ABSTRACT

Knowledge of the displacement and deformation fields beneath foundation elements obtained from carefully executed experiments is required to validate state-of-the-art numerical simulations, which in turn enable the development of better foundation design methods. This dissertation presents the results of an experimental program in which load tests were performed on model footings in a half-cylindrical calibration chamber with a transparent viewing window across its diameter. The digital image correlation (DIC) method was used to obtain the strain and displacement fields in the soil from digital images taken during the tests. Tests performed on both smooth and rough footings show a significant dependence of resistance on footing base roughness, with the DIC results providing insight into the reasons for that dependence. The experimental bearing capacity results are used to validate a previously proposed method in which an equivalent friction angle is used for calculation of the bearing capacity of footings in sand.

Schmertmann's method is one of the traditional methods for estimating the settlement of axially loaded footings in sand using cone penetration test (CPT) data. The method was developed for footings placed on the surface of a single, uniform sand layer; it assumes a depth of influence below the footing base within which most of the soil deformations take place and an influence diagram to quantify the influence factor as a function of depth. However, the literature contains limited information on the strain influence diagrams for footings on layered sands, and, as a result, there is no way to accurately account for the effect of sand layering on footing settlement. In this study, Schmertmann's approach for calculating the strain influence factor is modified to account for the effect of two sand layers with varying thickness and relative density. Penetration experiments were performed using a half-square model footing (width B = 90 mm) placed on the surface of both single and two-layered (dense over medium-dense and medium-dense over dense),

air-pluviated, silica sand samples prepared inside a half-cylindrical calibration chamber designed for digital image correlation (DIC) analysis. The test results indicate that both the thickness and relative density of the top sand layer (the layer in contact with the footing base) affect the parameters of the strain influence diagram. For dense sand over medium-dense sand, the depth to the peak strain influence factor varies with the thickness of the dense layer; however, when the thickness of the dense layer is $1.5B$ or greater, the strain influence diagram is similar to that obtained for a single, uniform sand layer. In contrast, for medium-dense sand over dense sand, the peak value of the strain influence factor varies with the thickness of the medium-dense layer up to a value of $1B$. Based on the results obtained in this study, new strain influence diagrams are proposed for settlement calculation of square footings on two-layered sand profiles. The proposed method for estimation of footing settlement in layered sand is validated against measured data obtained from a full-scale, instrumented footing load test reported in the literature.

The expressions for the shape and depth factors available in the literature for bearing capacity calculation are mostly empirical and are based on results obtained using limit analysis or the method of characteristics assuming a soil that is perfectly plastic following an associated flow rule. This study presents the results of an experimental program in which load tests were performed on model strip and square footings in silica sand prepared inside a half-cylindrical calibration chamber with a transparent visualization window. The results obtained from the model footing load tests show a significant dependence of footing penetration resistance on embedment depth. The load test results were subsequently used to determine experimentally the shape and depth factors for model strip and square footings in sand. To obtain the displacement and strain fields in the sand domain, the digital image correlation (DIC) technique was used to analyze the digital images collected at different stages during loading of the model footing. The DIC results provide

insights into the magnitude and extent of the vertical and horizontal displacement and maximum shear strain contours below and around the footing base during penetration.

The loading of a footing in sand generates substantial shear bands as a mechanism for failure develops with the formation of slip surfaces. The interaction of sand particles in the shear band governs its constitutive response to loading. This study provides the results of loading experiments performed under different conditions on half-square model footings (width B = 90 mm) in dense air-pluviated silica sand samples prepared in a half-cylindrical calibration chamber equipped with an observation window that allows collection of images of the sand domain during testing. Two sands (Ottawa sand and Ohio Gold Frac sand) with different roundness (angularity) were used to perform these experiments. The digital image correlation (DIC) technique was used to obtain the incremental strain fields in the sand domain. The zero-extension line (ZEL) concept was then used to study the shear strain localization process and to obtain the orientation of the shear bands from analysis of the incremental strain fields. The results show that sand particle morphology, footing surface roughness, load eccentricity, and depth of embedment of the model footing have an impact on the dominant shear band patterns that develop below the model footings, and, as a result, all of these factors affect the unit bearing capacity of footings. The estimated thickness t_s of the shear band from the experiments is approximately $6D_{50}$ for Ottawa sand and approximately $8D_{50}$ for Ohio Gold Frac sand.