A study on damage detection system using smart AE sensor

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ABSTRACT: The damage detection system using some AE sensors can presume the position which damage generates by carrying out waveform processing of AE wave. It had been used to evaluate correctly the position of AE source for the experiment of reinforced concrete structure. However, when we apply a damage detection system to a actual structure, it is not important to evaluate the position of damage correctly. Then, we developed the damage detection system using a smart AE sensor. A smart AE sensor includes a transducer, CPU and memory on a printed circuit board. .The size of the smart AE sensor is about 20mmx80mm. The AE counts exceeded four level thresholds are calculated on the smart AE sensor and transmitted to a personal computer. The AE counts are index for damage of this damage detection system. This paper reports the application of the developed damage detection system to the experiments of the reinforced concrete structure.

1 INTRODUCTION

The reinforced concrete structures constructed in 1970s have been used for more than 30 years. The maintenance and repair technique for these existing structures are becoming significant. The maintenance for most these structures has been performed at regular intervals by the visual and nondestructive inspection. These inspections can not identify the important information of the time that damage generates. And when sudden disturbance such as an earthquake happens, a lot of inspectors are necessary to grasp the damage situation of many structures. In order to improve these inspections, some damage detection systems for the structure have been developed and applied to actual structures. These damage detection systems use the following sensors.

1)Optical fiber sensor, 2) Acceleration transducer
3) Displacement transducer, 4) AE sensor

We choose AE sensor as the sensor of a damage detection system, because it was applied to the experiment at the laboratory. In an experiment at a laboratory, it was useful to evaluate correctly the position of the damage using some AE sensors. However, since measurement system was complicated and too expensive. So we needed improvement to apply it to the damage detection system.

When we apply damage detection system to the actual structure, it is most important to detect the occurrence of damage than to evaluate correctly the position of it. We developed damage detection system using only one smart AE sensor. The smart AE sensor can detect the damage around it, but can not evaluate the damage position. It is attached in the area to which the damage is expected. The feature of smart AE sensor is to process the AE wave which is received by AE transducer, to convert to AE counts as damage index and to transmit the data to the personal computer.

2 OUTLINE OF THE SYSTEM

2.1 *Damage detection system*

The damage detection system using smart AE sensor is shown in Figure 1. The damage detection system

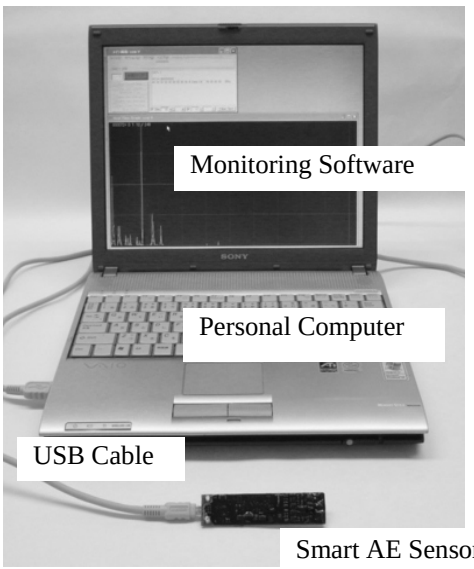

Figure 1 Damage detection system (type 1)

consists of a personal computer and a smart AE sensor. The smart AE sensor and the personal computer are connected by the USB cable. This system was used for experiments at the laboratory. We always monitored the damage index during the experiment.

To monitor for actual structure during about one month, we prepare the damage detection system with a smart AE sensor and a memory board shown in Figure 2. The memory board recorded the digital data as damage index is put in a case with a battery. We attach the damage detection system to the actual structure, and start data recording. We collect the system about one month later. And we detect the damage of the structure during one month.

2.2 *Smart AE sensor*

The smart AE sensor is shown in Figure 3. A smart AE sensor includes a transducer, CPU and memory on a printed circuit board. .The size of the smart AE sensor is about 20mmx80mm. The feature of smart AE sensor is to process the AE wave which is received by AE transducer, to convert to AE counts and to transmit AE counts to the personal computer. AE counts are the number of time which exceeds the four level thresholds in unit time as the damage index for the structure.

We developed damage detection system using only one smart AE sensor. The smart AE sensor can detect the damage around it, but can not evaluate the damage position. We need to attach it in the area to which the damage is expected.

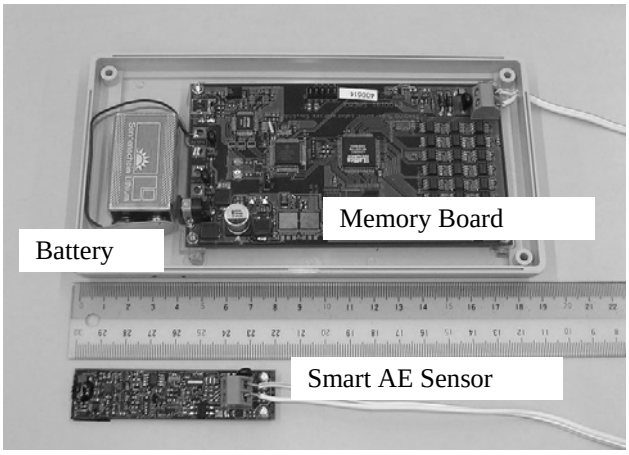

Figure 2 Damage detection system (type 2)

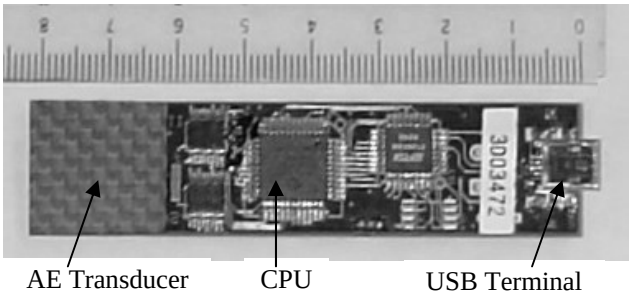

Figure 3 Smart AE sensor

2.3 *Health monitoring system*

The damage detection system uses a smart AE sensor to monitor the damage occurrence of a structural member. To monitoring the hole structure, we develop the health monitoring system using many smart AE sensors as shown in Figure 4. The system with a personal computer can always monitor the many sensors. The data received from many smart AE sensors is transmitted to the computer at the data center through the Internet.

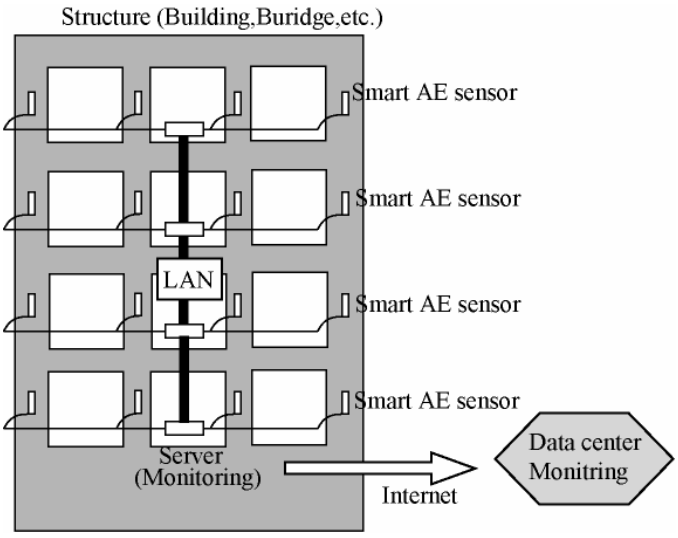

Figure 4 Health monitoring system using many Smart AE sensors

3 EXPERIMENT

We carried out two kind of experiment which attached a smart AE sensor on the specimen, reinforced concrete beam specimen (SB) and reinforced concrete column specimen (RN47). The monitoring of AE counts as damage index was performed throughout the experiment.

3.1 *Reinforced concrete beam*

The form and the arrangement of reinforcement of the specimen is shown in Figure 5. The size of rectangular section was 250mm×400mm, length of the span was 1,800mm. The specimen was supported by roller devices at the both ends. The load applied to center point of the specimen. There was less quantity of the traverse reinforcement than usual structure so that shear failure might occur. The strength of concrete was 36.9N/mm^2. We monitored the crack occurrence and propagation by visual observation and the damage detection system using a smart AE sensor. The smart AE sensor was attached to the specimen surface of the upper side with the adhesive shown in Figure 5.

The relationship between applied force and AE count obtained by the damage detection system is

shown in Figure 6. The crack pattern at the end of experiment is shown in Figure 7.

When the flexural crack occurred, AE count was observed for the first time. AE count was observed little until the occurrence of shear crack. After the shear crack occurred, AE count increased gradually according to applied force. The most AE count was observed when the applied force was about 225kN.

After the maximum force, the shear failure occurred at the other side of a smart AE sensor and the applied force decreased rapidly. Then the number of occurrence of AE count became small.

From this experiment of beam specimen, most AE count was observed at the occurrence and propagation of the shear crack. And the damage detection system using a smart AE sensor was able to detect these phenomena.

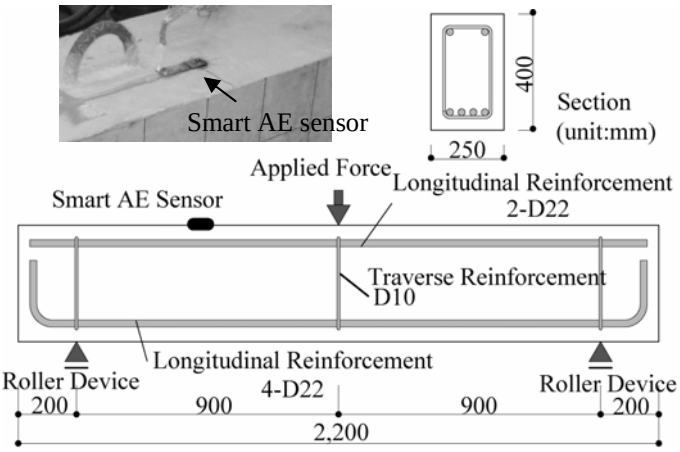

Figure 5 Outline of reinforced concrete beam specimen

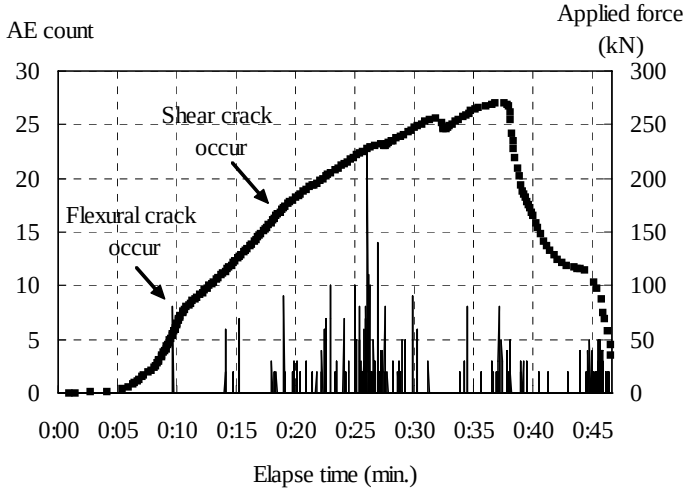

Figure 6 Relationship between applied force and AE count

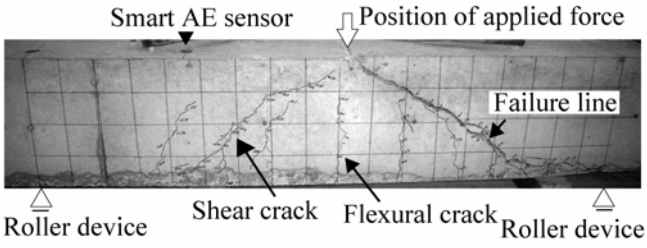

Figure 7 Crack pattern of beam specimen

3.2 *Reinforced concrete column*

The form and the arrangement of reinforcement of the reinforced concrete column specimen is shown in Figure 8 The size of rectangular section was 275mm×350mm, height of the column was 700mm. There is less quantity of the transverse reinforcements than usual structure so that shear failure might occur. Horizontal gradual increase load was applied repeatedly to the specimen. Axial load did not apply. We monitored the crack occurrence and propagation by visual observation and the damage detection system using a smart AE sensor. A Smart AE sensor is attached on the specimen surface at the height central part with the adhesive.

The relationship between shear force (Q) and deflection angle (R) for column specimen is shown in Figure 9. The crack pattern at the end of experiment is shown in Figure 10. When shear force was near Q=80kN of first loading cycle, bending crack occurred at the both ends of specimen. When shear force was near Q=140kN of second loading cycle, shear crack occurred at the center of specimen. When deflection angle was $R=15\times10^{-3}$rad., shear force was about 380kN of the maximum shear force. The width of shear crack which occurred on the diagonal became large after maximum shear force, and shear failure occurred rapidly.

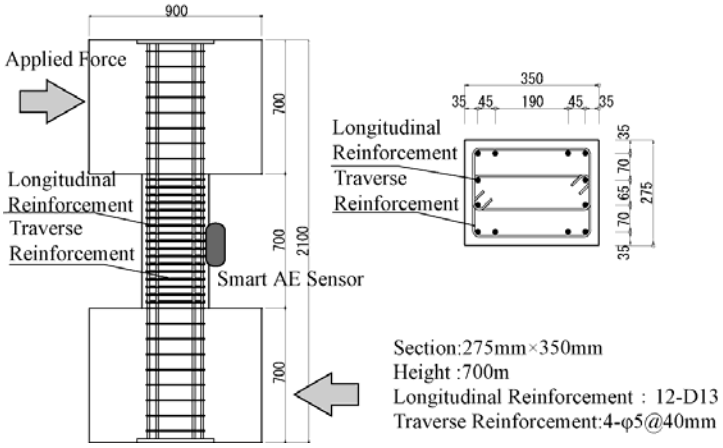

Figure 8 Outline of reinforced concrete column specimen

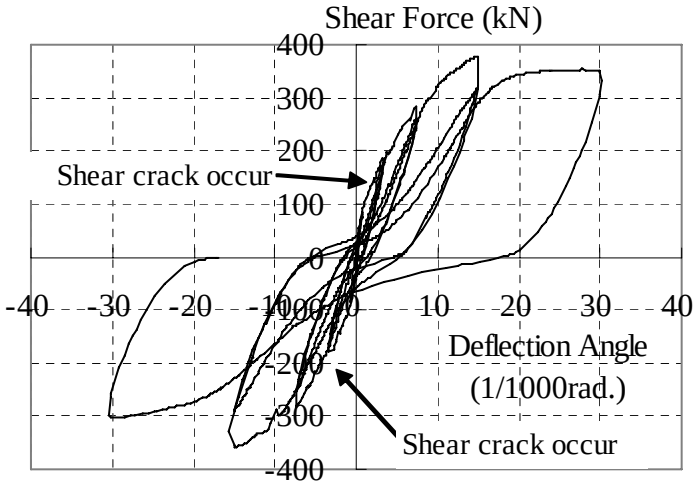

Figure 9 Relationship between shear force and deflection angle

The relationship between deflection angle and AE count is shown in Figure 11. The horizontal axis shows the loading step, and left-hand side and right-hand side of the vertical axis shows deflection angle and AE count, respectively. AE count is the value which exceeds the threshold of the lowest level. The deflection angle is increased gradually according to the load step. AE count was first observed, when shear crack occurred at second loading cycle. AE count was observed intensively near peak deflection angle. Few number of AE count was observed at the repetition of the same deflection angle until fifth loading cycle, which is called Kaiser's effect. AE count was observed regardless of the displacement after the sixth loading cycle which the shear force became maximum value.

From this experiment of column specimen, AE count was observed at the occurrence and propagation of the shear crack. AE count observed among the experiment. From the relationship between deflection angle and AE count, Kaiser's effect is observed until the maximum load. The damage detection system using a smart AE sensor was able to detect these phenomena.

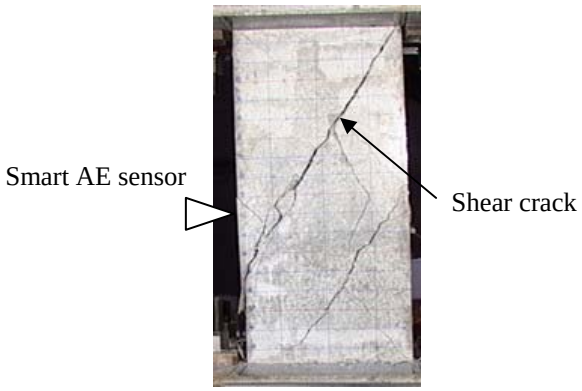

Figure 10 Crack pattern of column specimen

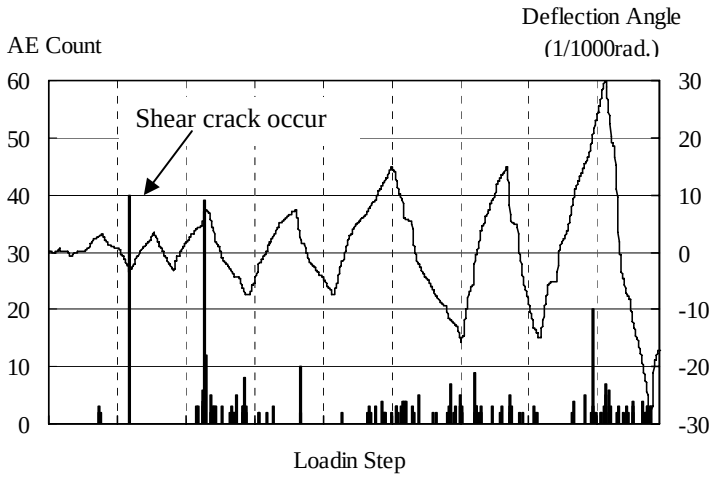

Figure 11 Relationship Between Displacement and AE Count

4 CONCLUSIONS

We developed the damage detection system using a smart AE sensor. The features of smart AE sensor are simple structure, easy to use and low price in comparison with ordinary AE measurement system. We applied the damage detection system to the experiments. The results obtained by the experiments are summarized below.

1) Occurrence and propagation of damage of the structure could be detected with the damage detection system.
2) The damage index transmitted from Smart AE sensor is observed according to the grade of damage.
3) Kaiser's effect accepted by the conventional AE method was observed.

REFFERENCES

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