Laboratory and Numerical Study of the Behavior of Skirted Foundation Located on a Buried Pipe under Static Axial Loading

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ABSTRACT

The bearing capacity and settlement of shallow foundations located on the pipe are usually not acceptable in sandy soils. Therefore, in order to improve the performance of strip foundations, various methods are proposed, as a cost-effective alternative is to add skirts to the edges of the shallow foundation. the addition of skirt to the edges of shallow foundation increases the effective depth of the foundation and soil trapped within the skirts, that the loads of the structure are transferred to the bottom depth at the level of the skirt tip. In recent years, performance assessment of skirted foundations has become one of the desired topics for civil engineers. In this article, the effect of the burial depth and horizontal distance from the center of pipe to single load have been evaluated using numerical and experimental tests. Therefore, the skirted foundations located on the buried pipe with the skirts B and 2B (B is the width of the foundation) has been used. The results of the laboratory tests show that by using the skirted foundation with skirts of 2B, the bearing capacity can be increased by more than 300% compared to the strip foundation. Numerical comparison of the skirted foundation with semi-deep and embedded strip foundation shows that the bearing capacity of the skirted foundation was less than 10% different from the semi-deep foundation. Civil engineers can be led towards more economical and accurate designs by using the skirted foundation.

KEYWORDS

Skirted foundation, Finite element limit analysis (FELA), Buried pipe, Laboratory model, Sand.

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INTRODUCTION

Over recent years, geotechnical engineers have created many methods for the development of the foundation behavior to increase the load-bearing capacity of soil and reduce the settlement of shallow foundations. One of these methods is to use skirted foundations in cases where the soil is weak. These foundations transfer the structural loads to the strong layers under the skirt, enhancing efficiency. Circumscribed skirts can have various geometries, i.e., circular, rectangular, strip, and square, with existing and new shallow piers. They are also utilized to improve the safety of buried pipelines.

Moreover, skirted foundations can prevent the exit of the soil under them and any probable damages caused by excavation in surrounding construction works. When a load is imposed on a foundation, the soil under it moves toward the two sides due to the shear failure. Confining the soil under a foundation can effectively control the failure mechanism. Given their easy installation and low execution costs, these foundations have received increasing attention over recent years. These foundations are alternatives to semi-deep and deep foundations used to support floating or fixed offshore structures in oil and gas industries. Al-Aghbari et al. (2021) conducted experimental and numerical studies on the bearing capacity and settlement of skirted shallow foundations under vertical and inclined loads. They proposed a relationship for the bearing capacity of these foundations. According to the results, the presence of skirts at a depth 1.25 times the foundation width increased the bearing capacity by 407% while reducing the settlement by 17% [1].

Methodology

Experimental modeling

Since the goal was to evaluate the behavior of a skirted strip foundation in plane strain conditions, a soil chamber with internal length, depth, and width of 1200 mm, 800 mm, and 400 mm, respectively, was used along with a steel plate, 100 mm wide, 395 mm long, and 20 mm thick, as the strip foundation. The skirts connected to the strip foundation were considered with lengths of 0, 1, and 2 times the foundation width at a vertical angle. The PVC tubes with an external diameter of 63 mm, a thickness of 2 mm, and a length of 395 mm were investigated at the depths of 1, 2, and 3 times the foundation width with the eccentricity of 0, 1, and 2 times it.

Numerical modeling

Finite element analysis software called Optum G2 [2] has been used to validate and compare the obtained results. Modeling is done in two-dimensional (plane strain). The failure mode of foundation and soil are considered rigid plate and Mohr–Coulomb (MC) failure criterion, respectively. The boundary between the foundation and the soil is considered completely rough using the reduction factor, R, so the value of 1 was assigned to the reduction factor. The bottom boundary is fixed in both horizontal and vertical directions and the side boundaries are fixed only in the horizontal direction. Upper and lower limit analysis has been done for each modeling and its average value is reported as the final result of each model. Numerical modeling and meshing are shown in Figure 1.

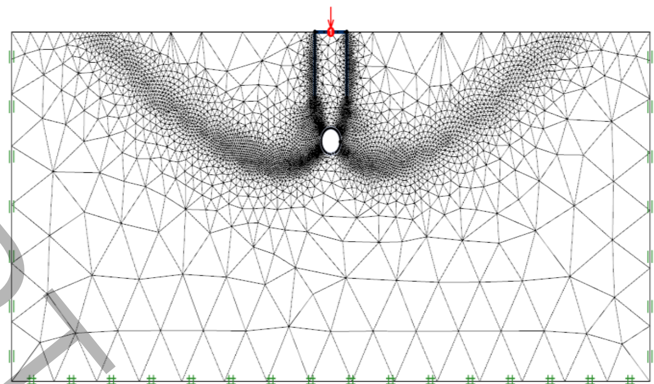
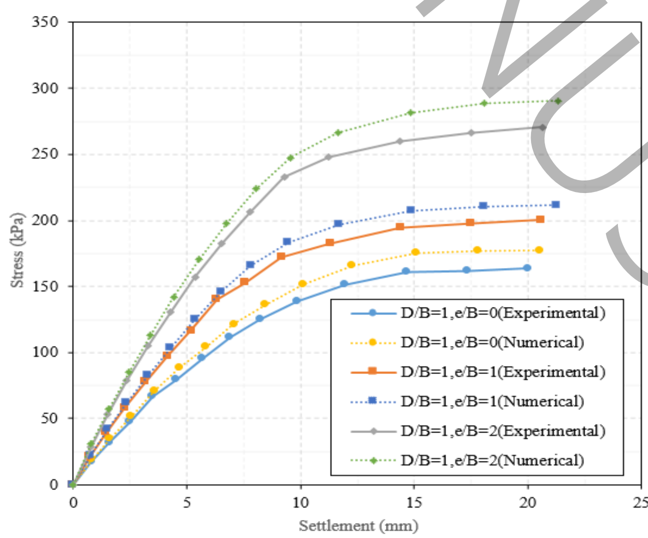


Fig. 1- Modeling and automatic meshing in Optum G2 software

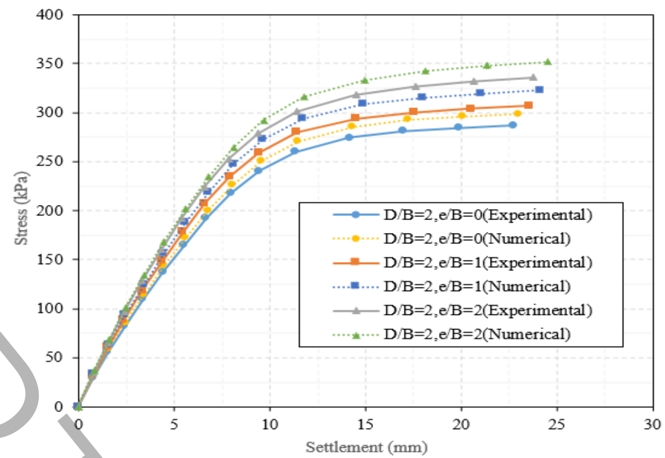
Results and Discussion

Effects of the depth and eccentricity of the buried pipe

According to Fig. 2, in the case with a D/B of 3 and an e/B of 2, the stress-settlement curves were fully in accordance with the case without pipes, indicating no interference between the stress bulb of the foundation and the buried pipe. For the shallow foundation without a skirt, the presence of pipe reduced the bearing capacity by up to almost 57%. One of the solutions to protect buried pipes is to place them between skirts. However, since it disturbs the rigidity and integrity of the soil confined within skirts, the bearing capacity for the skirts with lengths of 1 and 2 times the foundation width was lowered by about 58% and 60%, respectively.



a)



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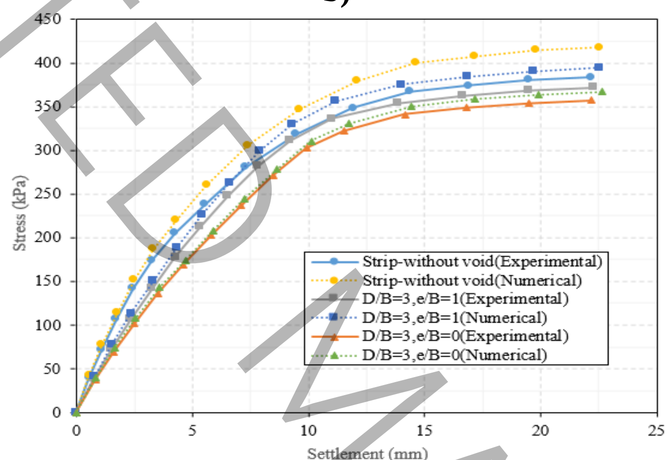

c)

Fig. 2- The effect of the pipe placement depth for strip foundations a) D/B =1 b) D/B =2 c) D/B=3

Conclusion

The obtained results are provided in the following:

- Adding the skirts under the strip foundation enhanced the bearing capacity. This rise was nonlinear, indicating the greater effect of skirts with larger lengths. The addition of skirts with lengths 1 and 2 times the foundation width made the bearing capacity 200% and 300% greater, respectively.

- The presence of cavities under foundations reduced the bearing capacity, while the addition of skirts to the strip foundations enhanced the performance. In the worst scenario of this research, adding a skirt with a length equal to the foundation width increased the bearing capacity by 92%, which can be an economical method to improve the bearing capacity.

- In order to verify and control the obtained results, the laboratory and numerical results have been compared and all the values obtained from the numerical results are higher than the values obtained from the laboratory results.

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