DIFFERENT ACOUSTIC EMISSION CHARACTERISTICS OF SATURATED PURE SAND AND CEMENT TREATED SAND IN TRIAXIAL COMPRESSION TEST

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1. INTRODUCTION

Acoustic emission (AE, i.e. stress wave emission) results from the transient elastic waves generated by the rapid release of energy in the local stress concentration region inside a stressed material (ASTM-E1316, 2014). Over the past decades, acoustic emission technology, as a non-destructive testing technique, has been widely used to detect and locate micro damage in many materials, including rock, concrete, metal, etc. Only a few researchers recently have introduced their successful applications in the sandy soils, like particle sliding and crushing behavior in sand (Mao et al, 2015 and Lin et al, 2019), and AE characteristics of a dry sandy soil under drained triaxial compression (Lin et al, 2020).

In this paper, AE technique was used with great interest in understanding the different AE characteristics of saturated pure sand and cement treated sand subjected to drained triaxial compression tests, and quantitative analysis of AE waves was made in terms of AE hit rate in 10 seconds.

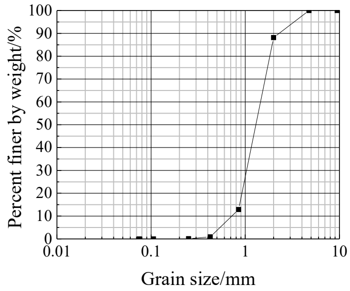

Fig. 1 Particle size distribution of silica sand.

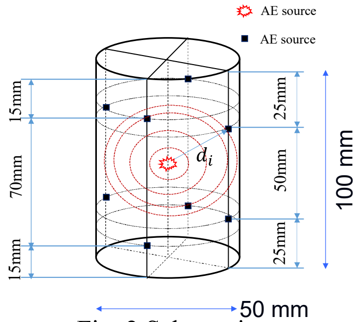

Fig. 2 Schematic arrangement of AE sensors.

2. EXPERIMENTAL METHODS

2.1 Testing Materials and Apparatuses

Black silica sand (mixture of No. 3 and No. 4), with a mean particle size (d_{50}) of 1.3 mm, maximum void ratio (e_{max}) of 0.96, minimum void ratio (e_{min}) of 0.67 and a specific gravity (G_s) of 2.64, was used to prepare specimens. Its particle size distribution is shown in Fig. 1. For cement treatment, high early strength cement, produced by Sumitomo Osaka Cement Company, was used.

Two specimens were prepared; one was pure sand and the other was lightly cement treated sand with cement content of 5 %. The specimens were 50 mm in diameter and 100 mm in height. The tapping method was adopted to prepare the specimens in a plastic mould. In the test on pure sand, the sand was mixed with water at a water content of 15 %, and then the specimen with the plastic mould was put into a refrigerator over a night to be frozen. In the test on cement treated one, the sand was mixed with the required amount of cement firstly, then 2 % water and later 8% water were added uniformly. The curing time in latter test was 3 days.

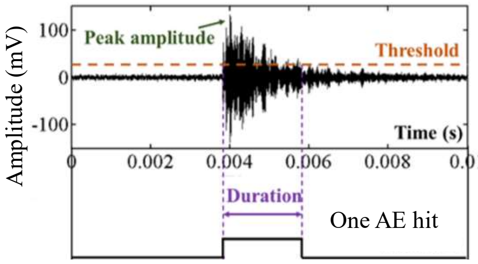

Fig. 3 A typical AE waveform.

After setting the specimen to the triaxial apparatus, 8 AE sensors were attached on the surface of the latex membrane with a thickness of 1.0 mm, and the specimen was saturated using double vacuuming method over one night to achieve the Skempton's B value larger than 95%. Subsequently, the specimen was loaded isotropically to an effective confining pressure of 400 kPa, while applying a back pressure of 200 kPa. Then the specimen was isotropically consolidated for longer than 30 minutes. Finally, axial loading was applied under a constant loading rate of 1.0 mm/min. The initial relative density of the two specimens was identical at 52.4 %, computed only by the weight of sand in the cement treated case.

2.2 Acoustic Emission (AE) Method

A piezo-ceramics type AE sensor, produced by Fuji Ceramics Corporation: M304A, was used; its working frequency is 10 kHz - 5 MHz (the resonant frequency is 300 kHz), and its sensitivity is 115 ± 3 dB (ref. 0 dB = 1 V/m/s). The positions of AE sensors are shown in Fig. 2.

Keywords: Acoustic emission, Cement treated sand, Drained triaxial compression test, AE hit rate
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The AE sensor was connected to a pre-amplifier, and its signal was measured with a data logger, NI PXIe-6366, with a sampling rate of 2 MS/s. As shown in Fig. 3, once a signal exceeds the pre-set threshold (set equal to 30 mV in this study), it is defined as one AE hit. The summation of AE hit in a certain time interval is defined as AE hit rate. Since eight AE sensors were applied, an average of their AE hit rates in 10 s was used for analysis in this paper.

3. EXPERIMENT RESULTS

3.1 Stress-Strain Relationship

The relationship between deviator stress and axial strain is shown in Fig. 4. In both cases, the deviator stress increases firstly to reach a peak value, then begins to reduce, followed by an unloading step. The cement treated sand shows more brittle behavior than pure sand. The peak deviator stress of cement treated sand is 1803 kPa at axial strain of 4.07 %, while the peak deviator stress of pure sand is 1308 kPa at the strain of 6.90 %. Cement improves the peak strength of sand.

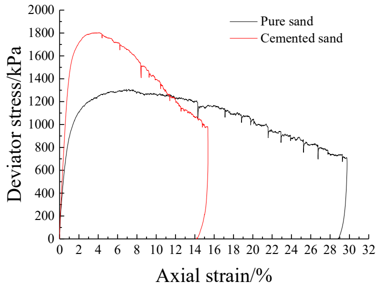

Fig. 4 Deviator stress-axial strain.

3.2 AE Characteristics

The relationship between AE hit rate in 10 s and axial strain is quite different from the stress-strain relationship of pure sand and cement treated sand, as shown in Figs. 5a and 5b. AE hit rate is small at the beginning and increases almost linearly up to the "yielding point", followed by a continuous increase at a slower rate to the peak. Then, it tends to become stable with fluctuation over the whole post-peak regime, finally followed by an unloading step.

Comparison of AE characteristics between pure sand and cement treated sand is made in the Fig. 5c. The peak AE hit rate in 10 s of pure cement is around 27000 at the strain of 18.27 %, while the peak AE hit rate of cement treated sand is around 4800 at the strain of 8.83 %. AE hit rate of pure sand is much larger than that of cement treated sand (about 5.63 times at the peak point). It is possibly caused by cementation. To some degrees, cementation may reduce the interactions between sand particle sliding or/and crushing.

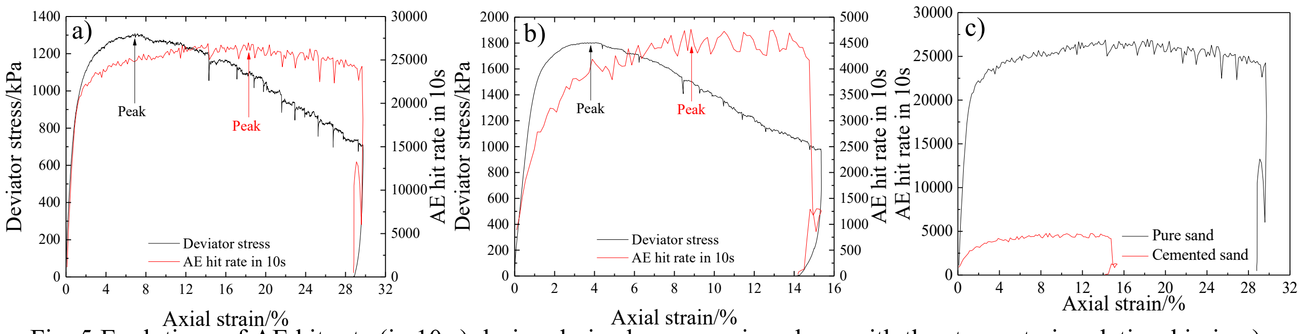

Fig. 5 Evolutions of AE hit rate (in 10 s) during drained compression along with the stress-strain relationship in a) pure sand, b) cement treated sand, and c) comparison of AE hit rates for the two types of sand.

4. CONCLUSION

Saturated pure sand and cement treated sand were subjected to drained triaxial compression tests, and quantitative analysis of AE waves was made in terms of AE hit rate in 10 seconds. The following conclusions can be drawn:

1) The relationship between AE hit rate (in 10 s) and axial strain shows a quite different tendency from the stress - strain curve.

2) AE hit rate of cement treated sand is much smaller than that of pure sand, possibly caused by cementation.

5. REFERENCE

ASTM: Standard Terminology for Nondestructive Examinations, E1316-14, 2014.

Mao, W., and Towhata, I.: Monitoring of single-particle fragmentation process under static loading using acoustic emission, Applied Acoustics, 94, 2015, pp. 39-45.

Lin, W., Liu, A., and Mao, W.: Use of acoustic emission to evaluate the micro-mechanical behavior of sands in single particle compression tests, Ultrasonics, 99, 2019.

Lin, W., Liu, A., Mao, W., and Koseki, J.: Acoustic emission characteristics of a dry sandy soil subjected to drained triaxial compression, Acta Geotechnica, 2020, pp.1-14.