Creep deformation characteristics of dense gravel

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Introduction:

On-going time-dependent deformation characteristics, especially creep deformation, are very important in many geotechnical engineering problems. The creep property controls long-term deformation of ground under sustained load. So far, the creep deformation of dense gravel has not been studied extensively, since gravel has been considered as a non-viscous material so that the creep deformation could be insignificant. In this paper, some creep test results are shown in order to demonstrate how important creep behavior is.

Testing procedure:

A large triaxial apparatus (Hoque et al., 1996) with some modifications for the purpose of the present study was used. The specimen is rectangular prismatic (58cm high and 23 cm times 23 cm in cross-section). Axial and lateral strains were measured by local displacement transducers (Goto et al., 1991) set on the surfaces of the specimen. The material used is very dense Chiba gravel with a water content of 5.5%, dry density of 2.25 g/cm^3 and void ratio of 0.196 before the start of consolidation. Isotropic consolidation was performed from 49 kPa to 490 kPa, and then axial loading was made at a constant axial stress rate $d\sigma_v/dt$=49 kPa/min under a constant confining pressure σ_h=490 kPa. During shearing, creep deformations were allowed at different stress levels under drained conditions (Fig. 1). Period of creep at each was about 6 hours.

Results and discussion:

The overall relationships between the stress ratio $R=\sigma_v/\sigma_h$ and the vertical and horizontal strains are shown in Figs. 2, 3. It is seen that in both vertical and horizontal directions, a considerable amount of creep strains occurred. It is also seen that creep strains became larger with approaching the failure. After the loading was resumed after creep, the stress-strain curve exhibited a very stiff response, followed by a marked yielding (Fig. 4), the stress and strain relationships tended to rejoin the primary ones as shown by dotted curves in Figs. 2, 3. It is evident that creep deformation increased the yield stress, expanding the size

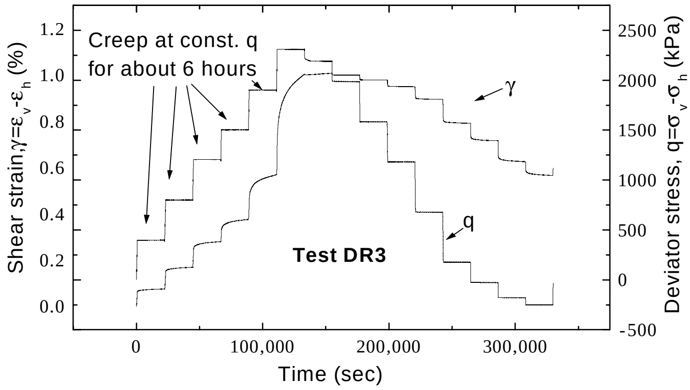

Fig. 1: Stress and strain history of test DR3

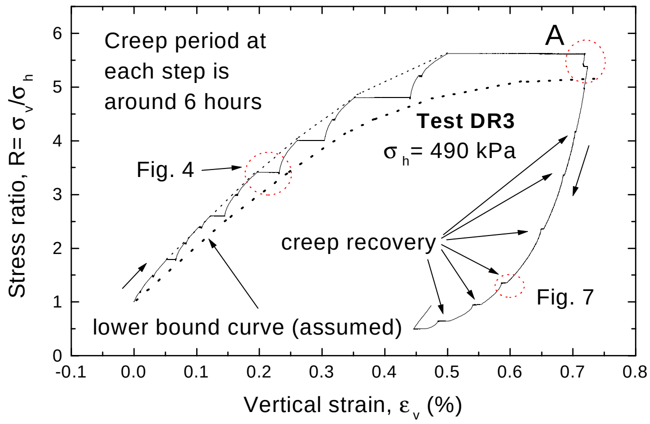

Fig. 2: Overall stress and vertical strain relationship

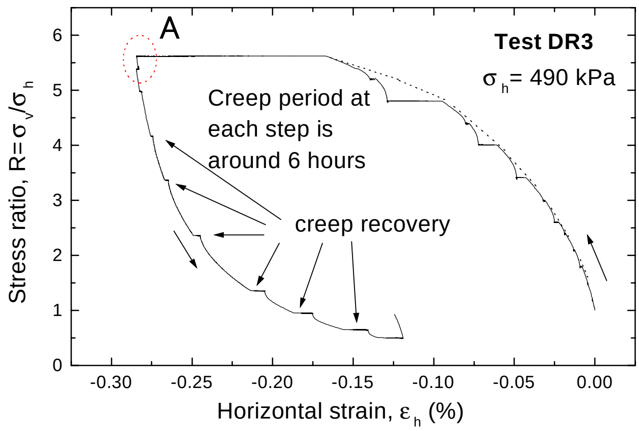

Fig. 3: Overall stress and horizontal strain relationship

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of high stiffness zone in the stress space. Probably, the response when loading is resumed gradually becomes more elastic as the creep deformation increases with time.

During the creep stages, the gravel tends to be more contractive or less dilative (Figs. 5, 6), indicating that the direction of irreversible strain increment vector is not a unique function of stress state (i.e., an irreversible potential, which is similar to the so-called plastic potential, does not exist), but is possibly also a function of instantaneous strain rate. That is, the direction of strain increment vector rotates with time during a creep stage. During creep, the strain rate decreases with time, and it can be seen from Fig. 6 that the gravel becomes more contractive at slower strain rates under otherwise the same conditions.

During the process of stress-unloading, creep recovery (negative creep deformation) was observed (Figs. 2, 3) except for the step A indicated in the figures. The positive creep deformation at step A can be explained by assuming existence of the lower bound curve (AnhDan et al., 2000) as shown in the figure, which is defined as the reference stress-strain curve that is achieved when loaded at nearly zero strain rate and reached at infinite time in creep or stress relaxation tests. The creep recovery deformations were large when stress states went far below the lower bound curve in unloading direction. When the unloading was resumed after creep recovery, the stress-strain curve exhibited a stiff response (Fig.7), in a similar manner to that of loading after creep (Fig. 4).

Conclusions:

As the shear stress level increased, the creep strains became larger. The behavior when loading or unloading was resumed after creep was nearly elastic. The re-joining behavior and creep recovery were also observed. The gravel becomes more contractive at slower strain rates during creep, and there does not exist a unique potential for irreversible strain rates that is independent of time or strain rate.

Reference:

AnhDan,L.Q. et al. (2000), "Lower bound stress-strain relationship of gravel", 35th Annual conference of JGS (submitted).

Goto,S. et al. (1991): "A simple gauge for local strain measurements in laboratory", Soils and Foundations, Vol. 31, No. 1, pp. 169-180.

Hoque,E. et al. (1996), "Measuring anisotropic elastic properties of sand using a large triaxial specimen", Geotechnical Testing Journal, ASTM, Vol.19, No.4, pp.411-420.

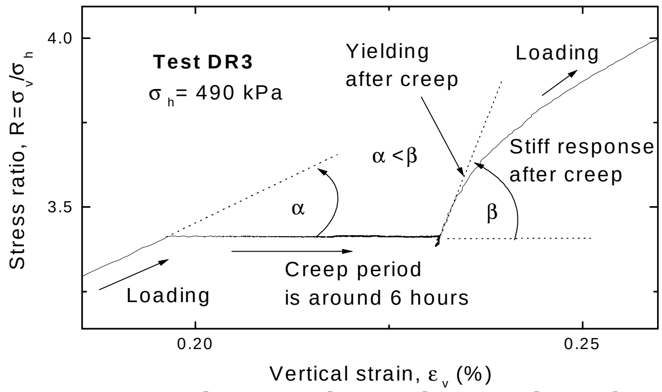

Fig. 4: Local stress and vertical strain relationship

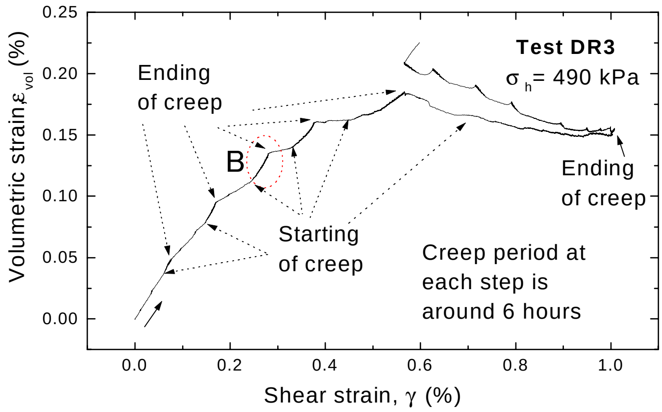

Fig. 5: Relationship between shear and volumetric strains

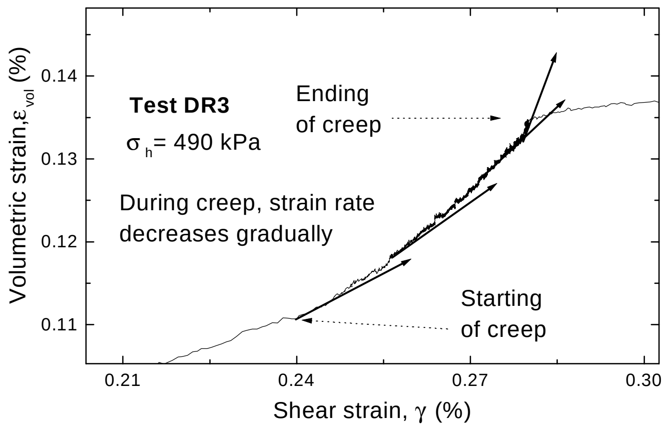

Fig. 6: Close-up of step B in Fig. 5

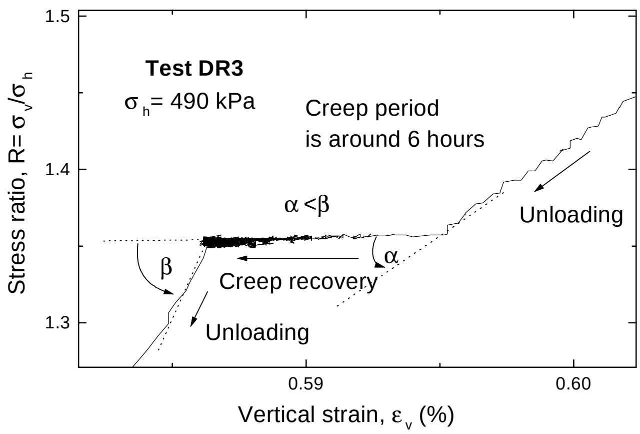

Fig. 7: Local stress and vertical strain during creep recovery