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UNDRAINED TRIAXIAL RELAXATION TESTS ON A FIBROUS PEAT

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INTRODUCTION

The long-term creep with comparatively great strain magnitudes makes peat a distinctive as well as problematic geomaterial in geotechnical engineering practice. Hobbs (1986) claimed the effective stress strength of peat is also state dependent as the void ratio continuously decreased under the maintained load. The inelastic behavior of peat materials consists of the hysteresis of the organic solid structure as well as the delayed pore water dissipation. Here, the rate-dependent hysteresis related to a viscous effect in the soil structure is investigated. Conventionally, creep behavior of peat was studied in one-dimensional (1D) drained fashion such as oedometer tests (den Haan 1996), whereas the effective stress strength parameters were obtained in undrained tests including undrained triaxial (Hendry et al. 2014) and simple shear (Farrell et al. 1998). It was found that peat continues to creep for years or even decades (Barden and Perry 1968) without reaching its creep limit/equilibrium state. Also, the creep rate increases at a critical point termed as tertiary compression (Dhowian and Edil 1980) which complicates the laboratory investigation as well as the mathematical formulation of creep models for peat. The result from drained creep tests is a hybrid effect of solid hysteresis and the delayed micro-pore/adsorbed water movement. Albeit the 1D creep behavior (secondary and tertiary compression) of peat has been well studied for decades, information reported in the literature about the solid structure rate-dependent hysteresis, which plays a crucial role in effective stress evolution, is still incomplete. For the advancement of constitutive modelling and a better understanding of peat, undrained triaxial relaxation tests were carried out in this study to investigate the inelasticity of peat organic solid structure.

The state-of-art in modelling the rate-dependency of peat is based on the isotache concept. A linear relationship is assumed between the Hencky strain and the logarithm of virgin compression stress. On each of the equidistant isotaches, the creep rate is constant (den Haan 1996). Elasto-viscoplastic models based on the Modified Cam Clay model have been extended using the isotache concept to predict peat elasto-viscoplastic behavior. In the above mentioned models, creep was taken to start simultaneously with the hydrodynamic consolidation process. The mechanism behind peat creep was assumed to be the micro-pore water dissipation occurring at a slower rate than the macro-pore water dissipation during the consolidation stage. This paper demonstrates a set of experimental data on undrained triaxial relaxation tests on a fibrous peat collected from Clara bog,

Ireland. The suitability of such tests as an alternative experimental means to investigate peat inelasticity is evaluated.

TESTING PROGRAM

Saturated undisturbed peat specimens were trimmed into diameter of 38 ± 1 mm and height of 76 ± 1 mm from the undisturbed peat block. Saturation was confirmed by a Skempton B value of larger than 0.95. The properties of the undisturbed peat can be found in Zhang and O'Kelly (2013). Unconsolidated undrained (UU) triaxial tests were carried out with and without pore water pressure measurements at a room temperature of 20°C . The testing program is listed as following:

1. Undrained loading and unloading (*lu*) with relaxation tests (relaxation duration of 1000 s) at two axial strain rates (2.032 mm/min (2.67 %/min) and 0.2032 mm/min (0.267 %/min)) were carried out without pore water measurement at a cell pressure of 30 kPa.
2. Two undrained triaxial relaxation tests were investigated with two axial strain rates, namely 2.032 mm/min and 0.2032 mm/min, with pore water pressure measured and zero cell pressure. The relaxation time period was 10 hours.
3. The loading-unloading-reloading (*lur*) UU triaxial relaxation tests without pore water pressure measurement at axial strain rate of 2.032 mm/min were compared with *lur* UU triaxial tests at a strain rate of 0.06096 mm/min.

RESULTS AND ANALYSIS

The UU triaxial *lu* tests with relaxation of 1000 s were compared between axial strain rates of 2.032 mm/min and 0.2032 mm/min. Figure 1 (a) shows the strain rate effect on the deviator stress during undrained compression and relaxation. At the very start of the compression, the two curves showed very similar slope. Higher deviator stress was achieved with the higher strain rate at the same level of axial strain. The deviator stress relaxations during loading stage decayed $14.6 \pm 0.5\%$ and $8.9 \pm 0.9\%$ of their original values for 2.032 mm/min and 0.2032 mm/min strain rates for the duration of 1000 s, respectively. Some stress points measured at the lower strain rate were below the relaxed values at the higher strain rate, which indicates incomplete relaxations. The deviator stress relaxation ratio (defined in Equation 1, where q : value after relaxation; q_0 : value before relaxation) is presented in Figure 1 (b). It can be seen that the relaxation ratio of deviator stress during the loading stage is nearly constant for the same duration whereas the relaxation ratio during unloading stage approaches 100% due to the zero value of q . The rate-dependent behavior can be represented by an overstress concept (Haupt 2002). Rate-independent hysteresis was recorded at the end of unloading, although the unloading results of the two tests are difficult to compare due to the different strain levels reached. The virtual elastic strain calculated using the stress relaxation increase during unloading divided by the tangent modulus of the unloading stress-strain curve is plotted in Figure 1 (c). A linear relationship can be found between the virtual elastic strain and the total strain during the unloading stage.

$$R\% = \frac{q_0 - q}{\max\{q_0, q\}} \% \quad (1)$$

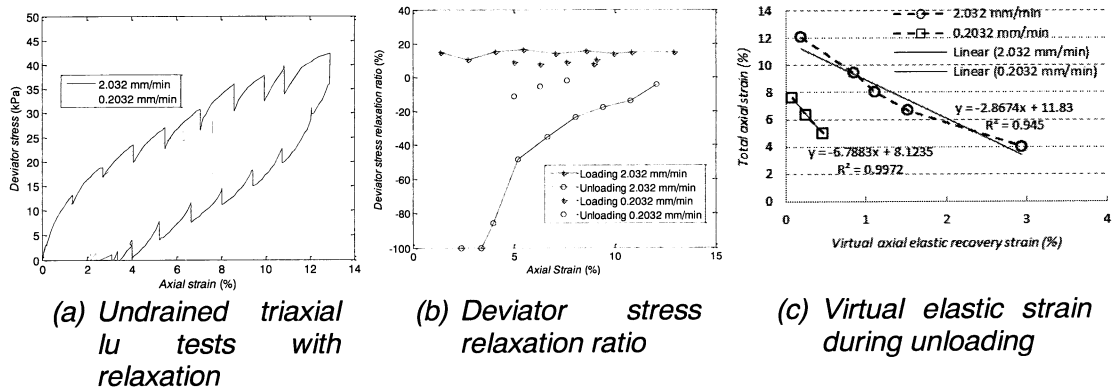


Figure 1. Undrained relaxation tests at two axial strain rates

Figure 2 presents the triaxial compression tests at strain rates of 2.032 mm/min and 0.2032 mm/min followed by a 10 hour relaxation phase with pore water pressure measurement and zero cell pressure. From Figure 2, the pore pressure variations were very small; the noise recorded was rooted in the 1 kPa resolution of the pore pressure transducer. Since the pore water pressure was practically zero, the relaxation behavior could be taken as solely from the peat organic solid structure. The tenfold increase of strain rate resulted in a deviator stress increase of 20.1 % to reach an axial strain of 5%. A linear relationship can be found between deviator stress and logarithm of time after an initial time period. Figure 2 also indicates that after 10 hour relaxation period the deviator stress tends to decrease continually for the 2.032 mm/min test.

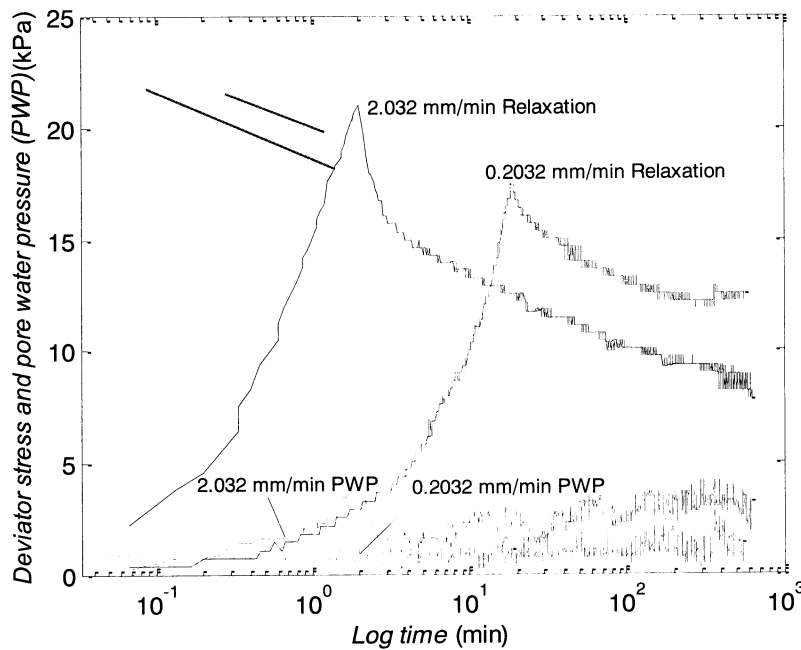


Figure 2. Undrained relaxation tests at two axial strain rates

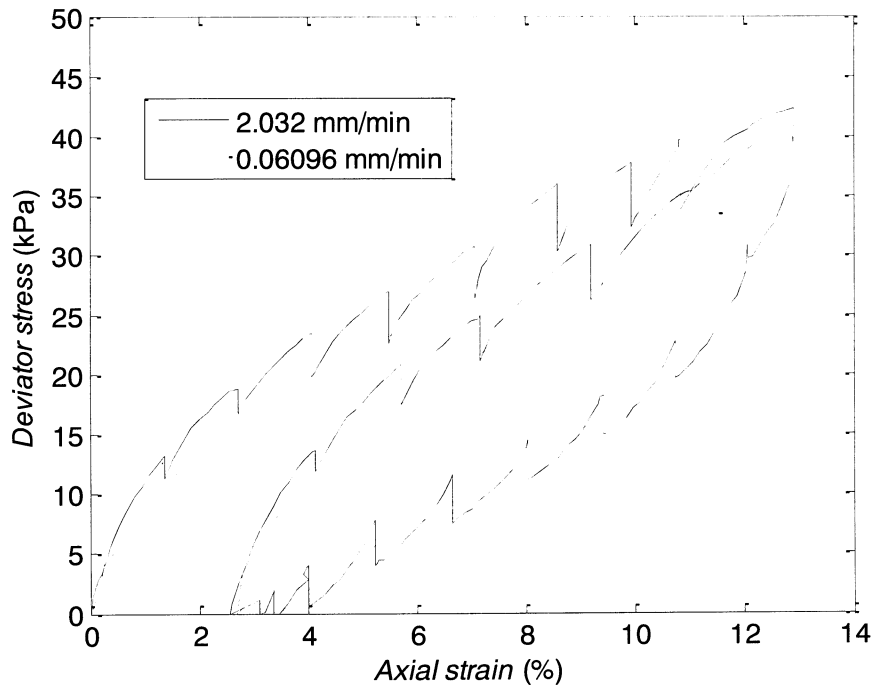


Figure 3. Comparison of *lur* relaxation test at 2.032 mm/min and *lur* test at 0.06096 mm/min

The triaxial *lur* relaxation test at an axial strain rate of 2.032 mm/min was compared with the triaxial *lur* test at a strain rate of 0.06096 mm/min (presented in Figure 3). Provided the relaxation time of 1000 s for the test at 2.032 mm/min, the termination points of the relaxation asymptotically approximated *lur* test at 0.06096 mm/min. It is reasonable to assume that if the relaxation test was leaved long enough, it would reach its creep limit, which according to Haupt (2002) is defined as *state of equilibrium*. For peat, however, creep continues for an extremely long period of time. Relaxation test provides a suitable means for the study of peat inelasticity.

CONCLUSIONS

From the results of the undrained triaxial relaxation tests of a fibrous peat with unloading, the following conclusions can be made:

- (1) Rate-dependent and -independent hystereses were observed in the undrained triaxial tests on the fibrous peat;
- (2) The pore water pressure variations during uniaxial stress relaxation tests were very small. Lower strain rate resulted in a time delay prior to the initiation of the deviator stress decay. A linear relationship can be found between deviator stress and logarithm of time after an initial time period;
- (3) Relaxation tests provide a suitable means for investigating strain rate effects in peat, especially for slow strain rates.

In order to investigate the creep limit, further relaxation tests should be carried out with longer relaxation time.

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