Viscous property of an air-dried micaceous sand in plane strain compression

Introduction: Clay, sand, gravel, rock, etc. have generally noticeable viscous property, either of isotach or TESRA type or their mixture. With the isotach viscosity, the stress is a unique function of instantaneous irreversible strain and its rate, therefore the change in the stress-strain relation upon a change in the strain rate is persistent as far as monotonic loading (ML) continues at a constant strain rate. With the TESRA (Temporary Effect of Strain Rate and Acceleration) viscosity, the change in the stress-strain relation upon a change in the strain rate and/or its rate decays with the irreversible strain, therefore the stress-strain relations at different constant strain rates tend to collapse into a unique one as ML continues. Clayey materials generally show the isotach viscosity, while poorly graded granular materials generally show the TESRA viscosity. In the present study, a series of drained plane strain compression (PSC) tests were performed on air-dried relatively fine natural river sand that is rich with flaky shaped mica particles.

Test procedures: A natural sand from the bed of Jamuna river in Bangladesh \((G_s = 2.7, D_{50} = 0.16, e_{min} = 1.173, e_{max} = 0.690, F_C = 7\%\); Fig.1) was used. The prevailing mica particles, coming from rocks in the Himalayas, are sand-sized (in plane) of biotite but very flaky with an aspect ratio of approximately 50:1. The mica inclusion is considered to be linked to a number of unexplained flow slides that occurred in the river training structures along the Jamuna river. The quantity of mica, its distribution and orientation in the natural deposit varies from place to place. It is extremely difficult to separate the mica mechanically. Hight and Leroueil (2003) reported a mica content of 5-10% by grain counting. A conventional PSC apparatus (Park and Tatsuoka 1994) was used. The major and intermediate principal stress boundaries were rigid and lubricated and the minor principal stress boundaries were flexible. The vertical stress was applied by automatically controlling the displacement of the loading piston and the minor principal stress boundaries were flexible. The cell air pressure, allowing to perform creep & relaxation loading, the loading piston and the minor principal stress were applied by controlling vertical stress was applied by automatically controlling the displacement of lubricated and the minor principal stress boundaries were flexible. The distribution and orientation in the natural deposit varies from place to place.

Drained tests (with air as the pore fluid) were performed along stress paths shown in Fig. 2 on relatively dense specimens, 20 cm-high and 8 cm-wide (confined side) by 16 cm-long, prepared by pluviating air-dried particles through a set of sieves. The axial strain rate \(\dot{\varepsilon}_a\) from the initial isotropic stress state \(\sigma_{is} = 30\) kPa to the end of the anisotropic consolidation path \((R = \sigma_{is}/\sigma_{as} = 3)\) was 0.0125 %/min. Then, \(\dot{\varepsilon}_a\) was changed as indicated in the respective figure. PSC loading started without any drained creep before the start of shearing. Axial strains \(\varepsilon_a\) were measured locally with a pair of local deformation transducers (LDTs) up to around 4 % and always externally with a dial gauge (DG). LDTs and DG measurements exhibited
nearly the same strains (as shown in Fig. 5-8), indicating very small bedding error in the present case. Lateral strains were measured with four pairs of gap sensor (GS).

**Test results:** Fig.2 compares the $R-\varepsilon_i$ relations from tests at constant $\varepsilon_i$ differing by a factor of 1/100 or 100 at the restart of ML. Fig. 3 shows the results from tests in which $\varepsilon_i$ was changed stepwise several times. For clarity, only $\varepsilon_i$ measured with a DG is shown in these figures. Fig.4 shows the relationship between the shear strain $\gamma = \varepsilon_i - \varepsilon_k$ and volumetric strain $\varepsilon_{vol}=\varepsilon_i + \varepsilon_k$ from these tests. The following trends of behaviour may be seen from these figures: 1) The stress changes noticeably upon a sudden change in $\varepsilon_i$ and the associated change in the stress-strain curve is essentially persistent with an increase in the strain $\varepsilon_i$, the isotach viscosity. The difference in the pre-peak $R-\varepsilon_i$ relations between the respective pair of tests at two different strain rates was not significant (Fig. 2). However, it is difficult to evaluate the effects of strain rate based on such test data due to an inevitable scatter in the data. 2) The effects of $\sigma_i'$ on the $R-\varepsilon_i$ and $\gamma - \varepsilon_{vol}$ relations were considerable. The sand became much more deformable in the $R-\varepsilon_i$ relations and contractive with the increase in the pressure level compared with ordinary clean sands. 3) The axial strain and the peak $R$ value are smaller at a higher constant strain. Further study is necessary to reconfirm this observation and find its reasons. 4) The strain path is insensitive to a difference and a change in $\varepsilon_i$ during otherwise ML. 5) The material is very contractive without exhibiting any tendency to dilate even at $R$ larger than five, near peak, in contrast to the behaviour of usual clean sands. Presence of mica in sand suppressed the tendency to dilate even at $\varepsilon_i$. 6) The effect of strain rate effects (including creep and stress relaxation phenomena) despite air-dried conditions. The observed viscosity was essentially of the isotach type. 7) The sand was very contractive, in particular at higher pressures. 3) The effects of $\sigma_i'$ on the $R-\varepsilon_i$ and $\gamma - \varepsilon_{vol}$ relations are considerable. 4) The sand exhibited other peculiar behaviours.