.2, 0.4, 0.6, 0.8) and circular footing. Form the result it is observed that the bearing capacity of circular footing is more than ring footing. Among all the ring footing the ring footing having ring radii ratio of 0.4 gives maximum bearing capacity.

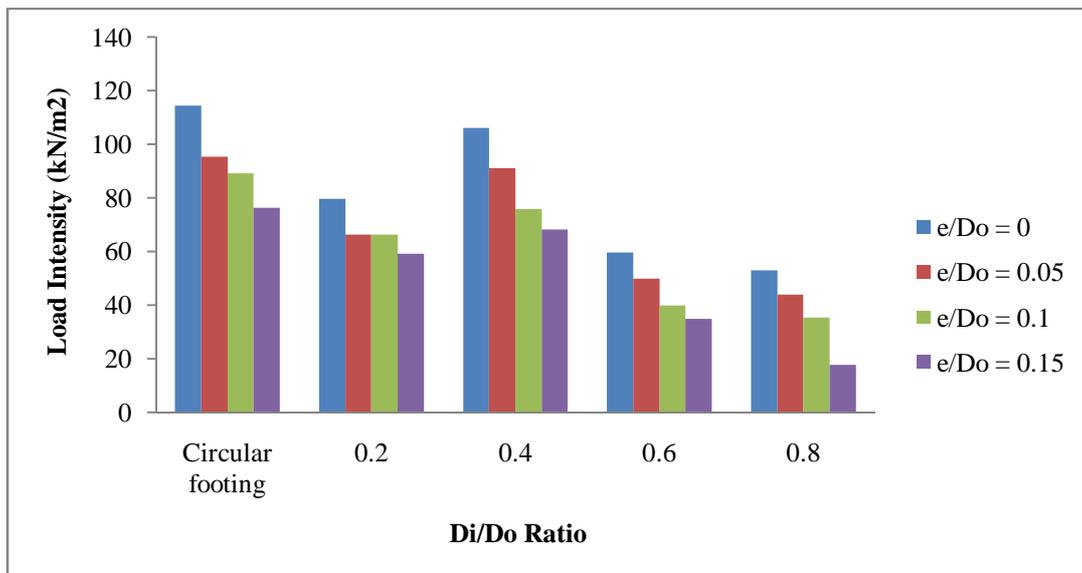


Figure 9: Comparison between ring footing and circular footing.

### V. CONCLUSION

Based on experimental investigation the following conclusions can be drawn-

- The bearing capacity of ring footing is found to be maximum at ring radii ratio (Di/Do) of 0.4.
- As eccentricity increases bearing capacity decreases.

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