Experimental Investigation of Eccentric Loading Effect on Circular Footing Located on Sandy Bed with a Weak Thin Layer

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ABSTRACT

In some cases, there is a weak thin interlayer in the soil profile, which may not reveal these complications in geotechnical studies. also, most of shallow footings are subjected to eccentric loadings that due to the existence of such loads, moments are imposed on the footing and as a result, the footing rotates and the pressure under the footing does not remain uniform. In this research, an experimental investigation has been carried out on a circular footing model located on a homogeneous sand bed with a weak thin layer with different thickness and depth of placement under vertical eccentric loads by small-scale physical model of soil-footing system. Physical model tests are performed in a cylindrical steel tank with an inner diameter of 70 cm and a height of 70 cm. Investigations have been carried out by changing the thickness and depth of placement of a weak thin layer due to eccentric loadings. The results show that the existence of a weak layer and eccentric load has increased the rotation of circular footing compared to the homogeneous sand bed. So that in the sand bed with a weak thin layer, the maximum rotation of circular footing has been obtained equal to 8.2 degrees for eccentric load 0.0625D (D is the diameter of footing) and thickness of weak thin layer 0.2D and depth of placement 0.5D and the minimum rotation of circular footing for homogeneous sand with eccentric load of 0.0625D is equal to 4.5 degrees, which shows a reduction of 45%.

KEYWORDS

Bearing capacity, rotation of footing, weak thin layer, eccentric load, circular footing.

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Introduction

While most analytical methods are based on the assumption of soil homogeneity usually the soils in nature are not homogeneous and they may have thin layers that are not usually revealed in geotechnical studies. Although the presence of thin layers seems to have little effect, it can fundamentally affect the behavior of soil-footing and other geotechnical systems.

In many cases, circular footings, as one of the common types of shallow footings are subjected to eccentric loading in addition to centric loading, as a result of this type of loading, moments are imposed on the footing. As a result of the moments applied to the footing, the pressure under the footing does not remain uniform and rotation occurs in the footing [1].

In the literature review, very little study has been performed on the effect of eccentric loading on the shallow footings [2-5]. In particular, the effects of eccentric loading on circular footing located on a sandy bed with a weak thin layer have not been studied. Therefore, in this research, the effect of eccentric loading on rotation of circular footing located on sandy bed with a weak thin layer are studied by small-scale physical models. The investigations were carried out by varying the thickness, and depth of the weak thin layer and eccentric loading.

The problem of the soil-circular footing system is schematically illustrated in Figure 1. The problem is investigated under the effect of eccentric loading condition, and the circular footing is rigid. This footing rests on the soil surface; on the other hand, the initial depth of embedment is nil. Figure 1 shows a typical schematic of the footing model on the sandy bed. For the bed sand, crushed uniform silica sand (*SP*) with medium density was used. For the thin layer, materials with weak strength properties in comparison with the sandy bed were used. For the weak layer, the clay powder with *CL* classification was used. Clay with a natural moisture content of 5.5% and a very low density of 12.1 kN/m^3 was used consistently in all of the experiments.

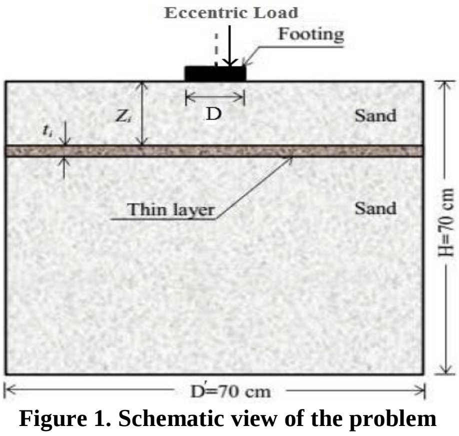

Figure 1. Schematic view of the problem

Experimental method

At the test beginning, the sand raining screen device was located directly above the test box. Then the following the sand was deposited in the 4 cm thick layers by using the raining method. The weak thin layer was made using simple templates at the specified depths and thicknesses and the subsequent sand layers were poured to the required level and were followed by placing of the footing model at a specific location on the surface of the sandy bed. At the end, the vertical pressure is transferred to the footing model by a manual hydraulic jack at a constant rate equal to 1 mm/min. Then a dial gauge with a precision of 0.01 mm measured the vertical settlement.

Experimental parameters and program

The variable parameters used in the experiments (in accordance with the schematic Figure 1) and their values are shown in Table 1. First, the behavior of the circular footing resting on a uniform sand bed is investigated. Then, the behavior of the circular footing resting on the sandy bed with a weak layer at different thicknesses, depths and loadings was investigated. Also in this research, circular footing on a homogeneous sand bed is abbreviated as CFHSB, and circular footing on a sand bed with a weak thin layer is abbreviated as CFWTL.

Table 1. Model test program

Test type	Constant parameters	Variable parameters
CFHSB	Dr = 39 %, D_f/D= 0	Z_i/D=0.5, 1 t_i/D=0.1, 0.2 e_i/D=0, 0.0625, 0.125
CFWTL	Dr = 39 %, D_f/D= 0	Z_i/D=0.5, 1 t_i/D=0.1, 0.2 e_i/D=0, 0.0625, 0.125

Results and discussion

When the load is applied eccentrically on the shallow footing, rotation of the footing occurs and the pressure under the footing does not remain uniform. The schematic diagram of circular footing rotation under the influence of eccentric loading is shown in Figure 2. Also, when a footing is subjected to an eccentric loading, footing tilt is inevitable. In this study, in order to calculate the tilt of footing in degrees, two gauges have been used to measure the settlement of footing on both sides of the circular footing in the direction of eccentric loading. The tilt of the footing has been calculated according to the difference between settlements recorded by two gauges.

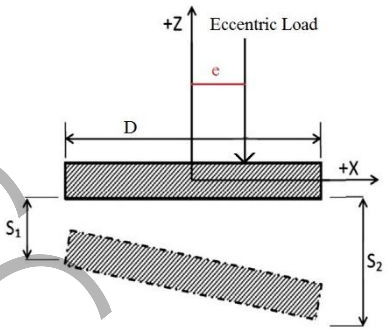

Figure 2. Rotation of circular footing under eccentric load

The bearing pressure-tilt curve of circular footing in both conditions of homogeneous sand and sand with a weak thin layer with a thickness of t/D=0.1 and t/D=0.2 at different depths and eccentric loadings are shown in Figures 3 and 4, respectively.

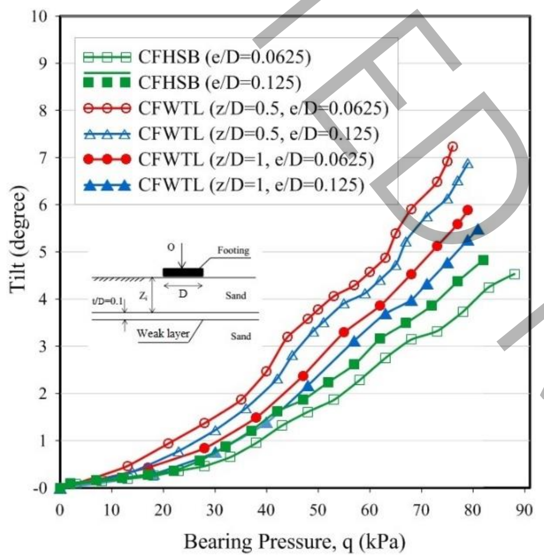

Figure 3. Bearing pressure-tilt curve with normalized thickness of weak thin layer equal to t/D=0.1

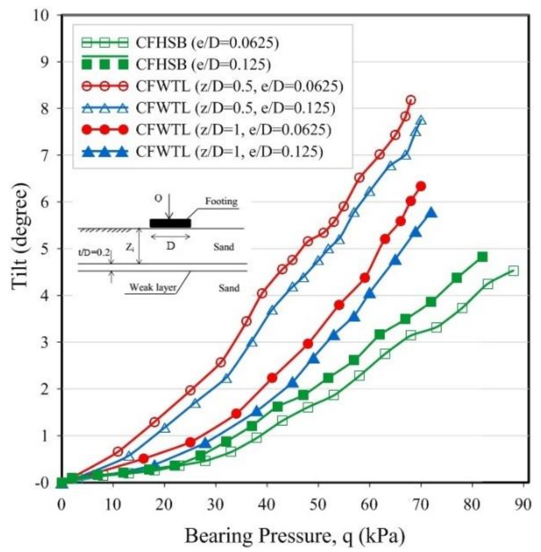

Figure 4. Bearing pressure-tilt curve with normalized thickness of weak thin layer equal to t/D=0.2

According to Figures 3 and 4, the tilt of the circular footing for homogeneous sand increased with the increase of eccentricity and the bearing capacity decreased significantly, but for the case where a weak layer exists, when the normalized eccentric loading equal to 0.0625 (e/D=0.0625) was applied, the tilt of the circular footing is slightly higher and the bearing capacity is slightly lower than the case where the eccentric loading was entered at the place equal to 0.125D.

Conclusions

The horizontal weak thin layer and eccentric loadings decreases both the ultimate bearing capacity and stiffness of the soil-footing system.

The maximum rotation of the circular footing from the moment of applying the load until it reaches the ultimate bearing capacity is related to the case where the thickness of the weak layer is 0.2D and the eccentric loading is 0.0625D and the location of the weak layer is at a depth of 0.5D and the rotation value of the circular footing in this case is equal to 8.2 degrees. Also, the minimum rotation of the circular footing corresponds to the case where the sand is homogeneous and the eccentric loading is 0.0625D and the tilt value of the circular footing in this case is equal to 4.5 degrees.

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