Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(4) (2018) 243-246
DOI: 10.22060/ceej.2017.12628.5235

Ultimate Bearing Capacity of Composite Shell Annular Foundations in Cohesionless Soil

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ABSTRACT: The foundation shape effects on the stress distribution induced in the soil. Moreover, it has influence on the failure mechanism of the soil. For these reasons, it plays an important role in the ultimate bearing capacity of the foundation. Due to lack of materials, the new design methods attempt to utilize the least amount of material and achieve the maximum efficiency. If shell elements are employed in composite foundations, and the interaction effects are considered, the cost can be reduced. This paper aims to compare the geotechnical performance of the composite annular shell foundation with that of the annular one. For this purpose, the ultimate bearing capacity and the settlement of these foundations are experimentally modeled for various shell angles. The findings prove that the ultimate bearing capacity of the composite foundations is more than that of the annular one. Furthermore, it is observed that increasing the shell angle reduces the ultimate bearing capacity. Moreover, the shell efficiency factor is decreased by increasing the soil relative density. This phenomenon shows that the shells perform more appropriately in low-density soils. Additionally, a novel relation is proposed for predicting the ultimate bearing capacity of the composite shell. It is worth emphasizing that adding the edge beam to composite foundations improves its performance in settlements during failure. Moreover, the efficiency of foundations with edge beams is more than the ones without beam in soils with any density. Hence, using of shells in annular foundation enhances its ultimate bearing capacity.

Review History:

Received: 7 March 2017
Revised: 23 April 2017
Accepted: 6 June 2017
Available Online: 13 June 2017

Keywords:

Ultimate Bearing Capacity
Composite Foundation
Shell Foundation
Annular Foundation
Sand

1- Introduction

Due to the fact that foundations play an important role in stability of structure, researchers attempts to construct more economical and safer foundations. One the new novel foundations is the shell and annular foundation. Annular foundation is suitable for most of the axisymmetric structures subject to vertical load. Moreover, it is more economical than the circular foundation [1]. Various researches were conducted to experimentally assess the ultimate bearing capacitance of the annular foundations on the sand and reinforced layered sand. Both axial and eccentric loads were considered. It should be noted that usage of the annular foundations with inner diameter to outer diameter ratio which ranges from 0.2 to 0.4 leads to ultimate bearing capacity increment of 20% to 25 %. In other words, the ultimate bearing capacity of the annular foundations is more than that of the circular one for similar outer diameter [2-5].

Shell foundations are inclined. Hence, soil-foundation contact area is larger for these foundations in comparison with flat ones. As a result, their ultimate bearing capacity is greater than that of the flat one. Recently, extensive experimental researches have been conducted on various shapes of shell foundations [6-11]. According to the obtained results, the rupture surfaces of shell foundations are deeper than those of the flat ones [12]. It is worth emphasizing that employing shell elements in the iterative mat foundations are more economical, in comparison to the flat ones [13]. A composite shell foundation includes an inverted truncated cone and a cone. The properties of this type of foundation are the same as the folded plates, shell foundations and the annular one.

This paper is devoted to assess the geotechnical behavior of the shell annular foundation. In addition, the behavior of this foundation is compared with the annular one. For this purpose, the ultimate bearing capacity and the settlements of various types of models are experimentally evaluated.

2- Methodology

In the present research, an experiment setup was prepared for applying a vertical force to a composite foundation placed on cohesionless soil. This setup included cylindrical container, sand curtain travelling pluviator to reconstitute sand specimens, hydraulic jack, load cell, linear variable differential transformer, recording device and a rigid frame. Note that performance of the experiment setup is highly dependent on its components.

In this study, six concrete model of the shell annular foundations were assessed in loose, medium and dense sand. These models are illustrated in Figure 1. Recall that usage of concrete models leads to more accurate results due to the fact the experiment situations become more similar to reality [14]. It should be added that three types of experiments were performed on all models including verifying the loading system, assessing the effect of the shell and the edge beams on each model.

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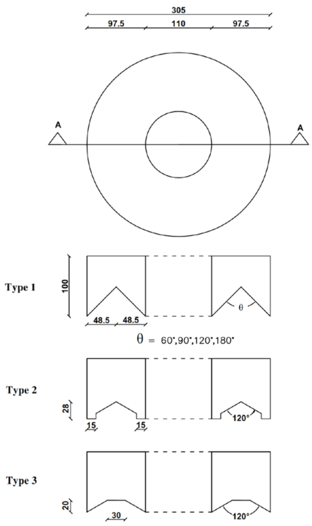

Figure 1: The utilized models in this work

3- Results and Discussion

To predict more precisely the behavior of a foundation under applied loads, it is required to assess simultaneously the deformation of the soil and the force which induces this deformation. Moreover, the soil load capacity should be investigated. To achieve this goal, the settlement-load relationship was evaluated completely during the tests. For different soil densities, the settlement-load curves of the composite foundation with shell of angle 60 degree are shown in Figure 2.

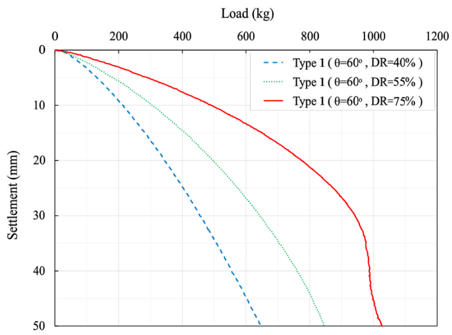

Figure 2: Settlement-load relationship of composite shell annular foundations

In this work, shell efficiency and settlement ratio were employed for studying the behavior of experimental models. These dimensionless parameters are listed in Table 1.

It is worth mentioning that shell foundation transfers the loads to lower layers. In other words, wedge of ruptures form in deeper layers. As a result, the ultimate bearing capacity is increased. It should be added that the increment of the ultimate bearing capacity depends on shell angle and soil density (internal friction angle). It should be emphasized that the obtained results are compatible with those of other researchers [15].

Table 1: Shell efficiency factor and settlement ratio

Settlement ratio ($*10^{-3}$)			Shell efficiency (%)			Foundation Type
Dense	Medium	Loose	Dense	Medium	Loose	
3.01	4.71	6.71	---	---	---	**Type 1 (θ= 180°)**
2.98	4.29	5.86	4.82	9.80	11.54	**Type 1 (θ= 120°)**
2.99	4.14	5.42	12.05	22.55	26.92	**Type 1 (θ= 90°)**
3.03	4.08	5.00	14.46	24.51	30.77	**Type 1 (θ= 60°)**
2.60	3.85	5.63	13.25	17.65	19.23	**Type 2**
2.70	4.15	5.66	7.23	13.73	15.38	**Type 3**

4- Conclusions

In this work, the performance of the shell annular foundation in sand soil is experimentally assessed. It was observed that they deform less than the annular foundations. Moreover, their ultimate bearing capacity is greater than that of the annular foundations. In addition, investigating the shell efficiency parameter and settlement ratio proved that the composite foundations perform better in loose soil, in comparison to the compacted soil. Moreover, usage of edge beam increase the shell efficiency factor by 8% and reduce the settlements.

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Please cite this article using:
M. Kazemi, J. Bolouri Bazaz, Ultimate bearing capacity of composite shell annular foundations in cohesionless soil , *Amirkabir J. Civil Eng.*, 50(4) (2018) 781-792.
DOI: 10.22060/ceej.2017.12628.5235