A method for determination of ϕ^b for statically compacted soils

S.Y. Oloo and D.G. Fredlund

Abstract: The unsaturated shear strength parameter, ϕ^b, is usually determined using triaxial or direct shear apparatus that have been modified to allow for the control and (or) measurement of pore-air and pore-water pressures. A fairly high level of expertise is required for the characterization of ϕ^b using these modified apparatus. A simple procedure for determining ϕ^b for statically compacted soils at different water contents is presented along with a method of analysis. The tests can be performed on a conventional direct shear apparatus. The unsaturated shear strength parameter, ϕ^b, obtained using the proposed procedure is shown to be comparable to that obtained using the modified direct shear test. Since the proposed procedure utilizes standard laboratory direct shear equipment and takes a relatively short time to complete, it offers an easy and convenient alternative for the determination of ϕ^b for statically compacted soils.

Key words: shear strength, matric suction, unsaturated soils, statically compacted soils, direct shear test.

Résumé : Le paramètre de résistance au cisaillement non saturé ϕ^b est habituellement déterminé en utilisant un appareil triaxial ou de cisaillement direct modifié permettant de contrôler et (ou) de mesurer les pressions intersticielles d'air et d'eau. La détermination de ϕ^b à partir de ces appareillages modifiés demande un niveau d'expertise relativement élevé. On présente ici une procédure simple pour déterminer ϕ^b dans des sols densifiés statiquement à diverses teneurs en eau ainsi qu'une méthode d'analyse. Les essais peuvent être effectués dans un appareil de cisaillement direct conventionnel. On montre que le paramètre de résistance au cisaillement non saturé ϕ^b ainsi obtenu est comparable à celui que l'on obtient par l'essai de cisaillement direct modifié. Comme la procédure proposée utilise un équipement de cisaillement standard et qu'elle peut être menée dans un temps relativement bref, elle paraît être une variante facile et commode pour la détermination de ϕ^b dans des sols densifiés statiquement.

Mots clés : résistance au cisaillement, succion matricielle, sols non saturés, sols densifiés statiquement, essai de cisaillement direct.

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Introduction

Compacted soils are used extensively in dams, embankments, and the substructure of pavements. A value for the shear strength of compacted soils is required in the evaluation of the stability of these structures. When the soil is saturated, the shear strength can be characterized in terms of the effective shear strength parameters, c' and ϕ'. Compacted soils are unsaturated, and it is necessary to use two independent stress state variables to characterize the shear strength. Each compaction water content represents a different state of stress, and the shear strength can be fully defined in terms of changes in two independent stress state variables (Fredlund and Morgenstern 1977; Fredlund 1979; Fredlund and Rahardjo 1987).

The shear strength of an unsaturated soil can be expressed in terms of the net normal stress $(\sigma_n - u_a)$ and the matric suction $(u_a - u_w)$ (Fredlund et al. 1978, 1987) as follows:

$$[1] \quad \tau = c' + (\sigma_n - u_a)\tan\phi' + (u_a - u_w)\tan\phi^b$$

where τ is the shear strength, c' is the effective cohesion, ϕ' is the effective angle of internal friction, ϕ^b is the rate of increase in shear strength with matric suction, and $(\sigma_n - u_a)$ is the net normal stress at failure on the failure plane.

Background on shear strength testing of unsaturated soils

The shear strength of unsaturated soils has been measured using triaxial equipment modified to allow for the control and measurement of pore-air and pore-water pressures (Gibbs et al. 1960; Bishop et al. 1960; Satija 1978; Escario 1980; Ho and Fredlund 1982; Peterson 1988; Toll 1990). Other researchers have used a modified direct shear apparatus with pore-air and pore-water measurements (Donald 1956; Escario 1980; Gan 1986). However, the equipment and level of expertise required for the characterization of ϕ^b using these tests are beyond the capabilities of most geotechnical laboratories. Furthermore, the time required to perform the tests runs into weeks or even months depending on the coefficient of permeability of the soil being tested.

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