Abstract

Shallow foundations can provide the most economical solution for supporting small-scale structures. The design approach is quite simple considering the ultimate bearing capacity and working-load settlement. Research has shown that settlement calculations, determined using a linear-elastic approach, usually govern the design but this approach is inappropriate because soil is highly non-linear, even at small strains. The result is that significant discrepancies are observed between predicted and actual settlements. This uncertainty has seen the development of settlement-based approaches such as Mobilisable Strength Design (MSD). MSD uses an assumed undrained mechanism and accounts for soil non-linearity by scaling a triaxial stress-strain curve to make direct predictions of footing load-settlement behaviour.

Centrifuge experiments were conducted to investigate the mechanisms governing the settlement of shallow circular foundations on clay and saturated sand models. Clay model tests were performed on soft or firm kaolin beds, depending on its pre-consolidation. Sand model tests were performed on relatively loose Hostun sand saturated with methyl-cellulose to slow consolidation. One-dimensional actuators were developed to apply footing loads through dead-weight or pneumatic loading. A Perspex window in the centrifuge package allowed digital images to be captured of a central cross-section, during and after footing loading. These were used to deduce soil displacements by Particle Image Velocimetry which were consistent with footing settlements measured directly. Deformation mechanisms are presented for undrained penetration, consolidation due to transient flow, as measured by pore pressure transducers, and creep. A technique was developed for discriminating consolidation settlements from the varying rates of short and long-term creep of clay models. Using MSD, a method for predicting the undrained penetration of a spread foundation on clay was proposed, using database results alone, which then provided estimates of creep and consolidation settlements that follow.

The importance of the undrained penetration necessitated further investigation by using the observed undrained mechanism as the basis of an ellipsoidal cavity expansion model. An upper-bound energy approach was used to determine the load-settlement behaviour of circular shallow foundations on linear-elastic and non-linear clays, with yield defined using the von Mises' yield criterion. Linear-elastic soil results were consistent with those obtained from finite element analyses. The non-linear model, as described by a power-law, showed good agreement with both centrifuge experiment results and some real case histories. The single design curve developed through this model for normalised footing pressure and settlement could be used by practising engineers based on existing soil correlations or site investigations.

Keywords: circular shallow foundations, centrifuge, clay, sand, load-settlement, cavity expansion, non-linear