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INCREMENTAL STRAIN RATE RATIOS AND STRENGTH OF SAND IN THE TRIAXIAL TEST
(BARDEN, L. and A. J. KHAYATT, *Géotechnique*, 16:338–357)

The Authors have presented a fine Paper on the extension of the stress dilatancy theory and on experimental techniques. This Writer has studied the behaviour of cohesionless soil from a different aspect and would like to make some comments on the Paper.

It is accepted that a cohesionless soil is a strain hardening material with both reversible and irreversible deformations occurring under an application of a load increment. The irreversible deformations or slips are caused mainly by shearing stresses, such as predominate in a constant cell pressure triaxial test, and reversible or elastic deformations are caused mainly by the changes of mean normal stress, such as occur in a consolidation stress path. The latter stress path refers to any constant stress ratio stress path which can also be called anisotropic consolidation. As a result, any general stress/strain theory has to consider both elastic and plastic behaviour if it is designed to accommodate every possible stress path.

The stress dilatancy describes the relationship of slip occurring as a result of shearing stresses—for example, in a constant cell pressure test—and gives a relationship between the instantaneous strain rate ratio and the instantaneous stress ratio. The Authors present a solution for a family of plastic potentials in the triaxial test as

$$f = \frac{\sigma_1{}^k}{\sqrt{2}\,\sigma_3} = A$$

where f is the plastic potential function.

This writer has also studied the irreversible behaviour of a cohesionless soil and found in his tests that the plastic potential is a function of the mean normal stress and the stress ratio (Poorooshasb, Holubec and Sherbourne, 1966). This can be represented as

$$g = p\phi\left(\frac{\sigma_1}{\sigma_3}\right)$$

where g is the plastic potential function. It has also been found that for cohesionless soil the yield criterion is a function of the stress ratio only (Holubec, 1966). Typical plastic potential and yield curves are shown in Fig. 1. Since the yield function and the plastic

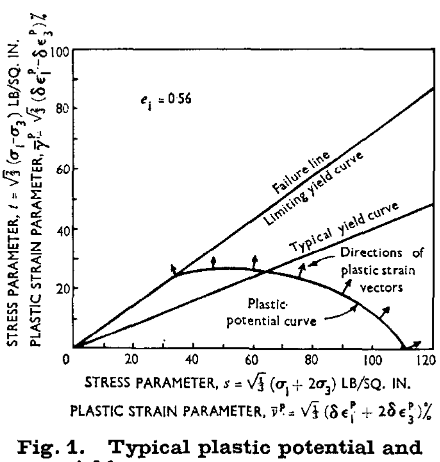

Fig. 1. Typical plastic potential and yield curves

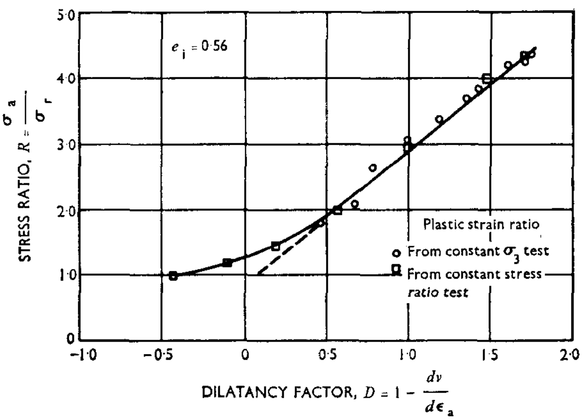

Fig. 2. Comparison of results from constant cell pressure and constant stress ratio tests in stress dilatancy plot

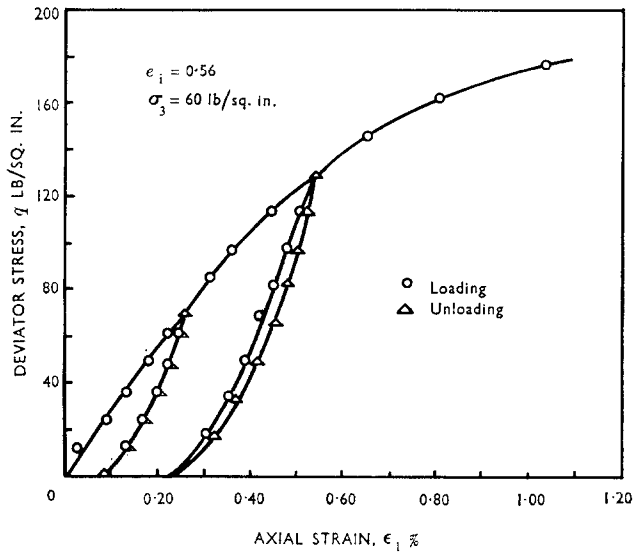

Fig. 3. Results from cyclic constant cell pressure test

potential function are not similar the normality condition cannot be employed to study the plastic stress/strain relationship of cohesionless soil.

If the stress dilatancy relation is a unique relationship it should be true for slips or irreversible deformations occurring in any stress path in a triaxial compression test. An experimental proof of this uniqueness is shown by Poorooshasb, Holubec and Sherbourne (1966) in their study of the inclination of the plastic strain increment vector, i.e. instantaneous plastic strain ratios. In this study it is shown that in a triaxial compression test the inclination of the plastic strain increment vector is a function only of the state of the element. As a result, any stress path can be used to study the stress dilatancy relation if plastic deformations only are considered. This means that the ratios of the plastic strain increments obtained from anisotropic consolidation tests should give the same plot as the strain ratio plots obtained from constant cell pressure tests. That this is so can be seen in Fig. 2 where the results from the two types of tests are shown. As it is difficult to measure the strains at low stress ratios in constant cell tests and obtain results for the stress dilatancy relation in this region, the plastic strain ratios can be obtained from anisotropic consolidation tests. This has been done by the Writer and the results for low stress ratios are shown in Fig. 2. These results show that at low stress ratios negative dilatancy factors are a possibility.

Further, the Writer would like to comment that the stress/strain curves at low stress level contain a significant amount of elastic deformations. The magnitude of the elastic or reversible deformations can be seen on observing the results from a cyclic constant cell pressure test in which the cycling was done at low stress ratios (Fig. 3). In this figure the unloading and reloading stress/strain curves show very little hysteresis and can be considered as reversible or elastic. Therefore when studying slips in this region the elastic or reversible deformations should be subtracted from the total deformations.

Finally, a possible reason for the fact that the Authors' reloading stress paths also follow the stress dilatancy plots is that the cyclic portions of their tests were carried out at stress ratios close to the maximum. At high stress ratios the material is approaching the critical equilibrium and many particles are in an unstable condition. Unloading and then reloading from this condition will result in a large number of slips as shown by the large hysteresis loop.

Therefore, if the elastic deformations are small, the total strains on reloading plot on the stress dilatancy line.

The results shown in the given figures are from drained triaxial compression tests on Ottawa Sand, ASTM Designation C-109, with minimum and maximum grain size of 0·15 mm and 0·75 mm respectively, maximum and minimum void ratio of 0·82 and 0·44 respectively and specific gravity of 2·67.

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BOOK REVIEWS

Calcul des fondations et des murs de soutenement par Wayne C. Teng (traduit par Jean-Michel Dupas). Editions Eyrolles (Paris) 1966

This is the authorized French translation of the Author's *Foundation design* (Prentice-Hall, Englewood Cliffs, New Jersey) published in 1962 (102*s*). As the English edition has not been reviewed in this journal, the following review refers to both editions except where indicated.

The book has been written as a textbook on design and application, intended for engineers concerned with the construction of foundations and for students entering practice. It deals with ordinary materials and circumstances, being essentially an American practising engineer's notebook with general principles added. Students will particularly appreciate the sheets of design calculations for numerical examples.

Part 1, on general principles, covers soil exploration, bearing capacity, earth pressure, settlement and drainage. It is very conventional, excluding for example the engineering implications of shrinkable clays, progressive softening of stiff-fissured clays and overall slope failure of a retained soil mass which would probably be thought essential in a European book.

Part 2 deals with foundations, covering shallow and piled foundations, large bored piles and caissons. The treatment of large bored piles in clay strongly suggests that the Author has not fully realized the importance of clay softening round the perimeter by water migrating from the concrete, or the importance of the perimeter adhesion (and concrete compressibility) in sharing of load between perimeter and base.

Part 3 deals with retaining structures, including sheet-pile walls and braced and cellular cofferdams. It would have been greatly enhanced by a clear warning of the importance of influences other than gravity on the actual pressures, which can differ so much from the simple theories.

In the English edition, the inclusion of a seismic map of the United States is most commendable, and the photographs are well reproduced. The Author index and proof-reading