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Autor: Kimura, Sadao / Adachi, Ichiro / Hironaka, Yoshiaki
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Acoustic Emission Evaluation of Concrete Structures

Evaluation de l'émission acoustique des structures en béton

Bewertung der akustischen Emission einer Betonstruktur

Sadao KIMURA
Civil Engineer
Sato Kogyo Co., Ltd
Tokyo, Japan

S. Kimura graduated in 1984 from Tokyo Univ. and received his M.E. degree in Civil Eng. He is researching into Acoustic Emission characteristics of concrete structures.

Ichiro ADACHI
Prof. of Civil Eng.
C.I.T.
Chiba, Japan

I. Adachi graduated from Waseda Univ. He obtained the degree of Doctor from Tokyo Univ. He is researching into the behavior of construction joint concrete.

Yoshiaki HIRONAKA
Civil Engineer
Sato Kogyo Co., Ltd
Tokyo, Japan

Y. Hironaka graduated in 1975 as a Civil Engineer from Tokai Univ. He is researching into Acoustic Emission characteristics of concrete structures.

Tetsuo ISHIBASHI
Civil Engineer
Sato Kogyo Co., Ltd
Tokyo, Japan

T. Ishibashi graduated in 1985 as a Civil Engineer from Kyushu Univ. He is researching into Acoustic Emission characteristics of concrete structures.

SUMMARY

This paper presents an experimental study to evaluate the degree of structural integrity using acoustic emission measurement as a method of nondestructive inspection. According to the results, the following possibilities of acoustic emission measurement were confirmed: to predict the generation of cracks during a month after placing of mass concrete; and to evaluate the deterioration degree of aged concrete structures.

RÉSUMÉ

Ce document présente une étude expérimentale pour évaluer le degré d'intégrité structurale à l'aide de mesures d'émission acoustique en tant que contrôle non destructif. Les résultats obtenus ont confirmé les possibilités suivantes de la mesure d'émission acoustique: afin de prévoir la formation de fissures dans les jours suivant la mise en place du béton, et afin d'évaluer le degré de détérioration d'anciennes structures en béton.

ZUSAMMENFASSUNG

Diese Arbeit stellt eine Experimentalstudie zur Bewertung der strukturellen Unversehrtheit vor, die als zerstörungsfreie Untersuchung die Messung der akustischen Emission benutzt. Die Ergebnisse bestätigten, dass die Messung der akustischen Emissionen folgende Möglichkeiten bietet: auf die Rissbildung in den ersten Tagen der Aushärtung zu schliessen, und auf den Alterungsgrad einer Betonstruktur zu schliessen.

1. INTRODUCTION

A large number of reinforced concrete(RC) structures constructed during the high-growth age of Japanese economy are now known to be approaching their service limit and have to be repaired or reinforced. Recently, in addition, the short-term deterioration of RC structures due to poor quality of construction, thermal stress, salt damage, alkali-aggregate reaction, and freezing and thawing action have been reported and generated widespread problems. Therefore the development of techniques which enable to readily evaluate the degree of deterioration of aged RC structures and to restore them are urgently required. Acoustic emission(AE) measurement is a well-known method for detecting microscopic cracks generated in the solid. Thus, basic experiments were performed to confirm AE properties in concrete and to apply AE measurement as one of the evaluation method of the structural integrity of RC structures. This paper reports the results of the basic experiments and presents some inspection methods of AE measurement as one of nondestructive testings.

2. INSPECTION METHODS OF ACOUSTIC EMISSION MEASUREMENT

Applications of AE measurement for the evaluation of the structural integrity of concrete are devided roughly into three categories.

(A) Quality controll of new construction.
(B) Evaluation of deterioration degree of existing structures.
(C) Evaluation on accelerated deteriorating tests.

Inspection methods of AE are closely associated with these applications, and would be devided into three categolies.

(a) To predict the progress of microscopic cracks by continuous or intermittent monitoring of AE signal in RC structures.
(b) To evaluate the structural integrity of RC structures by detecting AE signal from the structures driving external forces or elastic waves.
(c) To evaluate the material integrity of concrete by performing AE measurement during uniaxial compressive testing and to analyze the effects of existing cracks.

The choice of inspection methods is dependent upon the target of applications. Table 1 indicates possible combination for the purpose of applied fields. For more accurate evaluation, of cource, combination of other nondestructive testings and AE is desirable. In this study, basic experiments connected with the applications of AE measurements (A) and (B) were carried out.

3. ACOUSTIC EMISSION BEHAVIOR ON MASS CONCRETE

An experiment was performed to help predict the generation of cracks during one month after placing of mass concrete using AE measurement in the laboratory. The mix proportion of the concrete are shown in Table 2. Dimensional data of the mass concrete specimen and the locations of sensors installed in it are shown in Fig.1. Measurement items are temperature, longitudinal stress, longitudinal displacement and AE to obtain the information about the generation of microscopic cracks in the specimen. AE was detected using six transducers through wave-guides. In Fig.1, dotted points A,B,C,D,E, and F show the locations of six transducers to detect AE signals. The conditions of AE signal detection decided by preliminary examinations, are shown in Table 3. The effects of noise can be eliminated because the range of frequency of detected AE is about 100-300kHz and much higher than that of noise in the laboratory. Fig.3 shows the relationship between the time elapsed after placing of concrete and the temperature, longitudinal stress, logitudinal deformation and event counts of AE per 2 hours. Temperature at the central portion of the specimen rose to the peak(76C) at 1.5 days. At that time, compressive stress and tensile stress were set up at the central and the upper portion respectively. After removal of forms at 2 days, the temperature fell rapidly and both stresses changed to the opposite behaviors. Shrinking deformation of the specimen occured during the falling of its temperature, and the deformation at the upper portion was larger than that at the bottom portion. A large number of AE were detected during about 3 days after placing of concrete, but after that, the number of AE events decreased with time elapsed and finally became constant. A large number of AE were detected one day before the first discovery of cracks at the upper surface of the specimen. The generation of AE continued until one month after placing, and at that time, hair-cracks became visible. According to the results, it is confirmed that it is possible to predict the generation of cracks by AE measurement during one month after construction. It is considered that the causes of generation of cracks in the mass concrete specimen are as follows.

1) The cause of generation of the first crack at 2 days after placing of concrete is subsidence of concrete.
2) The cause of generation of cracks at one month is the combination of thermal shrinkage and drying shrinkage of the specimen.

4. TEST OF THE CORE SPECIMENS EXTRACTED FROM THE AGED CONCRETE STRUCTURE

The Shinomiyajuku bridge(Photo.1) was crossing Shakujii river and had been in service for 20 years after construction. Dimensional data of the bridge are as follows.

Height of abutment	:	4.2 m
Width of abutment	:	9.0 m
Width of girder	:	11.0 m
Span	:	10.0 m

Concrete cores were extracted from the abutment of the bridge. Coring(cylinderϕ 10cm×50cm) was performed as shown in Fig.4 and two sample specimens(ϕ10cmx20cm) were made from each core. The specimens were curred in water for one month and cured in the moisturized condition for one week. AE measurement was performed to evaluate the material integrity of the core specimens during a test of uniaxial compressive strength. Fig.5 show the uniaxial compressive loading system and the AE measurement system emplyed. A compressive loading test was carried out using two teflon sheet(thickness:2mm) laid between the loading plates and the specimen. Loading rate was set at 550N/sec. Table 3 shows the conditions of AE signal detection. AE measurement system includes the one-dimensional location system using two transducers installed on the side of the specimens in the axial direction. Determination of AE source location was performed only at the center portion(10cm) of the specimens in the axial direction as shown in Fig.5, in order to eliminate the effects of noise generated by the friction between the specimen and the loading plates. The measurement error of the source location was confirmed within several millimeters by preliminary examinations. Test results of uniaxial compressive strength and static Young's modulus of the specimens are shown in Fig.4. Compressive strength is lower at the surface portion and higher at the inner portion of the abutment. Static Young's modulus shows a similar tendency. The relationship between the compressive stress and AE events detected during uniaxial compressive testing are shown in Fig.6. According to these results, in the specimens made from the surface portion of the core, many AE signals were detected at a low stress level. On the other hand, in the specimens made from the inner portion, the number of AE signals detected at a low stress level was small. In addition, the speed of longitudinal wave through the specimens was about 3500 m/sec at the surface portion and that was about 4500 m/sec at the inner portion. The reason is considered to be the degree of internal defect in the concrete specimens.

5. CONCLUSION

Conclusions of these basic experiments are as follows.

(1) AE measurement is effective to predict the generation of harmful cracks during one month after placing of mass concrete.

(2) AE measurement is effective as well as compressive testing for evaluating the material integrity of core specimens extracted from existing structures, bcause the degree of internal defects can be estimated by it.

6. REFERENCES

[1] I.ADACHI,M.TSUDA and S.KIMURA : A study for evaluation of the structural integrity of concrete using acoustic emission, Transactions of The Japan Concrete Institute, Vol.8, 199-206, 1986

[2] I.ADACHI,S.KIMURA and Y.HIRONAKA : The evaluation of the structural integrity of concrete structures by acoustic emission measurement, Acoustic Emission Committee Report, 006-No.83, JSNDI, 1-6, 1987

[3] T.UOMOTO,S.SATO : Estimation of applied compressive stress in concrete acoustic emission measurement, Seisan Kenkyu, Vol.39, No.2, 24-27,1987

[4] M.OHTSU : Diagnostic application of acoustic emission to structural integrity of concrete structures, Concrete Journal, JCI, Vol.25, No.12, 5-11, 1987

Table 1 Applications and Inspection Methods of AE Measurement

Applications	Inspection Methods
(A)	(a) (b)
(B)	(a) (b) (c)
(C)	(a) (b) (c)

Table 3 Conditions of AE Detection

Wave Speed	2500-4500	(m/sec)
Attenuation	35	(dB/m)
Pre-gain	40	(dB)
Main-gain	40	(dB)
Threshold Level	1.0	(V)

Table 2 A Mix Proportion of Concrete

Gmax (mm)	Slump (cm)	Air (%)	W/C (%)	S/a (%)	Unit Weight (kg/m^3) W	C	S	G	Ad.
25	12	4.0	43.5	42.7	171	400	749	994	1.00

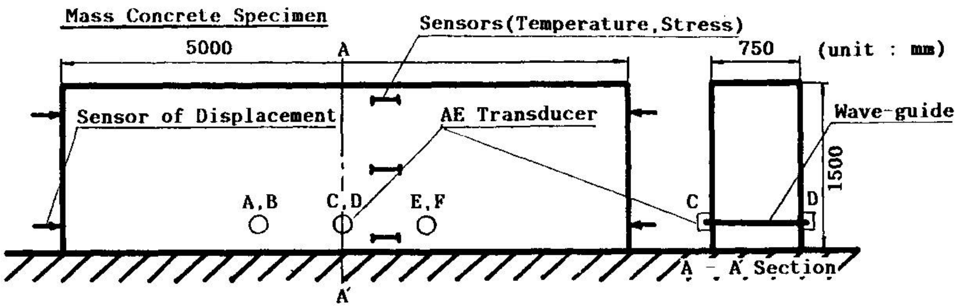

Fig. 1 Mass Concrete Specimen and Locations of Sensors

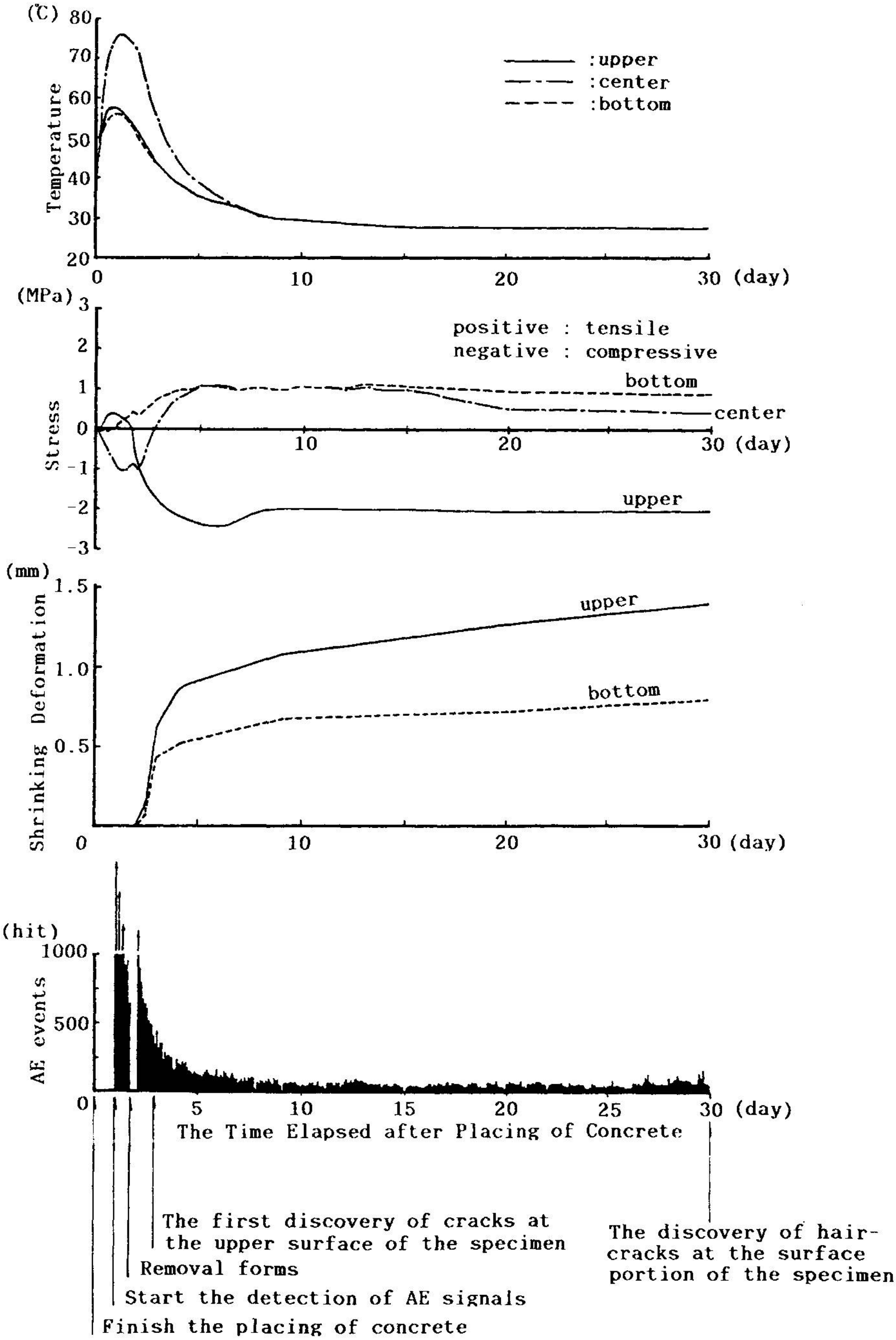

Fig. 3 The Time Elapsed versus Temperature, Longitudinal Stress, Longitudinal Deformation and AE Events

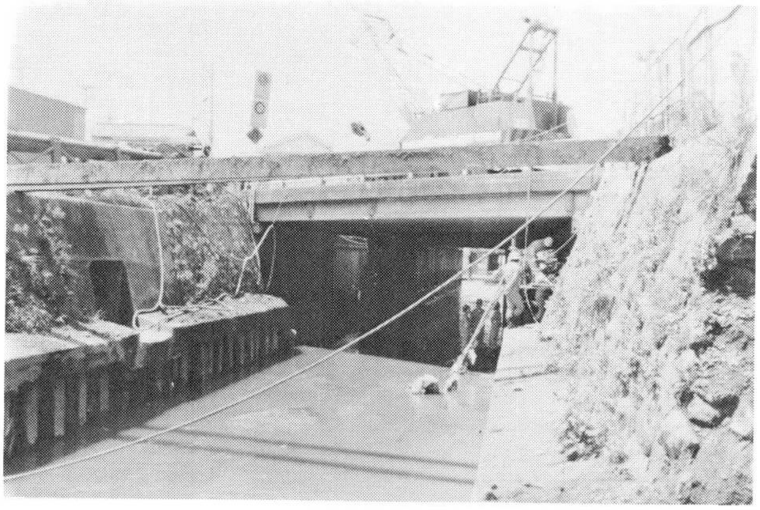

Photo. 1 Scene of the Shinomiyajyuku Bridge

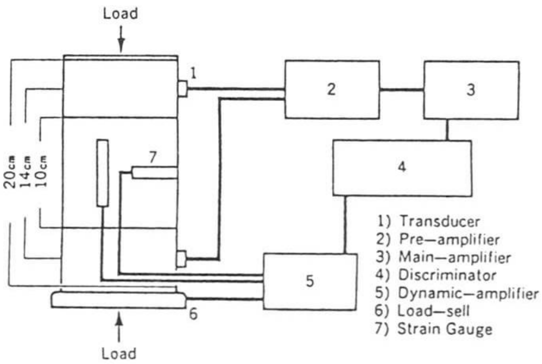

Fig. 5 Uniaxial Compressive Loading System and AE Measurement System

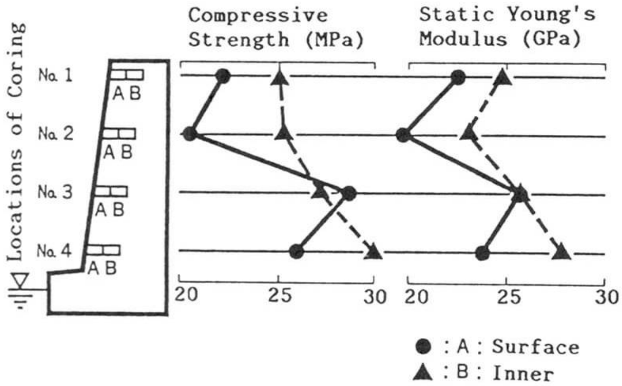

Fig. 4 Compressive Strength and Static Young's Modulus of The Core Specimens

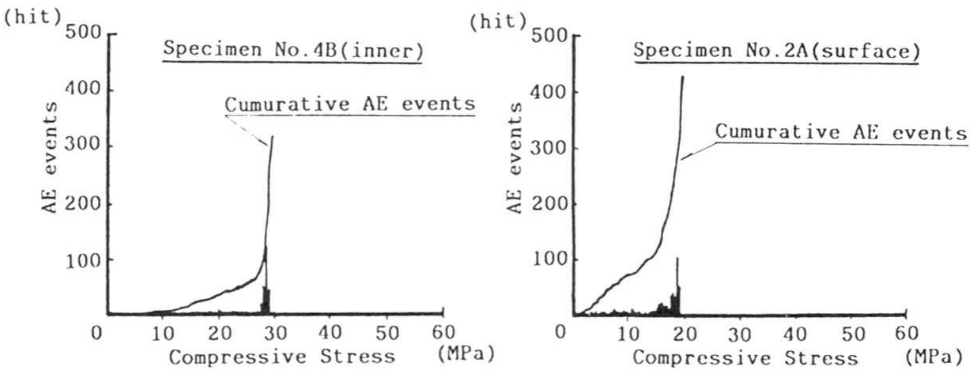

Fig. 6 Relationship between Compressive Stress and AE Events during Uniaxial Compressive Testing