Evaluation of the Thin Layer Effect on the Ultimate Bearing Capacity of Strip Foundation on Sand

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ABSTRACT

Shallow foundations such as strip foundations are widely used in transmitting loads from the superstructure to the supporting soils. In many cases, the ground materials are not uniform and may have thin layers, which are not usually detected in geotechnical site investigations. In this research, the effects of a thin layer on the ultimate bearing capacity of a strip foundation on the sand bed are investigated by small-scale physical models. Due to very limited research that has been carried out on the thin layer effect on the ultimate bearing capacity, it seems that further studies can understand the effect of this layer. The investigations were carried out by varying the material type, thickness, and depth of the thin layer. The results indicate that the weak thin layer decreases both the ultimate bearing capacity and stiffness of the soil-foundation system and the strong thin layer increases both the ultimate bearing capacity and the soil-foundation system stiffness. The amount of this effect depends on the thickness, depth of deposition, and material type of the thin layer. According to the results, the weak layer for the critical depth of 1.2*B* led to the most reduction in ultimate bearing capacity by 40%, while no effects were observed at the depth of 3.6*B*. The strong layer is also for the state where this layer is just below the footing, had the highest increase in ultimate bearing capacity by 76%, but at a depth of about 2.4*B*, it was ineffective.

KEYWORDS

Thin layer, ultimate bearing capacity, strip foundation, stiffness, physical modeling

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Introduction

Strip foundations as one of the common types of shallow foundations are extensively used in transferring loads from the structure to the underlying soils and the rock bed. In many cases, the ground materials are not uniform and may have thin layers, which are not usually detected in the geotechnical site investigations.

Terzaghi (1936) mentioned: "… the earth in its natural state is never uniform … Its properties are too complicated for the rigorous theoretical treatment … Even an approximate mathematical solution for some of the most common problems is extremely difficult" [1].

In the literature review very little study has been performed on the effects of a thin layer [2-5]. In particular, the effects of the strong thin layer have not been studied. Besides, it is worthy to know that the strip foundation has not been used either. Therefore, in this research, the effects of the existence of a thin layer on the ultimate bearing capacity of a strip foundation resting on the sandy bed are studied by small-scale physical models. The investigations were carried out by varying the material type, thickness, and depth of the thin layer.

The problem of the soil-strip footing system is schematically illustrated in Fig. 1. The problem is investigated under the plane strain condition, and the strip foundation is rigid. This foundation rests on the soil surface, on the other hand, the initial depth of embedment is nil. Fig. 1 shows a typical schematic of the foundation 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 different strength properties (strong and weak) 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/m3 was used consistently in all of the experiments. For the strong layer, a fine-grained asphalt mixture with a unit weight19.12 kN/m3 was used.

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. To visualize the displacements at the different depths, colored sand particles are placed horizontally and carefully between sand layers and in the direct contact with the glass plate. The weak and strong thin layers were 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 foundation model at a specific location on the surface of the sandy bed. At the end, the vertical pressure is transferred to the foundation model by a manual hydraulic jack at a constant rate equals to 1 mm/min. Then a dial gauge with a precision of 0.01 mm measured the vertical settlement. Extended Abstract Preparation

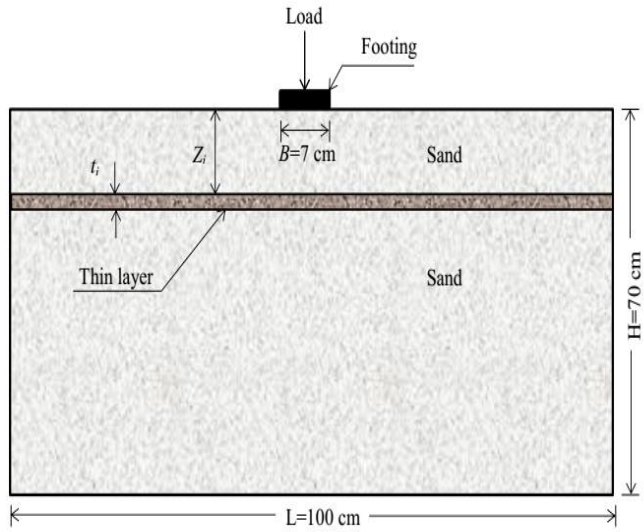

Figure 1. Scheme of the problem

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. Three series of tests have been carried out. First, the behavior of the strip footing resting on a uniform sand bed is investigated. Then, in the second and third series, the behavior of the strip foundation resting on the sandy bed with a weak or strong layer at different thicknesses and depths was investigated.

Table 1. Model test program

Type of test	Constant parameters	Variable parameters
Uniform sand	D_r = 41%, D_f= 0	---------
Uniform sand with weak layer	D_r = 41%, D_f= 0	Z_i/B=0, 0.6, 1.2, 2.4, 3.6 t_i/B=0.1, 0.2
Uniform sand with strong layer	D_r = 41%, D_f= 0	Z_i/B=0, 0.6, 1.2, 2.4 t_i/B=0.1, 0.2

Results and discussion

Foundation bearing pressure-settlement curves were obtained from the results of the testing model. Results indicate that the weak thin layer decreases both the ultimate bearing capacity and stiffness of the soil-foundation system and the strong thin layer increases both the ultimate bearing capacity and the soil-foundation system stiffness. The amount of this effect depends on the thickness, depth of deposition, and material type of the thin layer. The values of the ultimate bearing capacity for different states are compared in Figure 2 and 3. Obviously, the effect of a thicker layer is more evident.

According to the results, the weak layer for the critical depth of 1.2*B* led to the most reduction in ultimate bearing capacity by 40%, while no effects were observed at the depth of 3.6*B*. The strong layer is also for the state where this layer is just below the footing, had the highest increase in ultimate bearing capacity by 76%, but at a depth of about 2.4*B*, it was ineffective.

The contact of the weak layer with the failure surface at critical depth of 1.2*B* has caused the most reduction in the ultimate bearing capacity of the foundation and also because of reduction of the vertical pressure beneath of foundation up to 10% at a depth of about 3.6*B*, the weak layer was ineffective. Also the strong layer acts as a reinforcement layer, increasing both the ultimate bearing capacity of the foundation and the stiffness of the soil- foundation system.

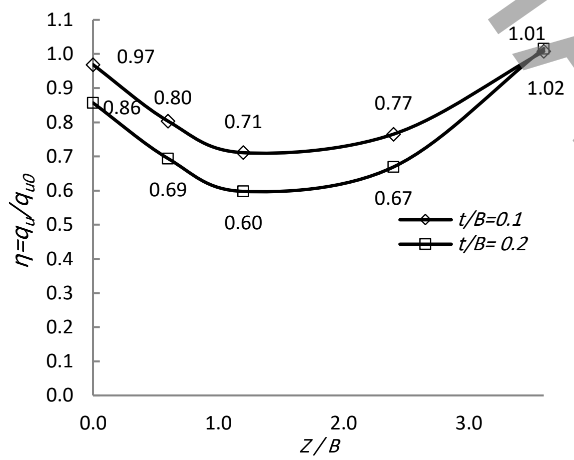

Figure 2. Comparison of normalized ultimate bearing capacity q_u/q_{u0} against normalized depth of the weak layer *Z/B*

Conclusions

The horizontal weak thin layer decreases both the ultimate bearing capacity and stiffness of the soil-foundation system. The extent of this effect depends on the thickness and depth of the weak thin layer. The weak thin layer for the critical depth of 1.2B led to more reduction in the ultimate bearing capacity by 40%. For both weak thin layers (t/B=0.1 and t/B=0.2) at a depth of about 3.6B, it was ineffective.

The horizontal strong thin layer increases both the ultimate bearing capacity and stiffness of the soil-foundation system. The extent of this effect depends on the thickness and depth of the strong thin layer. The strong thin layer for the state where this layer is just below the foundation (*Z/B*=0), had the highest increase in the ultimate bearing capacity by 76%. For both strong thin layers (*t/B*=0.1 and *t/B*=0.2) at a depth of about 2.4*B*, it was ineffective.

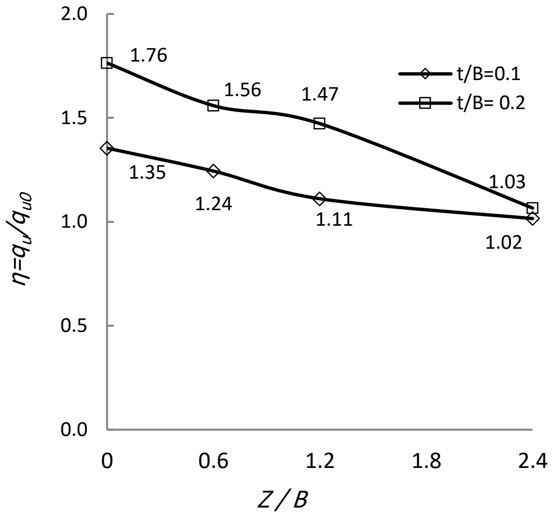

Figure 3. Comparison of normalized ultimate bearing capacity q_u/q_{u0} against normalized depth of the strong layer *Z/B*

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