Application of Acoustic Emission in In-Situ Test

Usage de l'Emission Acoustique aux Essais In Situ

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SYNOPSIS Fundamental study on acoustic emission in stressed soils was conducted by laboratory test methods, and the characteristics of acoustic emission, including the Kaiser effect, obtained by these were utilized in pressuremeter test to measure in-situ horizontal stresses in soil mass. As the results, it has been made evident that the determination of in-situ stresses by changes in the characteristics of acoustic emission is more effective and easier than by the conventional method.

INTRODUCTION

A technique of monitoring acoustic emission in soils under triaxial stresses was introduced and the characteristics of acoustic emission were correlated with shear process to failure in the previous papers (Tanimoto et al., 1977; Tanimoto et al., 1978).

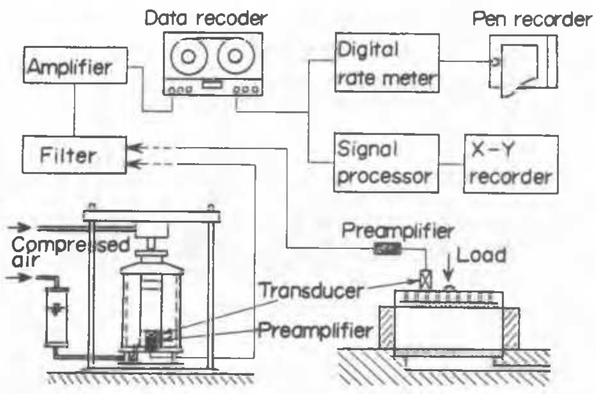
One of interesting phenomena in acoustic emission studies may be the Kaiser effect discovered in many materials including soils. In this paper, this phenomenon is reaffirmed with various soil samples in laboratory tests, and is applied to the measurement of in-situ horizontal stresses in soil mass. To conduct the field measurement, some pressuremeters capable of monitoring acoustic emission are developed and improved.

METHOD OF LABORATORY TESTS

Basic research on acoustic emission in soils is carried out by the methods of triaxial compression test and confined compression test. The schematic diagram of laboratory test setup is shown in Fig. 1.

In Fig. 1(a), a transducer, for detecting acoustic emission, is fixed in the pedestal of the triaxial test apparatus. Emission detected by the transducer is preamplified, filtered to eliminate background noise, amplified again and stored in a data recorder. The record allows to replay for emission counting and the other analysis. The way of counting is of ring down type which counts all pulses larger than a discrimination level taken to be 1.0 volt, unless otherwise specified, at the input to the rate meter.

Laterally confined compression test is schematically shown in Fig. 1(b), in which a transducer is fixed on the top of loading plate. Acoustic emission is monitored in a similar way to the triaxial test. The characteristics of frequency response of acoustic emission monitoring instruments are given in TABLE I.



(a) Triaxial compression test (b) Confined compression test

Fig. 1 Acoustic Emission Monitoring System in Laboratory Tests

TABLE I

Frequency Response of Acoustic Emission Monitoring Instruments

Type of test	Triaxial	Confined
Transducer	4Hz-17kHz	DC-55kHz
Preamplifier	4Hz-17kHz,54dB	1kHz-500kHz,46dB
Amplifier	4Hz-40kHz,20dB	1kHz-500kHz,20dB
Rate meter	DC-30kHz	1kHz-500kHz
Data recorder	Max.15ips, 100Hz-60kHz	

RESULTS OF LABORATORY TESTS

Fig. 2 is the results of a repetitive loading triaxial compression test with gradually increasing peak load on air dried specimen (decomposed granite, D_{10} = 0.027 mm, C_U = 35). It is noted in this figure that intensive emissions are monitored only in the virgin state of loading and few emissions are observed in the state of preloading.

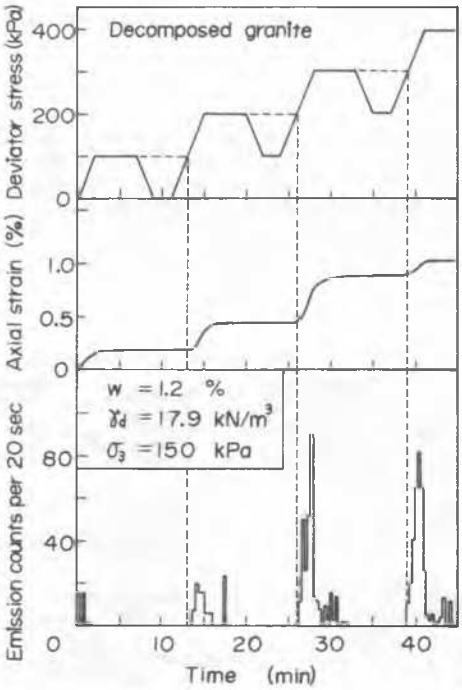


Fig. 2 Acoustic Emission Characteristics in Repetitive Loading Triaxial Test

Another example of the results of triaxial compression test is shown in Fig. 3. In this test, a preloaded specimen is loaded to failure under a stress-controlled condition as shown in Fig. 3(a). It is noted in Fig. 3(a) that the Kaiser effect can be seen in preloaded range and also the characteristics of acoustic emission have a few distinct parts, as seen in the following, in the overall shear process to failure.

Fig. 3(b) shows relationships among deviator stress σ_d, axial strain ε, volumetric strain v and emission counts per minute n_e, by use of Fig. 3(a). It is noted that n_e - σ_d relation has three distinct processes divided by two points Y and I.

The point Y may be the terminal of elastic deformation range, as understood from change in axial strain in Fig. 3(a), and deviator stress at this point, σ_{dy}, seems to be equal to preload, σ_{dp}. The point I may be the junction of contraction and expansion processes, and it is considered that local relative slip of particles begins at this stress, σ_{di}.

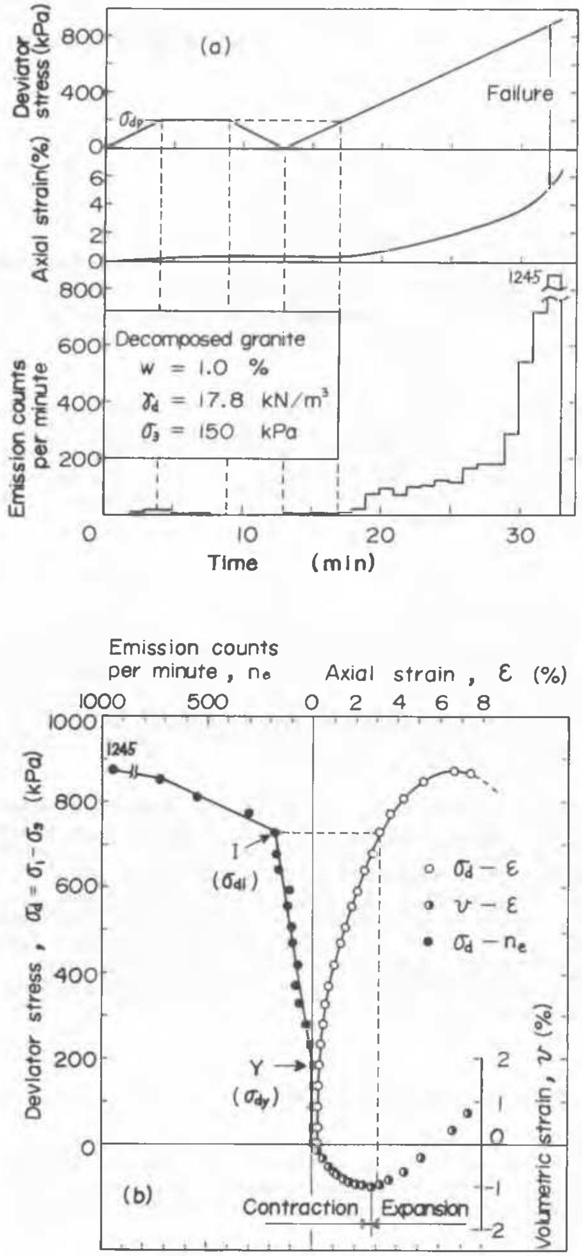


Fig. 3 Results of Triaxial Compression Test on Preloaded Soil

Fig. 4 shows the results of confined compression test on the same soil as in Fig. 3. Acoustic emission is monitored during recompression of a specimen, precompressed up to σ_p, and is counted during each loading step of 15 minutes. Emission counts n_t in each step are obtained for three discrimination levels. From Fig. 4, these three curves seem to give nearly the same yield stress p_y which is assumed to be at the maximum curvature. The value of p_y, independent of discrimination level, is considered to give a good approximation to the value of σ_p.

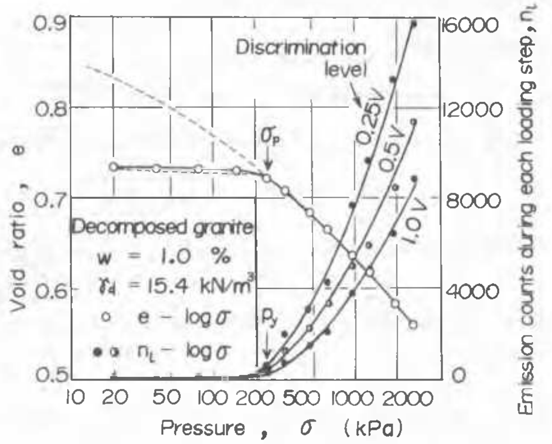


Fig. 4 Results of Confined Compression Test on Precompressed Specimen

Fig. 5 is the results of confined compression test on a specimen prepared by tamping. Test soil is air dried fine sand (Japanese standard sand, D_{10} = 0.1 mm, C_U = 1.58). It can be seen that the value of p_y at the point of maximum curvature of n_l - log σ curve is almost equal to precompression pressure σ_p determined by the Casagrande construction.

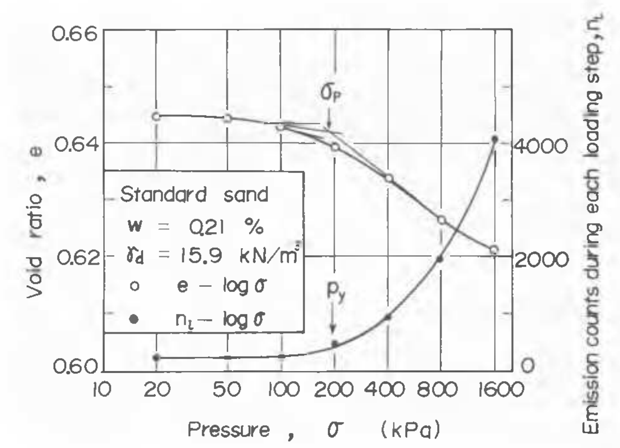


Fig. 5 Results of Confined Compression Test on Specimen Prepared by Tamping

ACOUSTIC EMISSION MONITORING IN PRESSUREMETER TEST

Pressuremeter test in a borehole has so far been often employed to measure stress states in fields. In this test, radial displacement of the wall of borehole is estimated from the quantity of water flowing into the pressure cell, and if the borehole is distorted, then it results in unsuitable estimation.

In the present study, the characteristics of acoustic emission are utilized to improve pressuremeter test. Preliminary tests have been

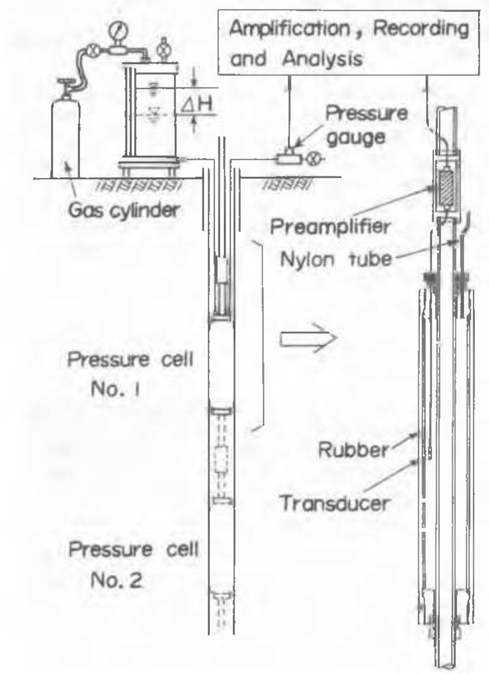


Fig. 6 Acoustic Emission Monitoring in Pressuremeter Test

conducted with an original of those shown in Fig. 6. A transducer and a preamplifier are accomodated in the apparatus, and instrumentation is the same as in confined compression tests described in the above.

A typical test result in a fill of decomposed granite is given by Fig. 7. From such figure, a customary method determines yield stress at the point Y_2 on r - p curve and local slip stress p_{i2} at the point I_2 on ΔH - p curve, where

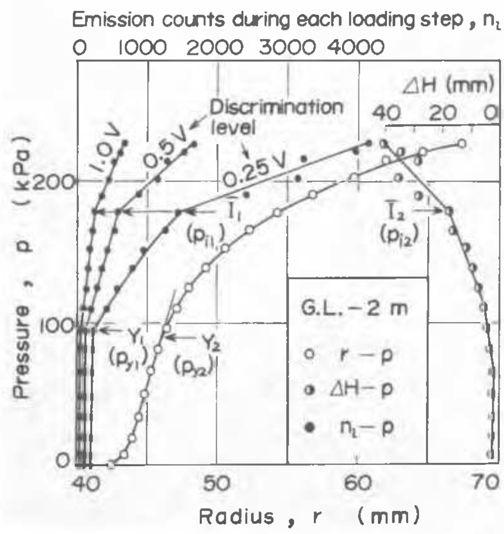


Fig. 7 Results of Preliminary Pressuremeter Test

r, p and ΔH are radius of borehole, applied pressure and change in supplying water level, respectively.

Besides the two curves, three n_t - p lines for different discrimination levels are drawn in the figure, where n_t is emission counts during each loading step of 120 sec. It is recognized that the three curves can determine nearly equal yield stress p_{y1} and local slip stress p_{i1} very easily at the points of break, which also approximate p_{y2} and p_{i2} determined by the customary method.

FIELD MEASUREMENT

Based on the preliminary studies, some pressuremeters are newly made as seen in Fig. 6. They can be used in series for simultaneous measurement at some depths, although two units are usually the most because of field conditions.

An example of test results at a compacted fill of crushed sandstone and mudstone is shown in Fig. 8. From this figure, stress states determined by both the methods are also nearly equal to each other. Some disturbance is seen in the beginning of the test, probably because of slime around the pressuremeter. The start of constant emission counts is considered to correspond to the state of earth pressure at rest p_{01} .

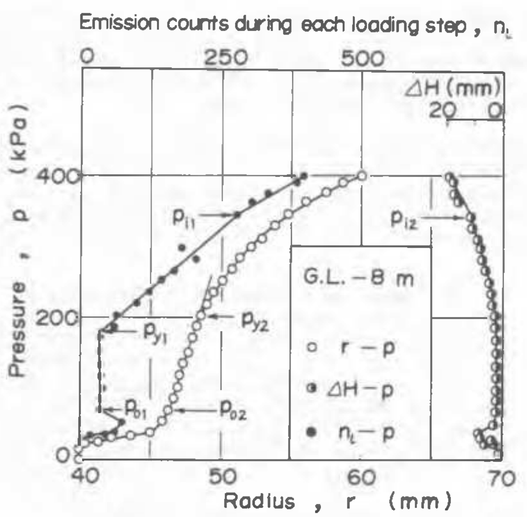


Fig. 8 Results of Pressuremeter Test

Fig. 9 shows the results at this site. The comparison of p_0 and p_y determined by both the methods shows that there seems a good agreement with each other, although some data of earth pressure at rest have been unable to estimate.

CONCLUSIONS

So-called Kaiser effect is reaffirmed in soils by a basic study on acoustic emission, and from the application study of this phenomenon, the following is obtained.

Acoustic emission monitoring together with pressuremeter test can be effectively used for measuring in-situ horizontal stresses in soil mass. The merit of using acoustic emission is that emission counts undergo very marked changes at particular stress states, which results in easier determination of those stresses than the customary method.

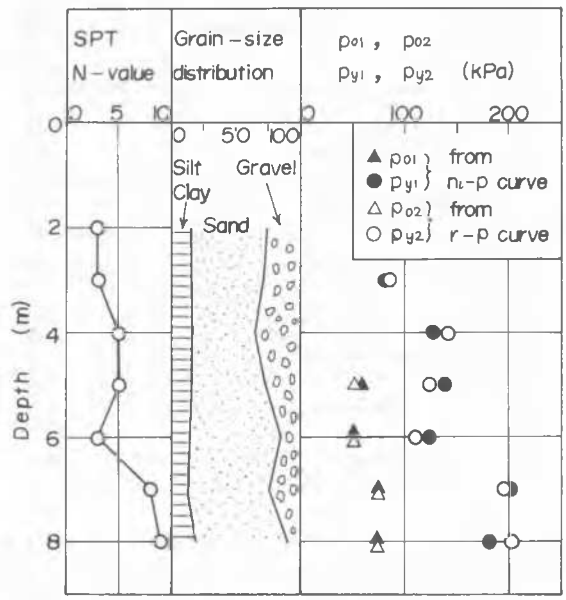


Fig. 9 Results of Site Investigation

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