

Eccentrically Loaded Ring Footing on Reinforced Sand

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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. This paper presents the behavior of ring footing under eccentric loading on sand. The model tests have been conducted using ring footing with ring radii ratio (D_i/D_o)=0.4, 0.6, 0.8 for varying eccentricity ratio. Parametric studies have been made to find the impact of eccentricity ratio, ring radii ratio and geogrid reinforcement on bearing capacity of the foundation.

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

I. INTRODUCTION

For any load-based structure, the foundation is very important and has to be strong to support the entire structure. For the foundation to be strong, the soil around it plays a very critical role. 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. The ring foundations are more suitable and economical to provide support for axi-symmetric structures such as bridge piers, underground stops, water-tower structures, transmission towers, TV antennas, silos, chimneys, and storage tanks. With the increasing use of these foundations in many important projects, interest in their behavior has intensified. This behavior includes the load-displacement response and the ultimate bearing capacity.

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 and reinforced by various authors.

Zhu (1998)¹ 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)² studied on Bearing Capacity and settlement of ring footings. The behavior of ring footing with circular footing are compared and presented its design method.

Sawwaf and Nazir (2012)³ presents an experimental study of the behavior of an eccentrically loaded model ring footing resting on a compacted replaced layer of sand that overlies an extended layer of loose sand. It was found that the inclusion of soil reinforcement causes additional considerable improvements in the BCR of the ring footings, which increases with the number of geogrid layers for both sand densities.

Albusoda and Hussein (2013)⁴ 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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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.

Atalar *et.al* (2013)⁵ 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.

Dhar *et al.* (2013)⁶ 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)⁷ 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.



Figure 1: Sand

The geotechnical and engineering properties of sand such as Bulk density, specific gravity, coefficient of uniformity, etc. are shown in table1.

Table 1 : Properties of sand

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

- Model Footing

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The model ring was fabricated by using mild steel plate. Model footing consists of ring footing of 100 mm outer diameter and different inner diameters were considered. The inner diameters 40 mm, 60 mm, 80 mm were considered.

▪ **Reinforcement**

Commercially available continuous biaxial geogrid was used for reinforcing the sand bed. It is usually made from polymer materials, such as polypropylene, polyethylene or polyester. The size of biaxial geogrid reinforcement used was four times the size of the footing. The top surface of the sand was leveled and the biaxial geogrid reinforcement was placed. The geogrid used for the test is as shown in Fig. 2.

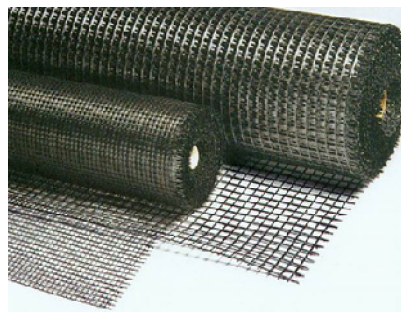


Figure 2: Geogrid

The various properties of geogrid such as ultimate tensile strength, elongation at break, aperture size etc., are mentioned in table 2.

Table 2 : Properties of Geogrid

Property		Test method	TGB-30	
Ultimate Tensile Strength (kN/m)	MD	ASTM D 6637 EN ISO-10319	30	
	CD		30	
Elongation at break (%)	MD		13	
	CD		13	
Tensile Strength at 2% strain (kN/m ²)	MD		7	
	CD		6.5	
Tensile Strength at 5% strain (kN/m ²)	MD		13	
	CD		12	
Aperture Size (mm)	MD X			26 X 26
	CD			

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 μ 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 is deposited up to the location of the desired layer of reinforcement, the top surface of the sand was leveled and the geogrid reinforcement was placed. The length of reinforcement (L) was taken as four times the outer diameter of footing (4Do). The number of reinforcing layer (N) was taken as 3. The spacing of reinforcing layer (s) and the depth of top layer of reinforcement (u) adopted was 0.3 times the outer diameter of footing (0.3 Do).

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Figure 3: Test Arrangement

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 placed on the flanges of the footing. The load was applied on the footing with the help of screw jack in increments. Each load increment was approximately equal to $1/5^{\text{th}}$ of the expected ultimate load. The load transferred to the footing was measured through 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 4.

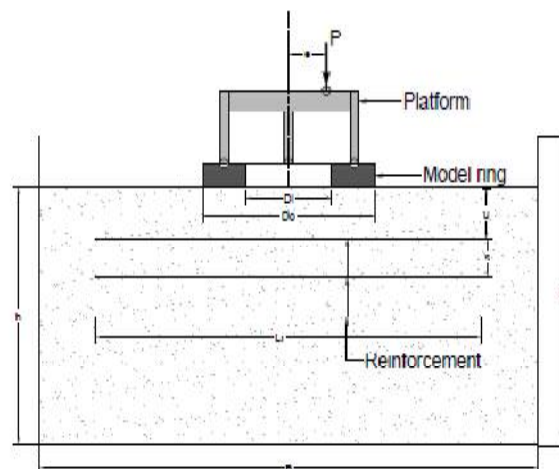


Figure 4: Equipment Setup

where, e = Eccentricity
 P = Load intensity

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- 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 is given in table3.

Table 3: Details of Size of Model Footing

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

The test was conducted on Ring footing of different ring radii ratios (D_i/D_o) 0.4, 0.6, 0.8 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 for ring footing of $D_i/D_o=0.4$ is shown in figure 5.

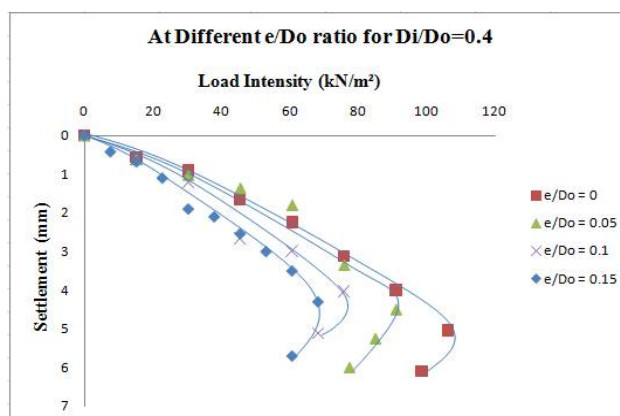


Figure 5: Load-Settlement curves of different e/D_o ratio for ring footing of $D_i/D_o=0.4$

The load settlement graph at different $e/D_o = 0, 0.05, 0.1, 0.15$ for ring footing of $D_i/D_o=0.6$ is shown in figure6.

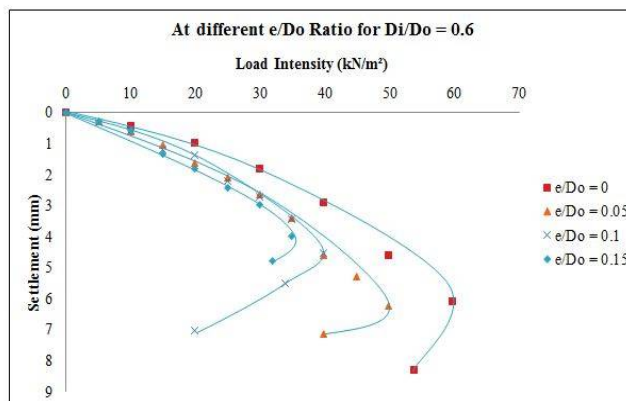


Figure 6: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.6

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 7. From the result it is observed that the ring footing having ring radii ratio of 0.8 gives minimum bearing capacity.

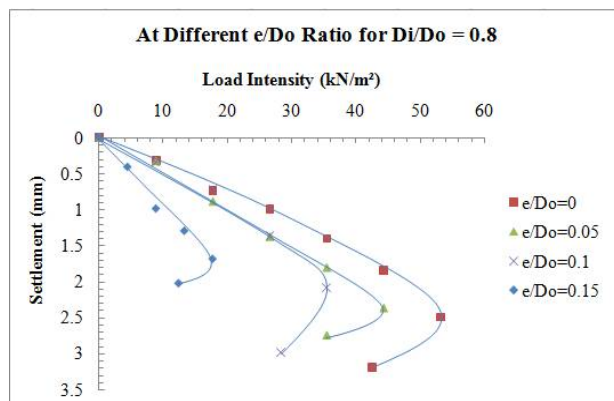


Figure 7: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.8

The test was conducted on Ring footing of different ring radii ratios (Di/Do) 0.4, 0.6, 0.8 with different ratio of eccentricity ratio (e/Do) on reinforced sand. The load settlement graph for ring footing of Di/Do=0.4 is shown in figure 8.

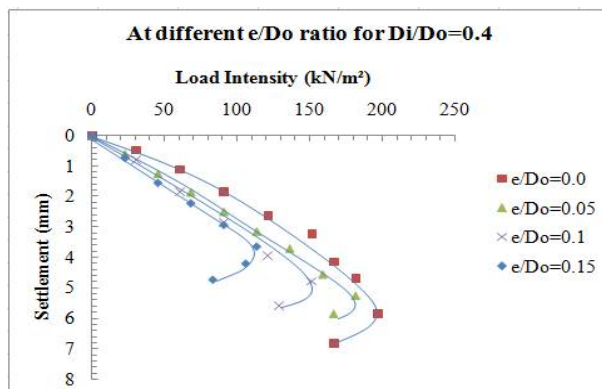


Figure 8: Load-Settlement curves of different e/Do ratio for ring footing of Di/Do=0.4 on reinforced sand

The load settlement graph at different $e/D_o = 0, 0.05, 0.1, 0.15$ for ring footing of $D_i/D_o=0.6$ is shown in figure9.

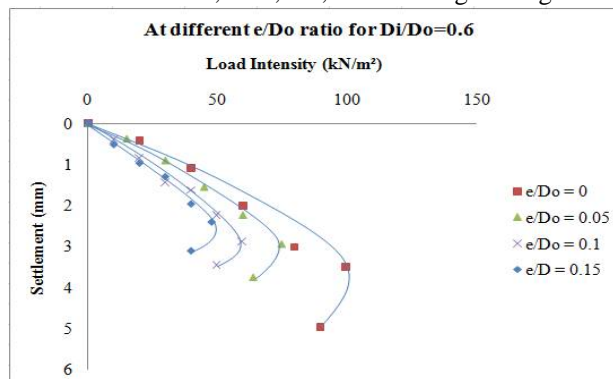


Figure 9: Load-Settlement curves of different e/D_o ratio for ring footing of $D_i/D_o=0.6$ on reinforced sand

The load settlement graph at different $e/D_o = 0, 0.05, 0.1, 0.15$ for ring footing of $D_i/D_o=0.8$ is shown in figure10.

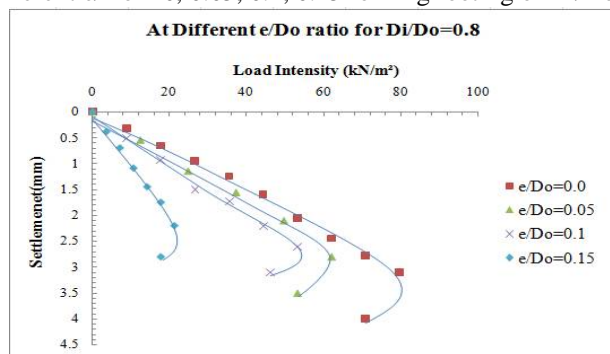


Figure 10: Load-Settlement curves of different e/D_o ratio for ring footing of $D_i/D_o=0.8$ on reinforced sand.

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 (D_i/D_o) of 0.4.
- As eccentricity increases bearing capacity decreases.
- Inclusion of geogrid reinforcement significantly improves the bearing capacity.

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