TIME EFFECTS ON STRENGTH AND DEFORMATION CHARACTERISTICS OF GYPSUM MIXED CLAY

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1. INTRODUCTION

A large amount (approximately 1.6-1.7 million tons) of gypsum plasterboards waste are generated annually in Japan and disposed to the landfills which have become a serious problem due to its high disposal cost, limited land, generation of hydrogen sulphide gases and release of fluorine, Ahmed (2013). As a prospective solution, researchers in Japan have recently started to use recycled gypsum produced from these undesirable gypsum plasterboards waste in soil improvement applications. A few numbers of researches have been conducted to investigate the typical stress-strain and chemical characteristics of soft soil stabilized with recycled gypsum, Ahmed (2015). However, the time effects (ageing and loading rate effects or viscous effects) on the strength and deformation characteristics of gypsum mixed geomaterials are not extensively investigated till now, which are one of the most crucial aspects in the field of geotechnical engineering, especially the long-term performance of foundations and risk assessment of the slopes.Therefore, to explore the loading rate dependency of the Gypsum Mixed Clay (GMC), a series of uniaxial monotonic loading tests were conducted at several strain rates. Significant effects of the strain rates on the failure strength and stiffness of the specimens were observed in the present study. In addition, to investigate the curing time/ageing effects on the failure strength, uniaxial monotonic loading tests were conducted on the GMC specimens with different curing periods. A significant reduction of failure strength was witnessed between the first 14 days of curing time, but the effects of ageing were found to be insignificant after 14 days.

2. MATERIALS AND TESTING PROCEDURES

To examine the behaviour of GMC, commercially produced gypsum has been used in the current study as the composition of recycled gypsum is complicated. Firstly, a fixed percentage (by weight) of DL clay (24.6%), kaolin (10.6%), commercially produced gypsum (28.2%), and water (36.6 %) were mixed uniformly to prepare slurry, and then the slurry was poured into air-tight plastic molds for the specimens (height =100mm, diameter = 50mm). The specimens were kept into the molds for 48 ± 2 hours for initial curing and afterward, the specimens were extracted from the molds and were wrapped with plastic sheet and tape for further curing. Before the start of the test, weight and height of specimen were measured, and the specimen was wrapped with a rubber membrane to avoid the loss of moisture content during the test. Dental gypsum was used for capping at the top and bottom ends of the specimen to avoid tensile cracking.

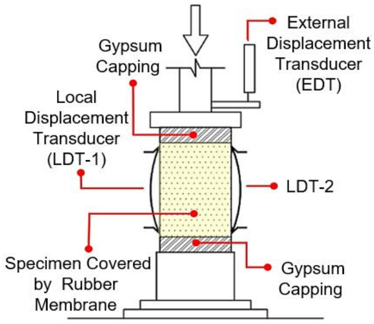

Fig. 1 Schematic illustration of specimen setting, Maqsood et al. (2019)

A pair of Local Displacement Transducers (LDTs) were attached on the opposite side of the specimen to measure the local displacement accurately, additionally conventional External Displacement Transducer (EDT) was also used as shown in Fig. 1. All the tests were performed using a strain-controlled apparatus having a moveable bottom pedestal with a fixed top cap.

3. RESULTS AND DISCUSSION

To investigate the curing time/ageing effects on the strength and deformation properties of the GMC, specimens were tested under controlled deformation at a strain rate of 0.02%/min at different curing periods ranging from 1 ± 0.5 days to 60 ± 0.5 days. The relationship between the Unconfined Compressive Strength (UCS) and the ageing/curing period is presented in Fig. 2. A significant reduction of failure strength was observed between the first 14 days of curing time and after that, it tends to be stable, as evident in Fig.2. On the other hand, to study the loading rate dependency of the GMC, a series of uniaxial monotonic loading tests were conducted at three different strain rates viz. 0.2 %/min, 0.02%/min and 0.002%/min. The typical stress-strain relationships of GMC specimens cured for 28±0.5 days are plotted in Fig. 3. The Isotach behaviour of GMC is clearly discernible from these stress-strain relationships as in the pre-peak region the strength and stiffness of the specimens decrease with the decrease of strain rates. Approximately 61% of failure strength reduction was witnessed for GMC with the decrease of strain rate by 100 times i.e. from 0.2 to 0.002%/min. Moreover, lower failure strain accumulation was observed at higher strain rates. Furthermore, the strain softening phenomenon in the post-peak region is clearly visible at a higher strain rate (0.2 %/min), whereas this phenomenon gradually disappears with the decrease of strain rates, as evident in Fig. 3. Additionally, the effects of strain rates on the strain localization or shear band formation

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of GMC were witnessed in the present study. At 0.2%/min loading rate, visible shear band formation was observed. Multiple cracks were witnessed at 0.02%/min loading rate, whereas no clear and distinct shear band formation or crack was visible at 0.002%/min loading rate, as shown in Fig. 4.

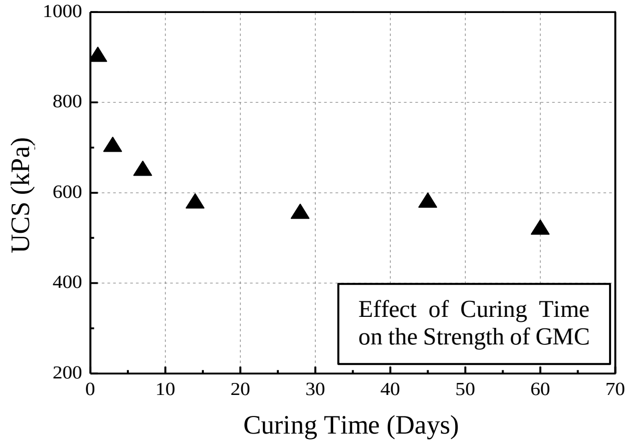

Fig. 2 Relationship between UCS and ageing/curing period (strain rate = 0.02 %/min.)

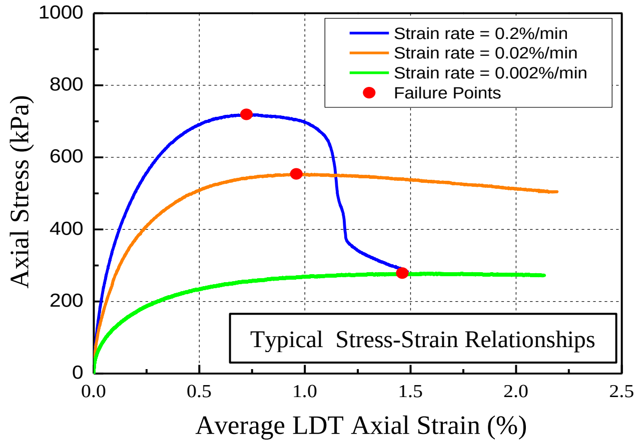

Fig. 3 Typical stress-strain relationships (curing period = 28±0.5 days)

In order to comprehend the loading rate dependency elaborately as well as the interaction between ageing and loading rate of GMC, a semi-logarithmic plot between normalized failure strength and strain rate at failure is presented in Fig. 5. The strain rates at failure were calculated by the slope of the average axial strain (%) vs elapsed time plot between the failure strain and 98% of failure strain. The normalized failure strength of each test series was evaluated by dividing the failure strength value with the failure strength obtained at 0.02%/min loading rate test of the same test series. The normalized failure strength values of GMC decrease with the decrease of loading rates for both 3±0.5 days and 28±0.5 days curing period, as shown in Fig. 5.

In spite of the effects of ageing/curing period on the failure strength of GMC between the first 14 days of curing time, the loading rate affects the normalized failure strength value of the same magnitude for both 3±0.5 days and 28±0.5 days curing period as evident from Fig. 5, which means the ageing does not affect the loading rate effects.Therefore, the interaction between ageing and loading rate does not exist in case of GMC. Furthermore, Maqsood et al. (2019) have found similar behaviors of Gypsum Mixed Sand (GMS) having mix proportion (by weight) of Silica Sand No. 6 (42.4%), commercially produced gypsum (33.9%) and water (23.7%) within the mentioned strain rates, as shown in Fig. 5.The sample preparation, curing, and testing methods of GMC and GMS are same.

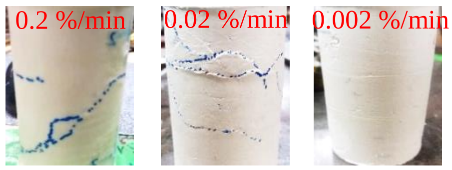

Fig. 4 Typical failure patterns of GMC at different loading rates

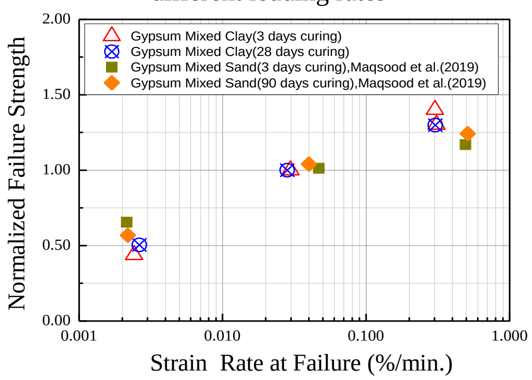

Fig. 5 Relationship between normalized strength and strain rate at failure

4. CONCLUSIONS

The ageing and loading rates effects on the strength and deformation characteristics of GMC were investigated in the present study. The ageing/curing time affects the failure strength of GMC between the first 14 days of curing, but this effect disappears after 14 days. The failure strength and stiffness of GMC increase with the increase of loading rates. However, at higher strain rates lower failure strain accumulation was observed. In the post-peak region strain softening phenomenon was observed at a higher strain rate, although this phenomenon was disappeared with the decrease of strain rate. Moreover, the interaction between ageing and loading rates was not witnessed for GMC in this study.

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