# ACOUSTIC EMISSION RESPONSE DURING SHEAR BAND FORMATION IN TRIAXIAL COMPRESSION TEST ON SAND

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## 1. INTRODUCTION

Strain localization, in the form of shear bands, is the main governing factor related to the strength and progressive failure in dense sands. Numerous pioneering works have been done to advance understanding of the initiation and evolution pattern of shear bands (Tatsuoka et al, 1990, Rechenmacher, 2006, Alshibli et al, 2008). However, it should be noted that, even so, almost all of the current research failed in directly detecting the internal micro-structure evolution of shear bands, which is the uppermost concern in this research topic. Acoustic Emission (AE) method, as a non-destructive testing technique, has a superior advantage over other techniques in that it enables a direct analysis of the micro-structure response inside the detected material. Over the past decades, AE technology has been widely used in many materials, including metal, organic matrix composites and rock, etc. A few literatures, recently, have even reported its successful applications in monitoring the sliding and crushing behavior in the sandy subsoil (Mao et al, 2015, Mao and Towhata, 2015). In this paper, AE technique was proposed with great interest in understanding the internal micro-structure response leading to the evolution of shear bands in densely saturated silica sands subjected to triaxial compression and the quantity and spatial distribution of AE sources were analyzed.

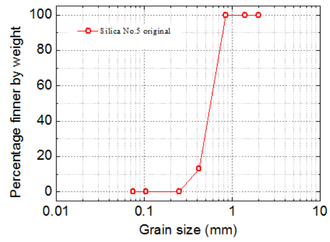


Fig.1 Particle size distribution of silica sand

## 2. EXPERIMENTAL METHODS

### 2.1 Testing Materials and Apparatuses

The silica sand No.5, having a mean particle size ($d_{50}$) of 0.557mm, maximum void ratio ($e_{max}$) of 1.09, minimum void ratio ($e_{min}$) of 0.66 and a specific gravity ($G_s$) of 2.651, was used herein to prepare the specimens. Its particle size distribution is shown in Fig.1.

The specimen (100 mm in diameter and 200 mm in height) was prepared in a split mold along with a thickness of 0.3 mm latex membrane using the tapping method to represent the dense distributed sand ($D_r$=90%). A consolidated-drained tiaxial compression test was conducted at a constant axial strain rate of 0.2mm/min under an effective confining pressure of 100 kPa. The triaxial compression apparatus is shown in Fig.2.

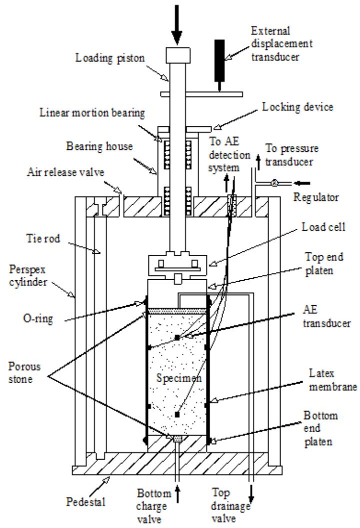


Fig.2 Schematic of experiment apparatus

### 2.2 Acoustic Emission (AE) Method

Acoustic Emission, sometimes known as 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). In general, the generated elastic waves could be collected by AE transducers and converted to electrical signals and recorded by a data logger, as shown in Fig.3.

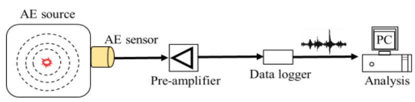


Fig.3 Schematic of AE detection system

Eight vibration transducers (with working frequency of 10 Hz-15 kHz, sensitivity of 20 dB and dimension size of 11.5 by 8.5 by 2.9 mm) produced by NEC/TOKIN Corporation, Model VS-BV210, were glued onto the latex membrane wrapping the specimen. The schematic arrangement of AE transducers is displayed in Fig.4. The AE events were collected using the NI PXIe-6366 data logger, which enables continuous data recording at a maximum analog input sampling rate of 2 MS/s (500 kS/s in this study) with a resolution of 16 bit for each channel. In estimating the location of AE events based on the multiple measurement data, a constant velocity of the stress wave ($v$=200 m/s in this study) was assumed.

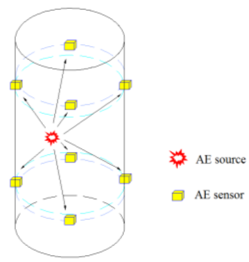


Fig.4 Schematic arrangement of AE sensors

## 3. EXPERIMENT RESULTS

### 3.1 Stress-Strain curve

The relation between deviator stress and axial strain is shown in Fig.5. The deviator stress increases firstly to reach a peak value, then drops gradually and slightly after the peak, in parallel with the formation of shear bands. The peak deviator stress is

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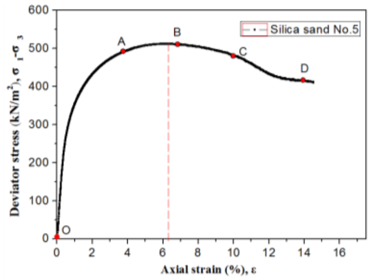



Fig. 5 Global deviator stress-strain behavior

marked by the dash line at an axial strain about 6.3%.

### 3.2 AE Characteristics

The quantity and nomalized spatial distribution of AE sources in four stages (O-A, A-B, B-C, C-D) divided by equal interval axial strains on the stress-strain relation curve are shown in Fig.6&7. The quantities of AE sources increase rapidly at first to a peak value at the peak stress state, followed by a gradual decrease in the post-peak region (see Fig.7), which is consistent with the evolution of the stress-strain relation shown in Fig.5. In the stage O-A (Fig.6a), the pre-peak region, most AE sources are concentrated in a limited area (-0.01m to 0.01m in the horizontal axis) of the specimen, which suggests that sand response in this area is more violent than others. In stage A-B including the peak stress state (Fig.6b), the AE sources are increasing intensively and distributed uniformly within the central part, indicating that the sand in this stage may suffer from the severest distortion and crushing. This phenomenon may contribute to the initiation of shear band. After the peak stress state, i.e. the stage B-C-D, in parallel with the bulging of the specimen (as shown in Fig.6e), AE sources tend to gradually decrease and mostly concentrate on the upper right part of the plot. Such evolving phenomenon may be induced by the formation of conjugate and multiple shear bands (as shown in Fig.6e), most of the soil particle structure distortion or particle crushing may have concentrated in this upper region, leaving the lower part beneath the shear band rather “silent”.

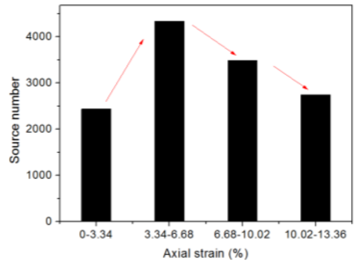
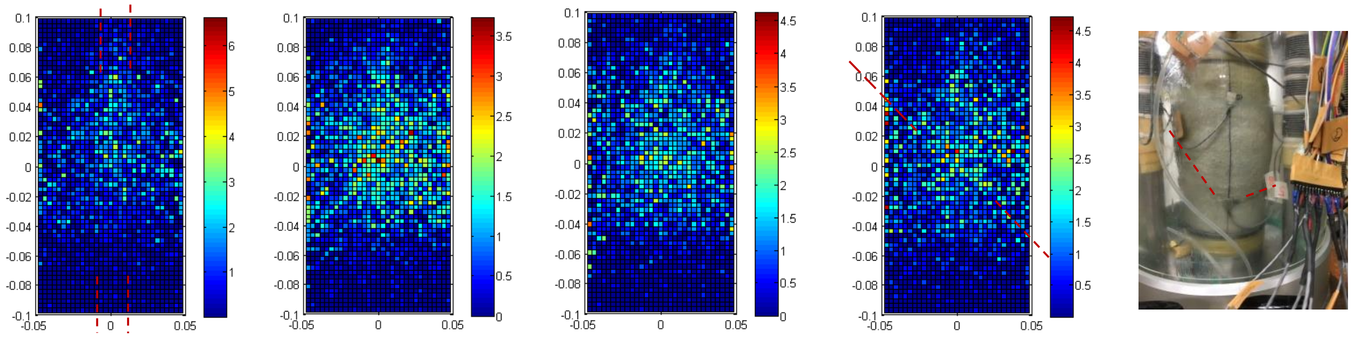



Fig. 7 Source number during shear banding



(a)0.0-3.34% axial strain (b) 3.34-6.68% axial strain (c) 6.68-10.02% axial strain (d) 10.02-13.36% axial strain (e) Example of image during testing

Fig.6 The spatial distribution of AE activities from 0.0-13.36% of axial strains

## 4. CONCLUSION

The AE technique was proposed in this paper to understand the internal micro-structure response leading to the evolution of shear bands in densely saturated silica sands under triaxial compression tests. The following conclusions can be drawn:

1) The quantities of AE sources during the process of shear banding, which increase rapidly at first to a peak value at the peak stress state and decrease gradually in the post-peak region, are consistent with the evolution of the stress-strain relation.

2) In the post-peak stress state, the AE sources tend to decrease and mostly concentrate in the upper right region where the shear bands were formed in the tested specimen, which may be induced by the formation of conjugate and multiple shear bands.

## 5. REFERENCE

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