EFFECTS OF LOADING RATE ON THE BEHAVIOR OF GYPSUM MIXED SAND

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1. INTRODUCTION

It is a well-acknowledged fact that mechanical behavior and deformation characteristics of soft rocks and other geomaterials are principally governed by the loading/strain rate. For instance, in a series of tests conducted on sedimentary soft rocks of Kazusa formation in Japan, Miyashita et al. (2015) reported that stress-strain responses in the pre-peak regions of these rocks were predominantly controlled by the applied loading rates; and such a behavior is regarded as Isotach. Similarly, it was also observed that strain rate generally decreases under creep load and failure occurs when stress-strain relationship touches the stress-strain curve corresponding to the minimum strain rate.

In order to examine the effects of loading rate, a number of laboratory prepared Gypsum Mixed Sand (GMS) specimens were tested under unconfined monotonic loading conditions at three different axial loading rates. Based on the results, the effects of loading rates on the stress strain response and peak strength values of GMS are discussed. In addition, unconfined creep tests were also conducted at four different stress levels to unveil the significance of loading/strain rate in creep failure mode. Finally, a generalized relationship between normalized failure stress and corresponding strain rate at failure is presented to quantify the loading rate dependency of GMS under unconfined monotonic and creep loading conditions.

2. MATERIALS AND TESTING PROCEDURE

In order to produce GMS cylindrical specimens (diameter = 50 mm, height = 100 mm), fixed percentages by weight of Silica Sand No. 6 (42.4%), gypsum (33.9%) and water (23.7%) were mixed uniformly in a bowl. The slurry was then carefully poured into plastic molds and were kept air tight for an initial curing period of 2 days (48 ± 2 hours). This initial phase of curing is kept the same for all the specimens and afterwards, the hardened specimens were removed from their molds and were kept wrapped in plastic sheets for 88 ± 3 days, as secondary phase of curing. The total curing period of all the specimens except CRP4-25% was 90 ± 3 days; whereas CRP4-25% was cured for about 10 months. Note that results also suggest that variations in peak strength of GMS after the curing period of 90 days are negligible. In order to avoid tensile cracking and ductile failure, all of the specimens were capped using dental gypsum, Maqsood et al. (2015). Furthermore, to preserve the moisture content, specimens were kept covered with rubber membrane during testing phase.

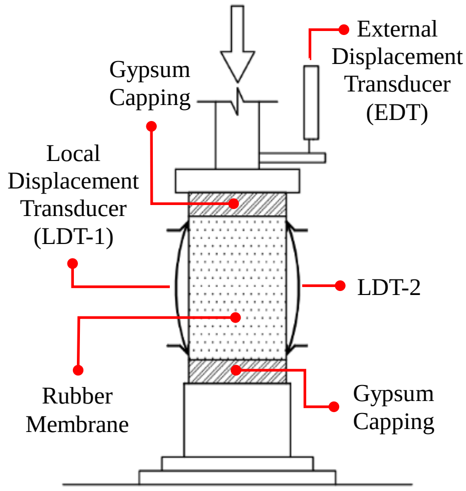

Fig. 1 Schematic illustration of specimen

Firstly, a series of unconfined monotonic compression tests were conducted at three different loading rates viz. 0.065, 0.011 and 0.004% per minute. In addition to these tests, GMS specimens were also tested under unconfined creep conditions at average creep loads of 2550, 2210, 1700, 850 kPa after monotonic loading at 0.065% per minute. Due to some technical limitations of the apparatus, average creep load was maintained using infinitely small cycles of loading and unloading. For precise axial strain measurements, a pair of Local Displacement Transducers (LDTs) was also attached at the opposite sides of the specimen, as shown in Fig. 1, Goto et al. (1991).

3. RESULTS AND DISCUSSION

The test results of specimens subjected to unconfined monotonic loading conditions are presented in Fig. 2. As anticipated, these results markedly confirm the Isotach behavior of GMS as peak strength values significantly decrease with the decrease in the applied axial loading rate. For instance, the average Unconfined Compressive Strength (UCS) of two tests conducted at a loading rate of 0.065% per minute is approximately 3400 kPa, viz. UCS_{avg} = 3400 kPa; and a peak strength reduction of more than 30%, compared with UCS_{avg}, can be witnessed for the specimen tested at slowest loading rate viz. MLT4-0.004PPM. Contrarily, the values of failure strain increase with the decrease in loading rate.

The stress-strain responses of specimens subjected to creep are shown in Fig. 3. For comparison purposes, a typical stress-strain curve of specimen subjected to monotonic loading at 0.065% per minute is also shown in Fig. 3; and the values of creep load are labeled as percentages of UCS_{avg} = 3400 kPa, which is herein denoted as normalized stress. It can be observed from Fig. 3 that all of the specimens failed under the action of creep loading and the amount of axial strain accumulated before failure increases significantly with the decrease in the magnitude of applied creep load. Moreover, it is also noteworthy that even a small magnitude of creep load i.e. about 25% of the peak strength of GMS, is sufficient enough for cause a creep failure, if kept sustained for a longer duration of time.

Keywords: Gypsum Mixed Sand, Unconfined Compressive Strength, loading rate effects, creep
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Fig. 4 shows the variation of axial strain rate with the passage of time, under the action of creep load. In all of the creep tests, strain rate generally decreased under the action of sustained loading and reached a minimum/threshold value. Afterwards, strain rate increased from this threshold and at a certain value of strain rate creep failure occurred, herein denoted as strain rate at failure.

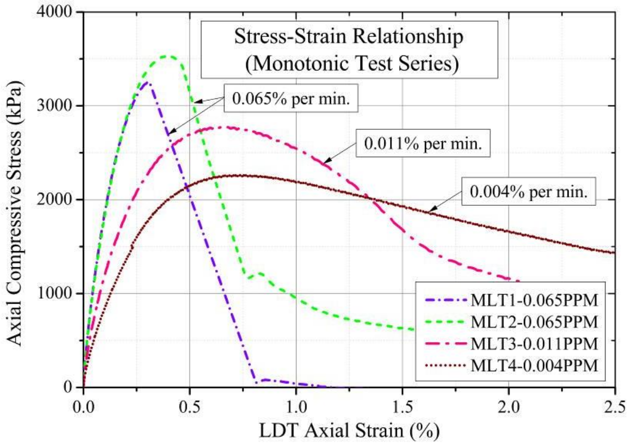

Fig. 2 Stress-strain relationship of specimens subjected to unconfined monotonic loading

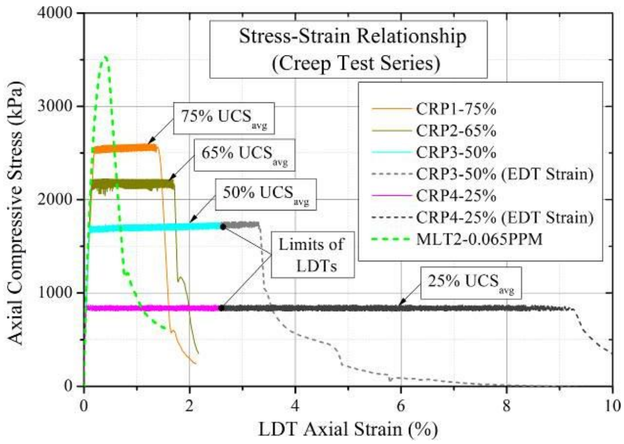

Fig. 3 Stress-strain relationship of specimens subjected to unconfined creep

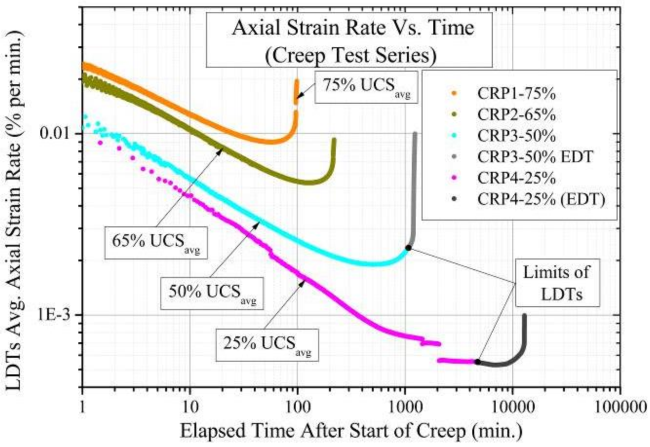

Fig. 4 Relationship between axial strain rate and elapsed time after the start of creep

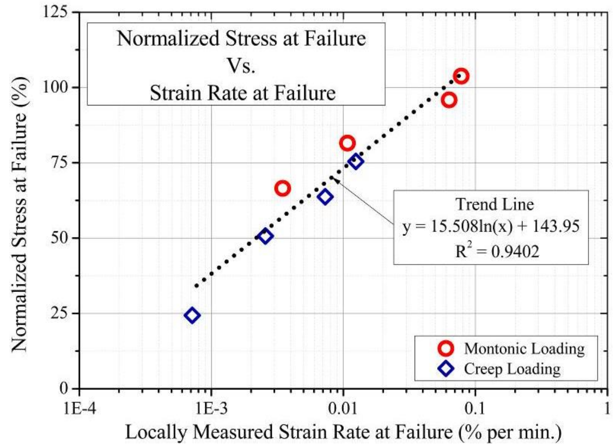

Fig. 5 Relationship between normalized stress at failure and corresponding strain rate at failure

In order to quantify the loading rate dependency of GMS under unconfined monotonic and creep loading conditions, normalized stresses at failure and corresponding strain rate at failure are plotted in Fig. 5. The normalized stress at failure was calculated by normalizing the actual stress at failure by UCS_{avg}. The said plot suggests that irrespective of the nature of loading viz. monotonic or creep, there exist a unique relationship between failure stress and corresponding strain rate at failure for GMS. Based on these findings, it becomes obvious that strain rate is the core parameter which dictates the peak strength and stress-strain response of GMS subjected to any type of loading condition.

4. CONCLUSION

The effects of loading rate on the behavior of GMS was studied by conducting a number of unconfined monotonic loading tests at three different loading rates. Isotach behavior was clearly witnessed for GMS and stress-strain responses in the pre-peak regions were primarily governed by the applied loading rate. In addition, series of unconfined creep tests were performed and variation of strain rate during creep loading was discussed. Finally, it was found that irrespective of the nature of loading viz. monotonic or creep, there exist a unique relationship between failure stress and corresponding strain rate at failure for GMS.

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