Settlement of Shallow Foundations on Granular Soils

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Abstract: A conceptual framework for understanding the effects of overconsolidation in reducing the compressibility of all types of soil is presented. A generally applicable method for estimating the settlement of footings on granular soils is proposed. The procedure uses a combination of dilatometer and cone-penetration test results to identify the preconsolidation pressure, while soil moduli—either Young's modulus or constrained modulus, depending on the boundary conditions—are obtained from the dilatometer test results. Calibration chamber test results are used to adjust the dilatometer moduli for the effects of stress path and for disturbance due to insertion of the instrument. Detailed examples are given to illustrate the use of the method and to compare the results obtained with those calculated using currently accepted methods for estimating settlements.

Introduction

It has long been recognized (Leonards 1975; Rowe 1975; Lambrechts and Leonards 1978) and fully confirmed by more recent studies (Jamiolkowski et al. 1985; Bellotti et al. 1986) that penetration resistance tests of whatever nature are inherently incapable of sensing the effects of prestress, or overconsolidation (OC), on the compressibility of granular soils. For example, a typical ratio of the cone-penetration resistance q_c in the OC condition to that in the normally consolidated condition (NC) is 1.1 to 1.2, while the corresponding ratio of the secant Young's modulus at 25% of the failure stress (E_{25}) is 6 to 10, with the higher value corresponding to lower relative densities. Accordingly, procedures for calculating the settlement of footings on granular soils based on correlations between penetration resistance and soil modulus [e.g., Terzaghi and Peck (1967) and Schmertmann (1970)] will seriously overestimate the amount of settlement if the deposit has been prestressed. Recognizing that some natural deposits and all compacted granular fills, including in-situ deposits that have been subjected to various ground improvement procedures, are prestressed, it must be accepted that the state of conventional practice is unsatisfactory.

It is clear that in-situ tests to measure soil modulus must in some way sense compressibility directly. Among the tools available for this purpose at present are plate load tests, the Iowa stepped blade (Handy et al. 1982), the Marchetti dilatometer (Marchetti 1975), the screw plate (Kummeneje 1956) and the self-boring pressuremeter (Wroth and Hughes 1973; Baguelin et al. 1974). It has been argued (Leonards 1985) that, at the present time, the Marchetti dilatometer is the most generally applicable practical tool for sensing soil compressibility directly, at least for those deposits loose enough so that compressibility is a significant practical problem. The purpose of this paper is to review, in principle, the advantages and limitations of this tool and assess its potential for improving the current state-of-the-art in regard to settlement prediction. In this connection, a new method is outlined for calculating settlements of shallow foundations supported on granular soils; also, a suitable framework is provided for incorporating the results of future research on the interpretation of dilatometer parameters to obtain soil moduli in situ, thereby enhancing the accuracy of settlement predictions.

Marchetti Dilatometer

The construction, calibration, and operation of the Marchetti dilatometer and the subsequent determination of parameters from the test results have been described in detail elsewhere (Marchetti 1980; Schmertmann 1981, 1984, 1986a). Briefly, the dilatometer consists of a thin steel blade