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Effect of Aggregates on Concrete Properties

Effet des granulats sur les propriétés du béton

Wirkung von Zuschlagstoffen auf die Eigenschaften von Beton

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SUMMARY

This paper presents a study on the characteristics of concrete with aggregates of inferior quality (low gravity and high absorption). Acoustic emission measurements were performed during uniaxial compressive testing of concrete specimens. According to the results, the quality of aggregates appear more clearly in the static Young's modulus than the compressive strength of concrete. These are simply phenomena caused by the quality of aggregates, but the difference of the fracture process of concrete due to the quality of aggregates is directly indicated by acoustic emission measurements.

RÉSUMÉ

Ce document présente les résultats d'une étude sur les caractéristiques du béton à granulats de qualité inférieure (faible gravité et haute absorption). Les mesures d'émission acoustique ont été exécutées durant l'essai compressif uniaxial d'échantillons de béton. Les résultats on révélé que la qualité des granulats se manifeste plus clairement dans le module de Young statique que dans la résistance du béton à la compression. Ces phénomènes sont causés par la qualité des granulats, mais la différence dans le processus de fissuration du béton due à la qualité des granulats est directement indiquée par les mesures d'émission acoustique.

ZUSAMMENFASSUNG

Diese Arbeit untersucht die Eigenschaften von Beton mit Zuschlagstoffen minderwertiger Qualität (niedriges Gewicht und hohe Absorption). An Betonproben wurden im Verlauf einachsiger Druckprüfungen Schallemissionsmessungen durchgeführt. Die Ergebnisse zeigten, dass sich die Qualität von Betonzuschlagstoffen am deutlichsten im Elastizitätsmodul und nicht in der Druckfestigkeit von Beton zeigt. Anhand der Schallemissionsmessungen war es jedoch möglich, das unterschiedliche Bruchverhalten von Beton in Abhängigkeit von der Qualität der Zuschlagstoffe direkt zu bestimmen.

1. INTRODUCTION

Deterioration of aggregates caused by exhaustion of sound aggregates has become a widespread problem. It is generally known that physical quality of aggregate effects the strength, Young's modulus and durability of concrete. The factor of these effects is considered to be the lower strength of aggregate compared to the strength of mortar or cement paste matrix. So, it is assumed that because of excessive load or repeated load, destruction occurs inside or on the surface of aggregates before it occurs inside mortar or cement paste matrix.Therefore, reduction of water cement ratio of concrete in order to make compensation for the low strength of aggregate is a generalized method. However, the fracture process of concrete with inferior aggregates not yet elucidated must be clarified in order to use such aggregates for concrete. In this paper, the fracture process of concrete with water cement ratio varying from 30 to 70% and with several kinds of aggregates contained is studied by AE measurement and observation with a microscope.

2. PROPERTIES OF AGGREGATES AND MIX PROPORTIONS OF CONCRETE

Table-1 shows the properties of aggragates used for the experiments. Sound aggregates are River Sandstone and River Sand. Inferior coarse aggregate is Crushed Andesite. And inferior fine aggregate is Scoria. Mix proportions of concrete are shown in Table-2. Water cement ratios are 30,50, and 70%. The volume of each material is fixed in order to make clear comparison of effect of aggregates. Table-3 shows the combination of coarse and fine aggregates.

3. PROCEDURE OF EXPERIMENTS

Fig-1 shows the AE measurement system employed during the uniaxial compressive testing of the specimens. The diameter of the specimen is 10cm and the height is 20cm. AE measurement system includes the one-dimensional location system using two transducers installed on the side of the specimen in the axial direction. Determination of AE source location was performed only at the center portion (10cm) of the specimen in the axial direction in order to eliminate the effects of noise generated by the friction between the specimen and the loading plates. Table-4 shows the conditions of AE signal detection. Compressive loading test was carried out using a teflon sheet laid between the loading plate and the specimen to minimize the generation of noise. Loading rate was set at 500N/sec. Three specimens for each combination were used for the observation of cracks either inside or on the surface of aggregates.At first, 30% of the breaking load was applied and removed. The specimen was cut and polished after loading, then inspected with a microscope. In this way, 50% and 100% of the breaking load was applied and observation was performed respectively.

4. RESULTS AND CONSIDERATION OF THE EXPERIMENTS

4.1 Compressive strength and Young's modulus

Figs-2,3 show the compressive strength and the Young's modulus of concrete containing several kinds of coarse aggregates. The compressive strength of the concrete with inferior coarse aggregate was lower than that of the concrete with sound aggregate. However, according to the result of the experiment, the compressive strength showed a variation of 10%. Therefore, there will be some cases where the quality of aggregate cannot be accurately evaluated by the compressive strength of the concrete. According to Fig-3, the difference of Young's modulus caused by the quality of aggregate was more conspicuous than

TABLE-1 PROPERTY OF AGGREGATES

	Specific gravity	Absorption (%)	Kind of stone
Sound Coarse Aggregate	2.62	0.81	Sandstone
Inferior Coarse Aggregate	2.26	4.66	Crashed Andesite
Sound Fine Aggregate	2.59	1.02	Sandstone
Inferior Fine Aggregate	1.94	15.11	Scoria

TABLE-2 MIX PPOPORTION OF CONCRETE

W/C (%)	s/a (%)	W (kg/m³)	C (kg/m³)	S (ℓ/m³)	G (ℓ/m³)
30	40.8	189	630	249	361
50	44.9	189	378	310	381
70	48.8	189	270	354	371

TABLE-3 COMBINATION OF AGGREGATES

Fine Aggregate	Coarse Aggregate	W/C (%) 30	50	70
Sound	Sound	SS3C	SS5C	SS7C
Sound	Inferior	SI3C	SI5C	SI7C
Inferior	Sound	IS3C	IS5C	IS7C

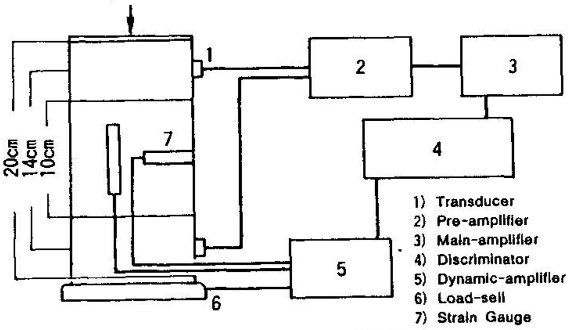

FIG-1 AE MEASUREMENT SYSTEM

TABLE-4 CONDITIONS OF AE DETECTION

Wave Speed	3500-4500	(m/sec)
Attenuation	35	(dB/m)
Pre-gain	40	(dB)
Main-gain	40	(dB)
Threshold Level	1.0	(V)

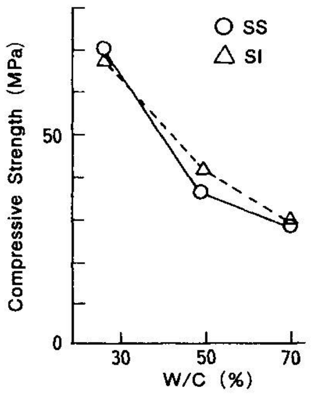

FIG-2 COMPRESSIVE STRENGTH OF SI SERIES

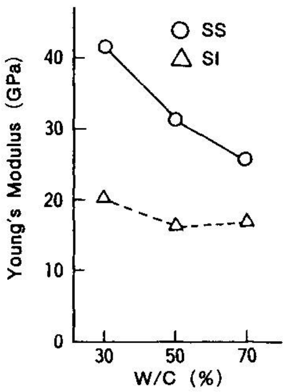

FIG-3 YOUNG'S MODULUS OF SI SERIES

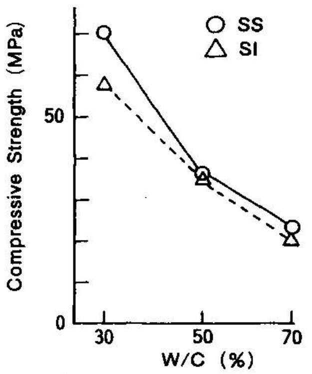

FIG-4 COMPRESSIVE STRENGTH OF IS SERIES

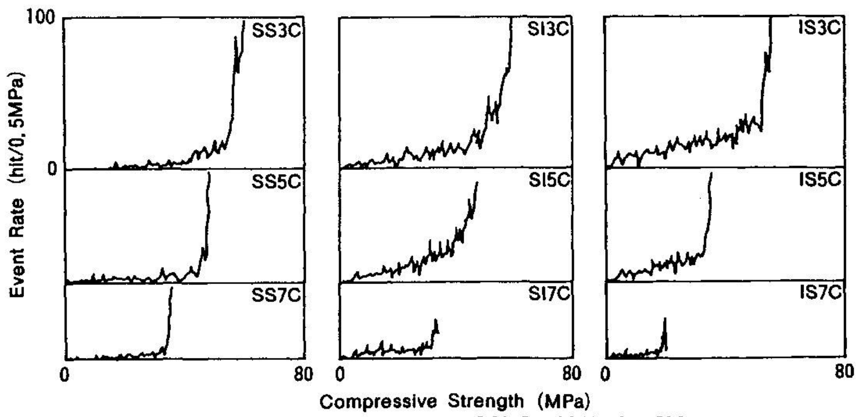

FIG-5 RELATION BETWEEN COMPRESSIVE STRESS AND EVENT RATE OF AE that of compressive strength. Fig-4 shows the results of compressive test of concretes which contained several kinds of fine aggregates. These results also show that the compressive strength of concrete with inferior sand was lower than that of concrete with sound sand.

4.2 Compressive stress and AE events

Fig-5 shows the relationship between compressive stress and event rate of AE detected from the concrete with sound aggregate (SS series), sound fine aggregate and inferior coarse aggregate (SI series) and inferior fine aggregate and sound coarse aggregate (IS series). The event rate means the number of AE per loading stress of 0.5MPa. These results show that, in the case of the SS series, most AE signals occured at the stress near the breaking point without reference to the water cement ratio. On the other hand, in both cases of the SI and IS series, a large amount of AE signals occured from the low stress level stage, and this phenomenon was obvious in the concrete with a low water cement ratio of less than 50%. The difference of AE characteristic is assumed to be caused by the quality of aggregate. It is considered that the sound aggregate can accumulate the strain energy,so that the generation of micro cracks inside or on the surface of aggregate are restrained at a low stress level. In addition, at the stress near the breaking point, a precipitious destruction occur. This tendency is considered to be remarkable in the concrete with low water cement ratio because the effect of breeding or vacant spaces around the aggregate become negligible in such concrete. But the effect of water cement ratio was not confirmed in the experiments on the SS series. On the contrary, in the case of concrete with inferior coarse aggregate, the stiffness of coarse aggregate is the same or lower than that of mortar. Accordingly, it is assumed that many micro cracks inside or on the surface of aggregate are generated at a low stress level because of the small capacity of strain energy accumulated in aggregate and the stress concentration on them. In the concrete with inferior fine aggregate, the stiffness of mortar is much lower than that of coarse aggregate, therefore, the inside or on the surface of fine aggregate is considered to be easily destructed because of the stress concentration on the mortar.

4.3 Peak amplitude distribution of AE

Fig-6 shows the relationship between the peak amplitude and event counts of AE signals. Specimens are the SS series, the SI series and the IS series concrete with water cement ratio of 30%. In the figure, the stress level i.e. the percentage of compressive stress to the compressive strength, is divided into 2 ranges (0-50%, 0-100%), and the amplitude distribution curve for each range is shown respectively. The solid line is the approximation of the amplitude distribution curve. At the stress level of 0-50%, in the case of SS3C, the event counts of AE were generally small, regardless of amplitude. However, in the case of SI3C or IS3C, many AE signals with small amplitude of 0.1-1.0mv were detected. Then at the stress level of 0-100%, the event counts of AE detected from every specimen increased, but the amplitude distribution showed a tendency to vary with the quality of aggregate. In the case of SS3C, a considerable number of AE with large amplitude, apx. 10mv, were detected. On the contrary, in the case of SI3C or IS3C, most AE signals showed small amplitude of 0.1-1.0mv. This phenomenon is considered to be caused by the quality of aggregate, that is, the difference of the capacity of strain energy accumulated in the aggregate as mentioned in 4.2. Therefore, the fracture process of the concrete with inferior aggregate is different from that of the concrete with sound aggregate.

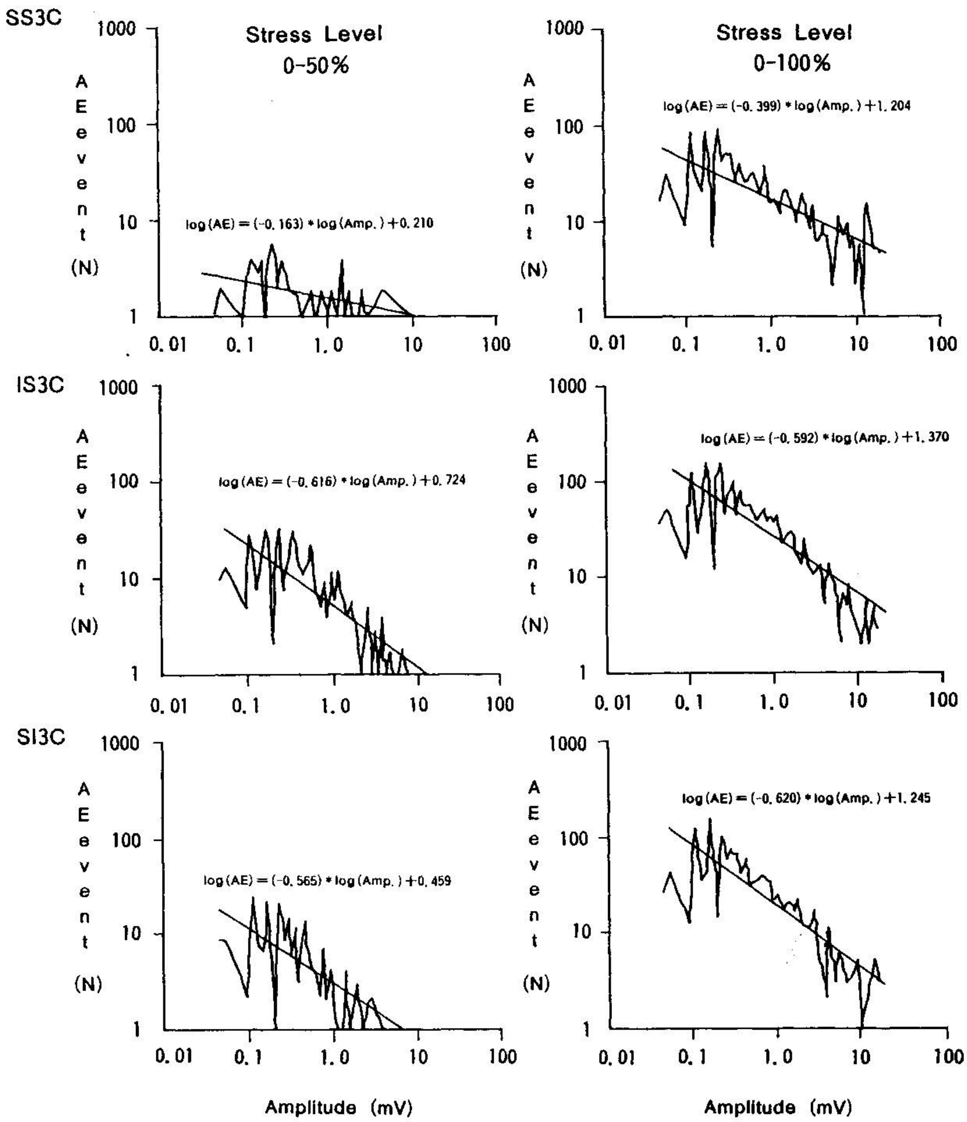

FIG-6 RELATION BETWEEN THE MAXIMUM AMPLITUDE AND EVENT COUNT OF AE

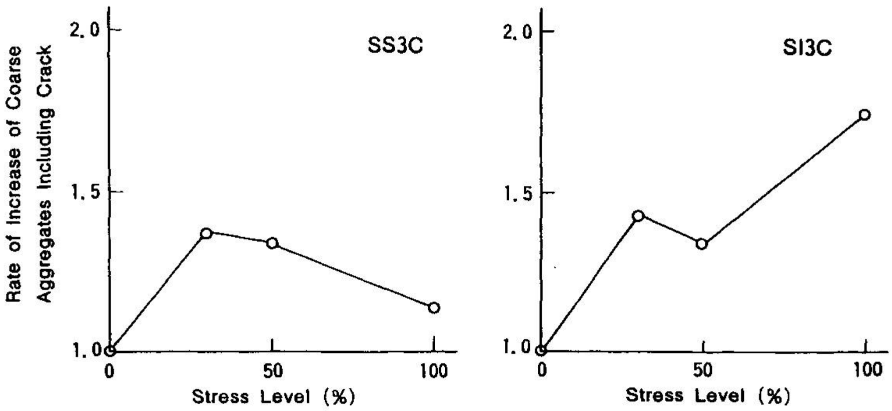

FIG-7 RELATION BETWEEN THE STRESS LEVEL AND THE RATE OF THE INCREASE OF COARSE AGGREGATES WITH CRACK INSIDE THEM

4.4 Micro cracks inside aggregates

Fig-7 shows the relationship between the stress level and the rate of increase of coarse aggregate with crack inside them. The rate of increase of coarse aggregate with crack was obtained by the following process.

1) To obtain the rate of destruction of coarse aggregate in the section of the specimen by observation with a microscope.

$$R = Gc/Go$$

where, R : the rate of destruction of coarse aggregate
Gc : the number of coarse aggregate with crack inside of them
Go : total number of coarse aggregate in the section of the specimen

2) To obtain the rate of increase of coarse aggregate with crack using the following equation.

$$C = Ra/Ro$$

where, C : the rate of increase of coarse aggregate with crack
Ra : the rate of destruction of coarse aggregate at the stress level of a %
Ro : the rate of destruction of coarse aggregate before loading

The results show that the number of inferior coarse aggregate with crack increased in proportion to the stress level while the number of sound aggregate with crack didn't indicate such a tendency. But, the fracture process of scoria which includes many voids in it, could not be confirmed clearly.

5. CONCLUSION

We conclude from the experiment as follows.

(1) Both compressive strength and static Young's modulus of the concrete containing inferior aggregates with low gravity and high absorption are lower than those of the concrete with sound aggregates. But because of the variation of compressive strength, there will be some cases where the quality of aggregate cannot be evaluated accurately by the compressive strength of concrete.
(2) During the uniaxial compressive testing of the concrete with sound aggregates, most of AE signals occur at the stress level near the breaking point. However, in the concrete with inferior aggregates, a large amount of AE are generated from the low stress level stage because of destruction inside or on the surface of aggregates.
(3) During the uniaxial compressive testing, many AE signals with relatively large amplitude are generated from the concrete with sound aggregates. On the contrary, amplitude of AE signals generated from the concrete containing inferior aggregates are generally small. This phenomenon is considered to be caused by the quality of aggregate including capacity of strain energy accumulated in them.

Accordingly, the quality of aggregate appears more clearly in the static Young's modulus than the compressive strength of the concrete containing them. These are simply the phenomena caused by the quality of aggregate and can by no means indicate the difference of the fracture process of the concrete. However, the difference of the fracture process of concrete due to the quality of aggregate is obviously indicated by the resuls of AE measurement during uniaxial compressive testing.