Variation in Shape Factors of shallow Footings Assessed by Model Tests and their Numerical Simulations

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1. Introduction and Problem Statement

One of the most fundamental problems in the field of geotechnical engineering is the prediction of bearing capacity and settlement of shallow footings on cohesionless soils subjected to vertical central loading. The fact is that commonly used “SHAPE FACTORS” in the current design for estimating the bearing capacity of shallow footings are partly empirical values proposed by Tezaghi,(1943), and they do not have enough background based on the concept of the three-dimensional (3-D) mechanism of deformation. Therefore, in order to take into account the realistic effect of the three-dimensional mechanism of soil failure for footings with various aspect ratios ***L/B*** on the shape factors in the classical formula of ultimate bearing capacity of shallow footing. Two series of small-scale model footing tests were carried out on a practical type of Toyoura sand; (dense and loose sands) and the traces of 3-D failure mechanism were closely monitored and recorded at the end of each performed test. This research presents the main observations and results of square, rectangular and strip footing model tests with constant footing base width ***B*** conducted on both loose and compacted sand. Furthermore, a 3-D analysis of deformation and realistic simulations of soil behavior for the performed model tests were made using a Finite Element code, then a comparison between the calculated and recorded relationship between footing pressures and relative footing settlement for the various cases was done.

2. Experimental Model Tests

The model footing tests were all performed on uniformly fine-grained Toyoura sand in a test container made of Acrylic-glass with as shown in Figure.1. The footing widths were constant $B=7.2cm$ in all tests and the aspect ratios were $L/B=1, 1.5, 2$ and ∞. The strip footing model test ($L/B=\infty$) was done purely under the plain strain conditions. The ultimate value of normalized bearing capacity factor $N_{\gamma ult}$ was used to compare all results from different model tests, where $N_{\gamma ult}$ is obtained from the model tests and equal to $(2q_{ult}/\gamma B)$.The maximum reached settlement S_{max} was $36mm$ in all tests. The adopted value of ultimate bearing capacity q_{ult} was corresponding to a relative settlement of (S/B) **=10%**.

3. Finite Element Model and Simulation of the Load Tests

In order to simulate the soil behavior in the performed small scale model tests numerically, several axis symmetric models are created in the FE code. The used finite element mesh and geometry components and their properties were similar to those footing models placed on the sand layers, where a 3-D model is created. In order to control the vertical displacements of the certain points on the model, prescribed displacements are applied on soil model. Consequently the Stress-Settlement charts and the reaction forces corresponding to the mentioned prescribed displacements in X, Y and Z directions are obtained at each certain moment of loading, from the FE solutions.

4. Conclusions

The following conclusions can be drown from the results presented above:

- In contrast to what concluded in literature that the footing length does not influence the bearing capacity (Golder,1941), the performed model tests conducted on both loose and dense sands show obviously that the least

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ultimate capacity was obtained from strip footing tests where the plain strain boundary conditions are considered, whilst the square footings have higher capacities.

- The FE solutions provided the accurate 3-D traces of the failure mechanism in the soil model and the behavior of footings with various L/B ratios. Figure.2 obviously shows that the 3-D mechanism of soil deformation should be taken into account in estimating the bearing capacity factors and shape factors as well. The obtained results from both of the model tests and the 3-D analysis using the FE code have a well agreement in defining the distribution of displacements and the soil behavior (failure mechanism) under footings with various shapes. Figure.3 shows the variation in shape factors for footing models based on the square footing case. This indicates that there is a necessity to insert some modifications on the current shape factors. It is highly expected that there is a significant effect of the deformed mass of soil in the failure zone (3-D MECHANISM OF FAILURE) on the shape factors and more researches in this concern are required.

Figure.1. .General view of experimental set-up for model-scale footing tests

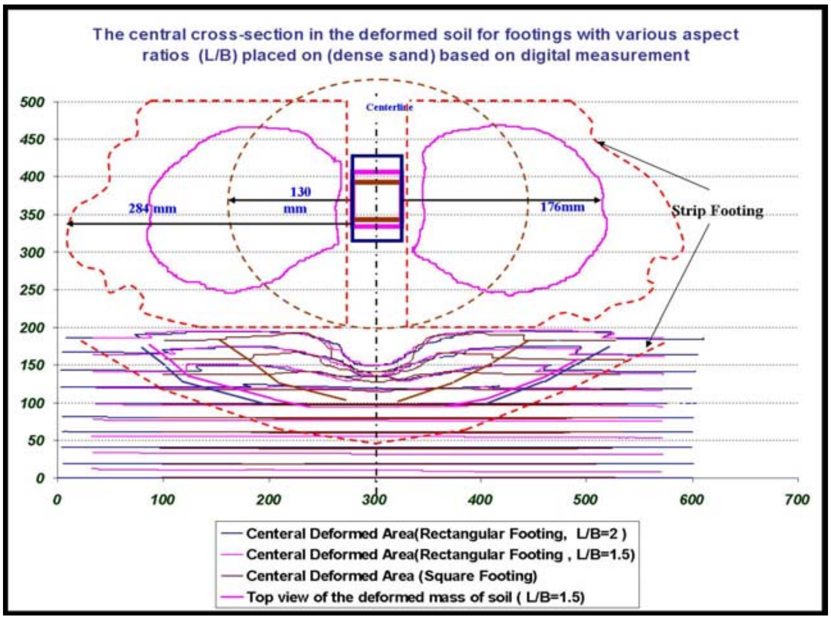

Figure.2. Traces of deformation mechanism for footing models with various aspect ratios (L/B)

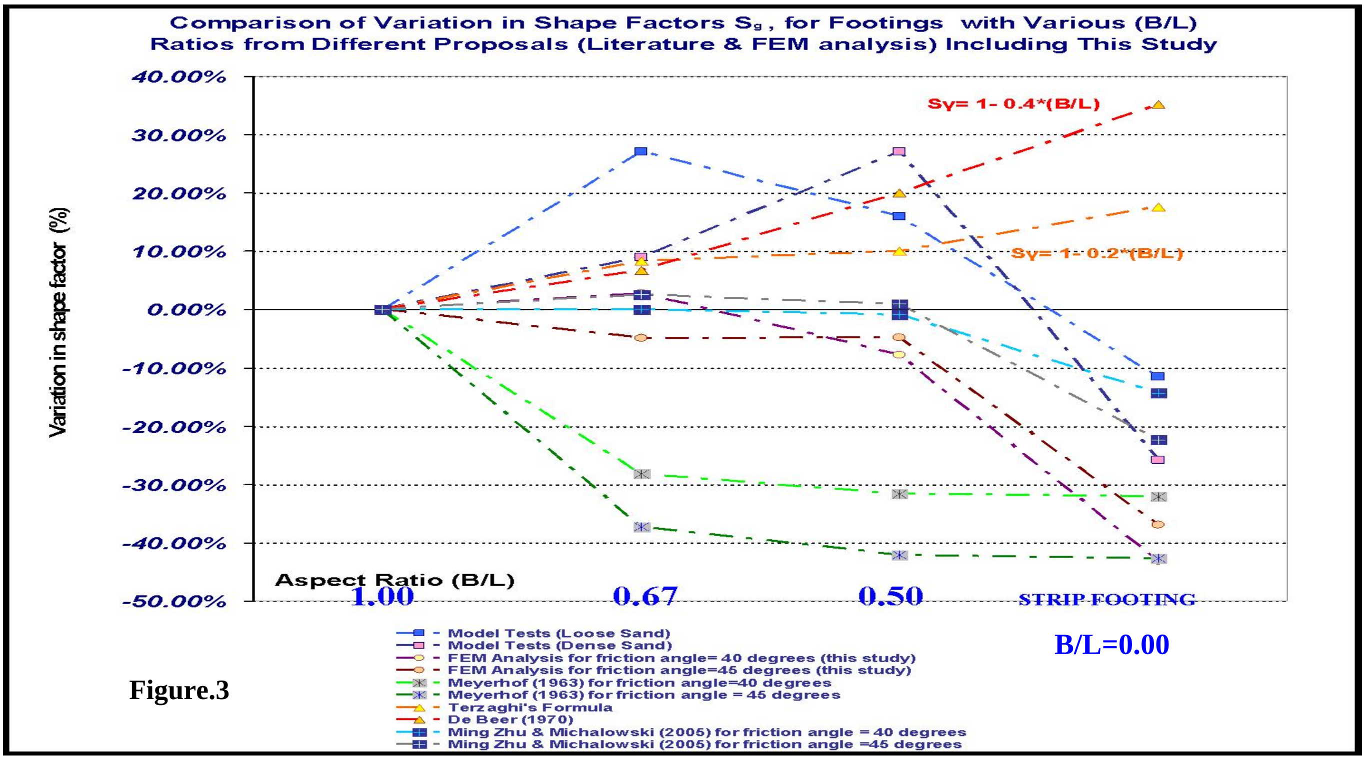

Figure.3