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Investigating Time-Dependent Deformations in Dry Sands

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1. Introduction

The behavior of sands is time-dependent and can affect the sustainability of many geotechnical projects. Applying load to the soil leads to deformation in the soil mass. Deformations do not end immediately after the load is applied but will increase over time and gradually, called creep in the soil. In other words, creep means the deformation of the soil under constant stress and over time. All soils experience creep, but the amount of creep depends on the soil type, ambient temperature, gradation, and particle shape. Soft clay shows more time-dependent deformations in minutes or hours, while sands may take several days to show creep deformations. This is one reason why so far, most researches have focused on the creep behavior of sand, and few researches have studied the creep behavior of sands. In general, two main factors are defined for sand creep: the fragmentation and failure of particles due to contact stresses between the grains. The other is the rearrangement of particles over time due to micromechanical slippage. Creep deformations increase with increasing stress, which can be due to more crushing of sand particles. However, the crushed particles will gradually become more stable, and therefore the long-term deformations will be more minor. The study of the time-dependent behavior of sands is one of the important topics in geotechnical engineering that despite various researches, there is a need to predict axial deformations over time in dry sandy soils.

2. Materials and Test Procedures

In this study, nine different sand types with different particle shapes and grain sizes and different granulations have been used to investigate the time-dependent behavior of dry sands under constant stress. Figure 1 shows the sand grading curve.

Figure 2 shows the odeometer apparatus. All specimens were remolded in a consolidation ring with a diameter of 7 cm and a height of 2 cm. After applying stress, they were evaluated for a creep at regular time intervals.

3. Odeometer Experiments

The test process is the same as the consolidation test, except that the specimens are remolded, and the studies are performed in dry conditions. First, the inner parts of the consolidation ring are well coated with grease to minimize the friction of the sand grains with the ring wall, and then each sample was made by the dry precipitation method.

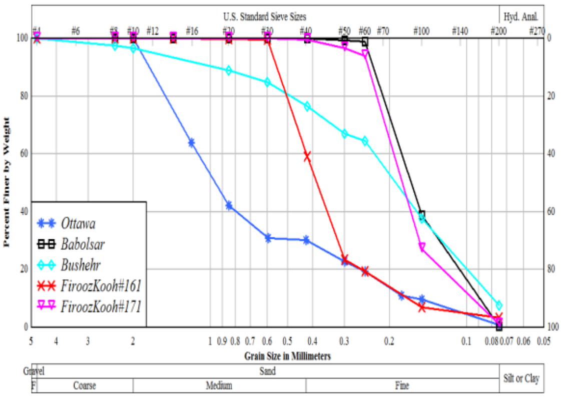

Figure. 1 Grain size distribution of sand samples

Figure 2. Odeometer apparatus

The applied method of preparing soil samples was to pour sand through a funnel in consolidation mold with specified height. Pouring sand was performed carefully and without any vibration. In the first stage, Ottawa sand samples were tested in three initial void ratios (minimum, maximum, and 60% relative density equivalent) to determine the most suitable overhead stress for 30-day creep tests. Initially, the sample was subjected to 45 kPa stress for 48 hours, and at the end of the time, the following stress phase (twice the previous state) was applied to the sample. Each sample was tested for 12 days. The three selected void ratios were found for a total of 36 days in the odeometer test. Figure 3 shows the deformation diagram of the samples at the beginning of the experiment and after the end of 30 days, separately for each type of sand. As shown in this figure, *Firoozkooh#161* sand has undergone the most deformation in the test process. Moreover, the local sands of Kermanshah (*KRSS#1*, *KRSS#3*) have experienced the slightest deformation. This is because these two types of sands are of the same sample but have different granulation.

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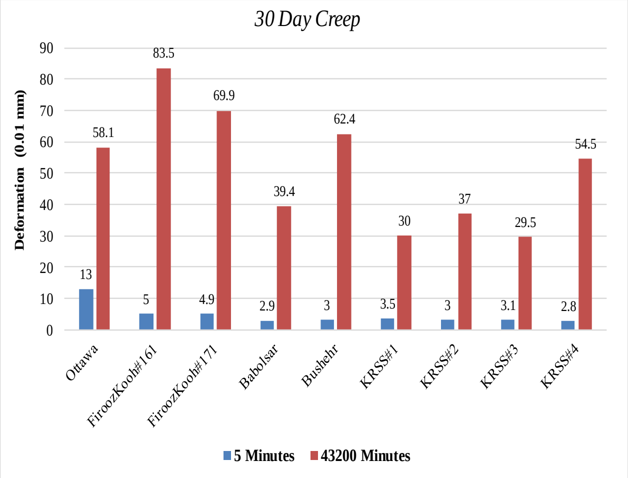

Figure 3. Sand deformations at the beginning and the end of tests

Figure 4 shows the creep strains created at the end of the experiment for each specimen. *Firoozkooh#161* sand with 4.2% creep and *KRSS#1* and *KRSS#3* with 1.5% creep had the highest and lowest creep rates in 30 days, respectively.

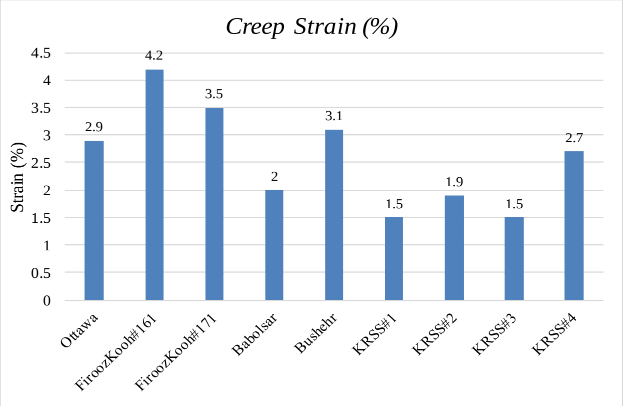

Figure 4. Creep strains for samples after 30 days

According to the linear equations, the following equations are proposed as the mean of the equations for coarse-grained sands (Equation 1) and finer-grained sands (Equation 2).

$$y = 10 + 0.001t \qquad (1)$$

$$y = 8 + 0.001t \qquad (2)$$

Where t is the time in minutes and y is the deformation of the sand in hundredths of a millimeter.

3. Conclusion

In this study, the creep behavior of dry sands under constant stress for 30 days and a range of stresses (26 to 416 kPa) for seven days were evaluated in an Oedometer experiment. Previous studies, using Oedometer experiments, have often examined the creep behavior of sands at incremental loading steps. In contrast, this study investigated the creep behavior of sands at constant stress (30 days) and, in addition, several stresses at 7-day intervals. This study shows that attention to creep strains and the temporal behavior of sands is of particular importance as it can affect the stability of geotechnical projects. The nine samples were tested for 341 days at intervals of 2, 7, and 30 days and under different loads. Samples with a density of 60% were subjected to 45 kPa stress for 30 days and at 7 day intervals under 26 to 416 kPa stresses (with double increments) were subjected to an Oedometer dry test. Oedometer experiments in dry conditions showed that the cause of creep (deformation under constant stress) is slippage, rearrangement of grains, and breakage of particles. Factors that play a role in grain slippage include particle shape, porosity ratio, grain size, and grain type. It is noteworthy that a complex combination of all the above factors causes creeps in the dry sands, which are not easily separable, and all factors are interdependent. Except for standard sands, which have a wide range of particles in the soil mass, other specimens show an irregular increase in time-dependent deformation. Accordingly, it is relatively easy to predict the creep pattern of standard sands, but this is not easily identifiable for poorly grained sands (whether samples with fine or coarse particles). In poor granular soils, each specimen exhibits a unique behavior according to its structural characteristics (sharp or rounded grain and fine or coarse particles). The results showed that rotation, slip, and crushing of sand grains on top of each other at tested intervals under constant loads caused creep deformations in the samples. Sand samples showed between 1.5 to 4.2% creep strains in 30 days and between 0.61 to 2.5% creep strains in 7 days.