Bearing Capacity of Surface Footing on Soft Clay Underlying Stiff Nonhomogeneous Desiccated Crust

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The aim of this paper is to provide a reasonable approach for the evaluation of the bearing capacity of a shallow footing on a very soft clay overlaid by a stiff nonhomogeneous crust layer, based on both numerical analyses and a reappraisal of field load tests reported in the literature. Finite element analyses were carried out for the above problems with varying shape and magnitude of a nonhomogeneous shear strength distribution in the crust and crust thickness to a footing width (or diameter) ratio H/B (or H/2R). In addition, recently reported in-situ plate load tests conducted in a reclaimed area of dredged marine clay were reappraised so as to characterize the bearing behavior of the deposit, and to assess the shear strength mobilization in the crust related to the bearing capacity estimation.

INTRODUCTION

The evaluation of the bearing capacity of a shallow footing on an undrained clay deposit is an important problem in foundation engineering, and a number of analytical, numerical and empirical methods has been proposed for various cases of single-layered (Terzaghi, 1943; Meyerhof, 1964; Vesic, 1973) and multi-layered clay deposits (Button, 1953; Brown and Meyerhof, 1969; Chen, 1975; Merifield et al., 1999). These methods commonly estimate the bearing capacity of the footing as a product of the area of the footing, the shear strength of the clay $\phi_s$ and the bearing capacity factor $N_c$. The latter mainly depends on the failure mechanism, which in turn depends on the geometry of the footing and characteristics of the soil, such as the ground’s layered condition, the shear strength of each soil layer, the relative magnitude of shear strengths for the soil layers, etc.

However, most of the existing equations and design charts for the estimation of bearing capacity have dealt with a homogeneous or layered clay whose shear strength is constant in each layer, despite the fact that most natural soil deposits exhibit varying shear strength distributions, even within a given layer. For a surface foundation on clay in particular, the above assumption becomes invalid, since a typical clay deposit has a stiff crust layer at the surface developed from weathering, desiccation and/or chemical processes (Lutenegger, 1995). The upper crust layer is much stiffer than the underlying clay, and its shear strength varies dramatically from the surface to the lower boundary, while the lower clay exhibits relatively constant (Konrad and Ayad, 1997; Lee et al., 2006) or gradually increasing shear strength with depth (Lefebvre et al., 1974). These conditions are frequently observed in newly reclaimed clay or slurry tailings. In such cases, the undrained bearing capacity becomes important because of the potential for failure of the stiff crust due to construction equipment’s traffic load (Wels et al., 1999). According to Lee and Park (1999), the shear strength of the desiccated crust is more than 10 times that of the lower soft clay in reclaimed deposits of dredged marine clay. Then it may be difficult to estimate the bearing capacity due to the nonhomogeneous shear strength distribution in the crust and the extremely large difference in the shear strength between the upper and lower clay layers.

Two different approaches can be applied to estimate the bearing capacity of 2-layered clay: The first is to take into account the nonhomogeneous shear strength profile in the evaluation directly, and the second is to determine a reasonable constant value for the shear strength of the crust and subsequently to estimate the bearing capacity using the reported solutions for double-layered clay. For the first approach, however, few studies have reflected the nonhomogeneous shear strength distribution within the upper layer for the bearing capacity estimation. Even though a number of solutions has been proposed to calculate the bearing capacity of a footing on cohesive soils whose properties vary with depth (Davies and Brooker, 1973; Tani and Craig, 1995), these works mainly focused on cases where the shear strength increased with depth in the entire soil strata. Button (1953) developed a design chart for evaluating the bearing capacity of a double-layered clay where the shear strength of the upper layer linearly decreases with depth. However, the reported field shear strength distributions in the crust layer appear to take the shape of exponential (Bjerrum, 1954) or elliptical (Graham, 1979) decay rather than the linear degradation considered in Button’s chart.

In the same breath, it may also not be suitable to follow the second approach regarding a homogeneous crust layer, because a method to determine a representative value of the shear strength in the crust has not yet been proposed in the literature. Plus, it is also questionable whether the conventional 2-layer solutions can reasonably consider the nonhomogeneity of the shear strength in the...