STRENGTH AND DEFORMATION CHARACTERISTICS OF GYPSUM MIXED SAND UNDER WIDE RANGE OF AXIAL STRAIN RATE

The University of Tokyo, Student Member, ○Zain Maqsood
The University of Tokyo, Fellow Member, Junichi Koseki

1. INTRODUCTION

The ample cognizance of loading rate dependent characteristics is of vital importance for the constitutive modeling of natural rocks and other geomaterials. In the past few decades, numerous prolific attempts have been made, throughout the globe, to comprehend the salient aspects of this rate dependent behavior. For instance, the findings of multiple strain rate tests along with creep at different stress levels performed on sedimentary soft rocks established far beyond any doubt that the stress-strain responses in the pre-peak regions for these rocks were strictly governed by the instantaneous loading rate, Hayano et al. (2001). Such a tendency is regarded as Isotach and it is believed to be vanish after the formation of shear band in the post-peak region. In the light of these facts, it becomes essential to utterly examine the rate dependent behavior for the rational prediction and evaluation of strength and deformation characteristics of geomaterials.

In an effort to study the rate dependency, a series of unconfined monotonic tests were conducted on Gypsum Mixed Sand (GMS) specimens at a wide range of average axial strain rates ranging from 1.7E-05 to 1.9E-01 % per minute, viz. 10,000 folds. As expected, significant effects on the peak strength and stress-strain responses were witnessed and are discussed along with the details of failure modes. In addition, four unconfined creep tests were also performed on GMS at different stress levels and were compared with the results of unconfined monotonic tests. The results indicate an abrupt change in behavior of GMS for specimen tested at strain rate lesser than 2.0E-03 % per minute. Based on this finding, the test results are classified in two distinct strain rate zones and behavior of GMS in each of these zones is discussed.

2. MATERIALS AND TESTING PROCEDURE

GMS specimens (diameter = 50 mm, height = 100 mm) were prepared in laboratory by uniformly mixing fixed percentages by weight of Silica Sand No. 6 (42.4%), gypsum (33.9%) and water (23.7%). It is noteworthy that two different batches (Batch A & D) of same type of gypsum were used in the present study. After mixing, the slurry was poured into the plastic molds and were sealed tightly. After an initial curing of 48 ± 2 hours within molds, the specimens were removed, and were wrapped in plastic sheets for further curing. The tests were conducted at two different periods of curing; viz. 3 ± 0.5 days and 90 ± 3days. However, one of the specimens used to perform creep test at 1035 kPa was cured for about 10 months. Before testing, the cured specimens were capped using dental gypsum to avoid tensile cracking, and were also covered with rubber membrane to avoid moisture loss during testing. The details have been reported by Maqsood et al. (2015).

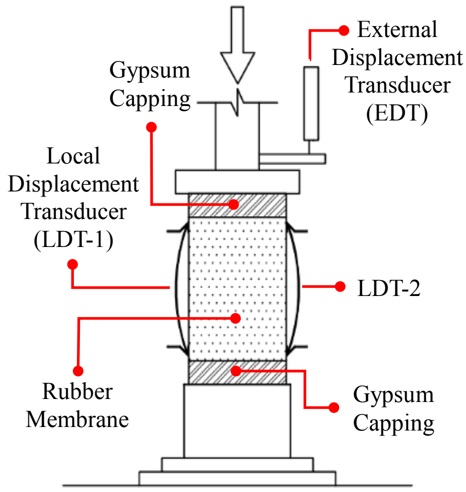

Fig. 1 Schematic illustration of GMS specimen

A total of nine unconfined monotonic tests were performed at eight different average loading rates ranging from 1.7E-05 to 1.9E-01 % per minute. In addition, four unconfined creep tests were performed at average axial creep stresses of 2735, 2365, 1875 and 1035 kPa. In order to overcome the technical limitation of the apparatus used in this study, the creep load was maintained by applying infinitely small loading and unloading cycles. As shown in Fig. 1, a pair of Local Displacement Transducers (LDT, Goto et al. 1991) were also attached to the opposite sides of specimen to accurately measure the axial strain rates free from the undesirable influence of bedding error.

3. RESULTS AND DISCUSSION

The stress-strain relationships of unconfined monotonic tests performed on GMS specimen prepared using Batch-D gypsum and cured for 3 ± 0.5 days are shown in Fig. 2. The Isotach behavior is clearly evident from these stress strain relationships as peak strength values and stiffness of GMS decreases with the decrease in loading rate. The peak strength value of specimen D1 tested at highest loading/strain rate of 1.9E-01 % per minute showed a peak strength of 4004 kPa. On the other hand, a peak strength value of only 115 kPa (specimen D21) was obtained by reducing the loading rate by about 10,000 times; indicating a reduction of about 97% in peak strength. Moreover, the phenomenon of strain softening is fairly significant for specimens tested at higher loading rates while it diminishes with the decrease in loading rates.

In order to elaborate the dependency of peak strength values on loading rate, the relationship between normalized strength and tangential strain rate at failure is plotted in full logarithmic plot in Fig. 3. The normalized strengths are obtained by dividing failure stress values with the unconfined compressive strength obtained at a strain rate of 2.0E-02

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Contact address: Geo-lab, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan, Tel: +81- 3-5841-6123

% per minute. The tangential strain rate at failure was obtained by computing the slope of axial strain and time plot between 98% of peak strain and peak strain. As anticipated, the normalized strength values of GMS decrease with the decrease in loading rate but an abrupt and a sharp drop can be witnessed when the strain rate was further reduced from a critical value of strain rate, viz. 2.0E-03 % per minute, as shown in Fig. 3. Therefore, the plot can be divided into two zones of strain rates and pronounced effects of loading rate can be witnessed in zone-2 as compared to zone-1. Furthermore, the specimens tested under creep loading showed higher peak strength reduction with the decrease in strain rate compared with the unconfined test results of zone-1.

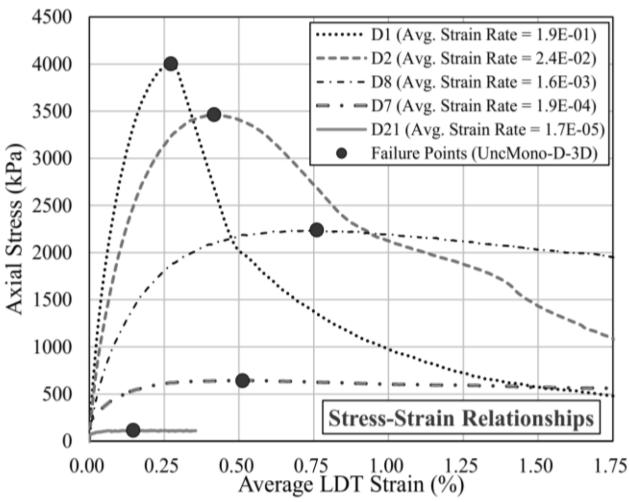

Fig. 2 Stress-strain relationship of GMS specimens tested under unconfined monotonic loading condition

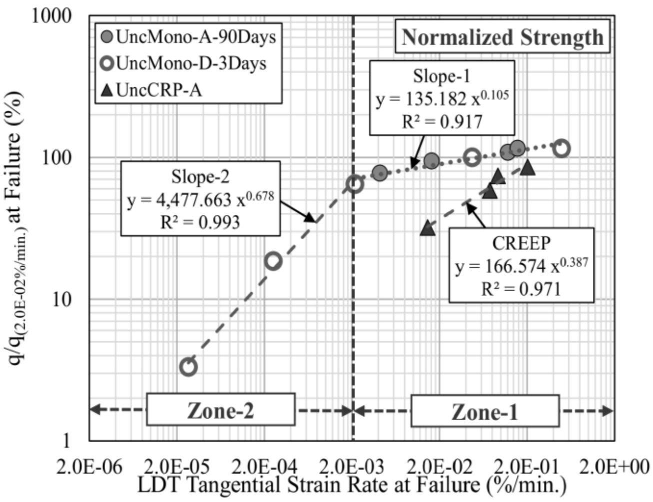

Fig. 3 Relationship between normalized strength of GMS specimens and tangential axial strain rate at failure

The full logarithmic plot between average values of locally measured failure strains and tangential strain rates at failure is shown in Fig. 4. The average local/LDT strain at failure was evaluated by computing the average of strains measured by each of the LDTs at peak strength. Fig. 4 also confirms the abrupt change in the behavior of GMS for strain rate lesser than 2.0E-03% per minute; and this plot can also be divided into similar two zones of strain rates. In zone-1, the failure strain increases with the decrease in strain rate but after reducing the strain rate further from the critical value of 2.0E-03 % per minute the values of failure strain start decreasing with relatively a sharp slope in zone-2, as shown in Fig. 4. Moreover, the effects of strain rate on the failure strain of specimen tested under creep are quite significant compared with the monotonic tests results of zone-1.

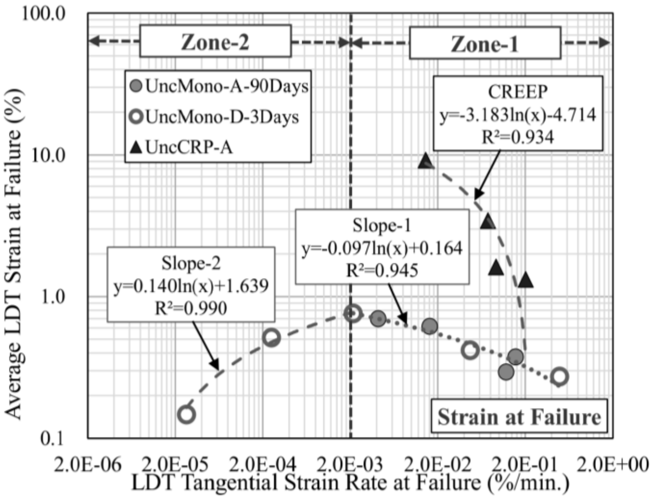

Fig. 4 Relationship between failure strain of GMS specimens and tangential axial strain rate at failure

The formation of shear band is also influenced by the strain rate as clear and distinct shear bands were witnessed for almost all the specimens belonging to zone-1. Contrarily, severe bulging with no visible crack or shear band was observed for specimen belonging to zone-2.

4. CONCLUSION

The loading rate dependent behavior of GMS was studied by conducting unconfined monotonic loading tests at a wide range of strain rates, viz. 10,000 folds. In the pre-peak regions, Isotach behavior was observed as peak strength and stiffness of GMS specimens decrease significantly with the decrease of loading rate. However, an abrupt and distinct change in the behavior of GMS was observed for specimens tested at strain rate lesser than a critical value of 2.0E-03 % per minutes. A more pronounced reduction in the peak strength and failure strain values was witnessed for specimens tested at strain rates lesser than the said critical value. Moreover, the failure mode of GMS specimens also changes from distinct shear failure to bulging with the decrease in loading rate.

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