III-208 PRINCIPAL STRESS ROTATION - MORE MISSING PARAMETERS

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INTRODUCTION

Actual in-situ loadings such as those caused by vehicular traffic and earthquake involve rotation of the directions of the three principal stresses. However, previous experimental studies have all been concerned only with the rotation of the principal stress directions in the σ_1- σ_3 plane. A truly three-dimensional rotation of principal stress directions can not be attained with any of the testing equipment presently available. It is, however, possible to conduct tests in the hollow cylindrical apparatus that will involve rotation of the other principal stress directions although the rotation will be confined only to one plane. This paper presents the results of a series of such tests. Hopefully, the results will provide additional insights into the response of sand during rotation of principal stress directions under three-dimensional stress conditions.

TESTING PROGRAM

The experimental program was conducted using a hollow cylindrical apparatus (dimensions: r_i=3.0cm, r_o=5.0cm, H=19.5cm). The test material used is the Toyoura sand with D_r=70-75%. Three types of tests were conducted (Fig. 1): (1) rotation of σ_1- σ_3 axes (R13 test), (2) rotation of σ_1- σ_2 axes (R12 test), and (3) rotation of σ_2- σ_3 (R23 test). The tests were conducted at constant $p=\sigma_{kk}/3$ = 1.0kg/cm^2, b-value = 0.5 and Φ_m = 20°. The low shear stress level was necessary to keep the difference in inner and outer cell pressures used in the tests to small value. The tests involve 180°- rotations of the principal stress direction β_σ, maintaining the other parameters constant. The same parameter β_σ has been used to denote the direction of principal stress directions in all types of rotations but no confusion should arise from this as the meanings of β_σ are shown in Fig. 1. The stress paths for the three tests are shown in Fig. 2 in a Mohr's circle plot.

TESTS RESULTS AND DISCUSSIONS

The results for the three types of rotations are shown in the volumetric strain, $\varepsilon_v = \varepsilon_{kk}$, and shear strain, $\bar{\varepsilon} = (\frac{2}{3}e_{ij}e_{ij})^{1/2}$, versus β_σ plots in Figs. 3 and 4. As can be seen, the rotation of the principal stress directions in the three types of loadings caused continous deformation as evidence by the accumulation of the volumetric strain. The shear strain in the three tests increased until about β_σ=90° and proceeded to decrease thereon.

The results show the importance of considering the effect of the rotation of all the principal stress directions and bring to question the adequacy of the usual parameter such as Φ_m in dealing with problems where the three principal stress directions rotate. Evidently, rotations of the three principal stress directions in different amounts will result in different magnitudes of deformations, even though the same Φ_m, b-value and p are maintained

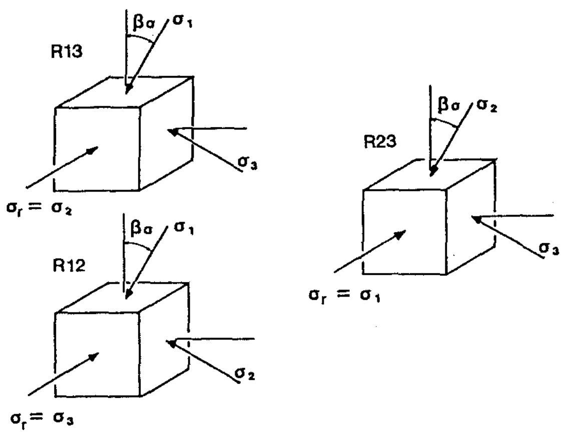

Fig. 1 Types of planar rotation tests

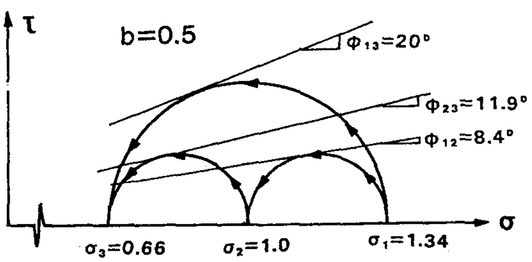

Fig. 2 Stress paths in the Mohr's circle plot (all stresses in kg/cm^2)

constant as can be seen in Fig. 3 and 4.

For planar rotations of principal stress directions it has been found that the parameter

$$\sin\Phi_{ij} = \frac{(\sigma_i - \sigma_j)}{(\sigma_i + \sigma_j)}$$

which gives the mobilized angle in the plane of rotation, is an adequate parameter in predicting the amount of deformation. The mobilized angle of friction Φ_m is equal to Φ_{13}. The Φ_{ij} values for the tests performed in this study are shown in Fig. 2.

The above results and the results of tests at different b-values appear to support the validity of this parameter - the magnitude of deformation during planar rotation of principal stress directions is directly related to Φ_{ij}. However, this parameter is only good for planar rotations. The question of what parameter to use during three-dimensional rotations of principal stress directions remains, pending results of tests where all directions of principal stresses are rotated simultaneously.

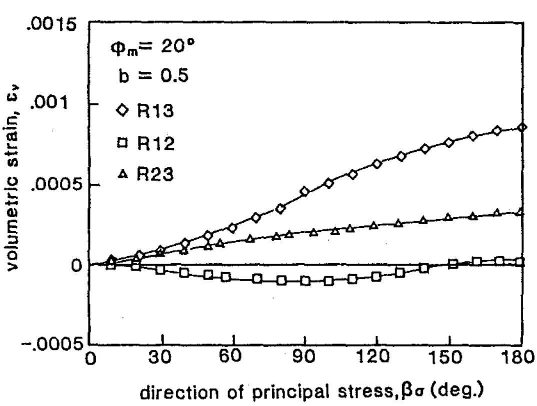

Fig. 3 Volumetric strain during 180°-rotation of β_σ

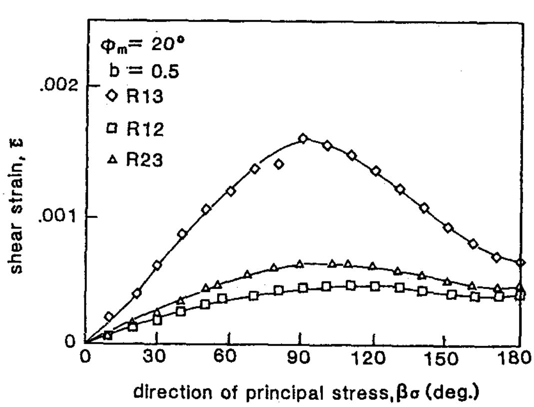

Fig. 4 Shear strain during 180°-rotation of β_σ