EFFECT OF EXTERNAL LOAD AND TEMPERATURE CHANGE ON DELAMINATION BEHAVIOR AND INTERNAL CRACK DEVELOPMENT

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1. INTRODUCTION

Rebar corrosion can lead to concrete cover delamination by means of corrosion-induced crack development. The effects of corrosion expansion on corrosion-induced-crack propagation have been investigated by many researchers. However, the study on delamination behavior of cover concrete is limited. It is supposed that the delamination is affected by not only corrosion-induced crack propagation but also several actions that can promote internal crack propagation, such as the loading and thermal actions. In this study, loading test and thermal cycle test are carried out to investigate how they will affect the internal crack development and delamination behavior.

2. LOADING TEST

2.1 Specimen and test method

Fig.1 shows the dimensions of the specimen, of which the width and height are both 200mm. An artificial crack is introduced in the specimen, shown as the red polyline. To imitate corrosion-induced crack, the center of the artificial crack is set at 40mm depth which is the position of an imaginary corroded rebar, and inclined towards the concrete surface, leaving a remained cover of 10mm thickness. The 200mm-long artificial crack is modeled by wave-shaped soft cardboard with a thickness of 0.5mm. This method was proved feasible to model internal crack by previous studies (Ikehata *et al* (2020)). The compressive strength of the specimen is 46.2MPa and the elastic modulus is 34.1GPa. For the loading test, a thick steel plate is attached to the upper surface of the specimen with epoxy resin adhesive. The concrete surface is loaded by lifting the steel plate. The displacement of the steel plate is measured by four LVDTs. The crack opening and closing behavior during loading is measured by DICM at the five positions (1,2,3,4,5) shown in Fig.1.

2.2 Crack development behavior due to loading

The load-displacement relationship is shown as the black line in Fig.2. The load increases linearly until point A and then the stiffness sudden decreases. The load slightly increases after point A and reaches the peak value at point B. The crack width changes at each position are also shown in Fig.2. At the initial stage before point A, internal crack widths don't open. After point A, crack widths gradually develop. The crack width change is dominant only the left side (position 1 and 2) because of the eccentricity effect during loading. At point B where delamination strength is reached, crack widths increase rapidly. The crack width changes at peak load are in the range of 0.015mm to 0.035mm. It can be observed that internal cracks propagate to the surface in the direction of the artificial crack after point A, which resulted in delamination.

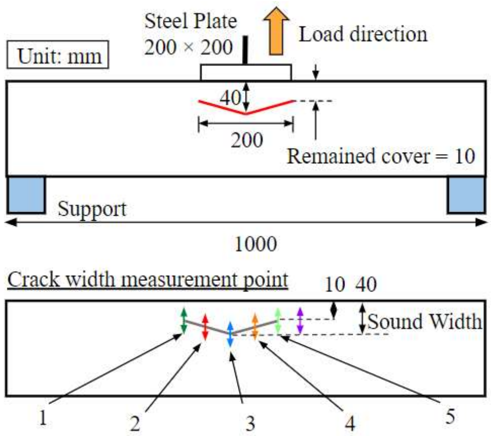

Fig.1 Specimen dimensions and loading test setup

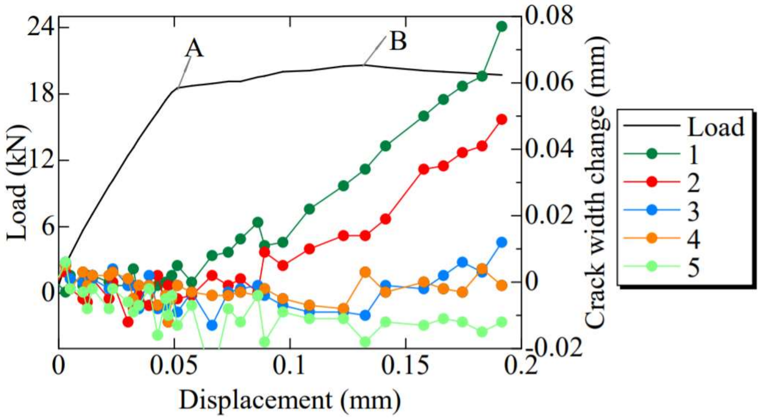

Fig.2 Load-displacement relationship and crack width change

3. THERMAL CYCLE TEST

3.1 Test method

To simulate crack opening and closing behavior due to temperature change, a test method using water to create thermal cycles on the concrete surface is developed. The specimen has the same dimensions as the loading test specimen in Fig.1.

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Fig.3 shows the schematic diagram of the experiment setup. The upper surface of concrete is heated and cooled by pouring water onto the plastic sheet bag in the pool fixed on the specimen. In order to keep the temperature stable in the pool, the water flow is continuous and draining is simultaneous. The heating and cooling process each lasts 20min, making a full cycle (heat-cool) 40min. 25 cycles are conducted in total. Temperature change behaviors at different positions (sound part/crack part, different heights) are measured by thermocouple. The opening and closing behavior of crack width is measured by 50mm pi-gauge at the edge (position 1 and 5), center (3) and middle (2 and 4) part of the artificial crack indicated in Fig.1. Also, the concrete expansion and shrinkage deformation due to temperature change are measured on the sound part at the same height as the edge and middle of the crack, as shown in purple in Fig.3.

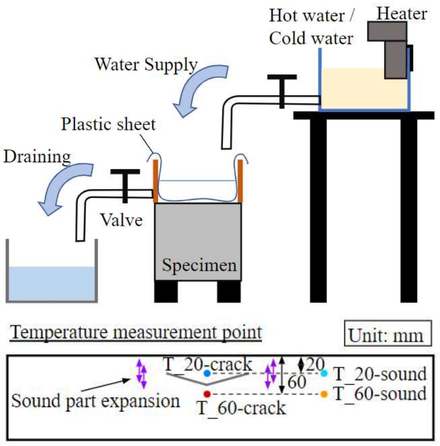

Fig.3 Schematic diagram of test setup and temperature measurement position

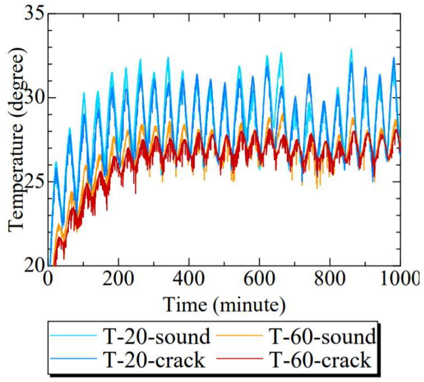

Fig.4 Temperature change at different positions

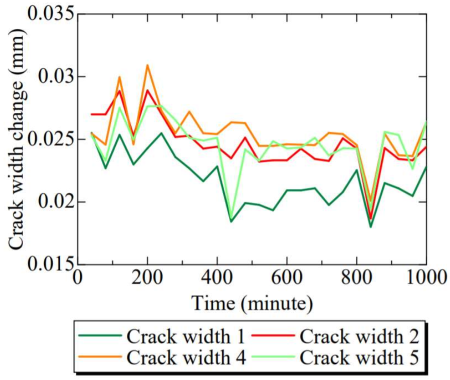

Fig.5 Crack width change

3.2 Temperature Change at different positions

Fig.4 shows the temperature change at different positions of the specimen. After 200 minutes, the temperature stabilized. The concrete surface temperature is about 22°C during cooling and 42°C during heating. It can be observed that at the depth of 20mm (T-20-sound and T-20-crack), where it is closer to the surface, the temperature change is about 5°C in a thermal cycle, larger than the temperature change of 2°C at 60mm depth. Meanwhile, the temperature at T-60-sound shows more sensitiveness to temperature change and reacts relatively faster than the temperature at T-60-crack, because artificial crack imitated by cardboard has smaller thermal conductivity than concrete.

3.3 Crack width change during opening and closing behavior

The length change of a certain cracked concrete surface area due to temperature change can be divided into two parts, the expansion/shrinkage of sound concrete and the opening/closing behavior of the crack. The data obtained by pi-gauge at crack positions include both parts. By removing the influence of sound part expansion and shrinkage, the only crack opening and closing behavior can be obtained.

Fig.5 shows the crack width change at each cycle, which is calculated by the difference between maximum (opening) and minimum (closing) crack width. The crack width at the edge position (1 and 5) is smaller than the one at the middle position (2 and 4). This phenomenon occurs by that the edge area is more constrained by the surrounding concrete. The crack width change during temperature change is between 0.02mm and 0.03mm for only 5°C temperature change at cracked position. Comparing the crack opening behavior in Fig.5 with the results of the loading test in Fig.2, it can be inferred that the damage caused by small thermal cycle has the same level as loading action, which could result in internal crack development and lead towards delamination behavior.

4. CONCLUSION

The crack opening behavior of internal crack during loading and temperature change, which resulted in concrete delamination, was clarified. A test method using water to create thermal cycles on the concrete surface was developed to investigate crack opening and closing behavior due to temperature change. It was observed that the damage of internal cracks caused by small temperature change has the same level of influence on concrete delamination behavior as load action.

REFERENCE

Ikehata, S., Ishiguro, H., Nakano, T. and Nakamura, H., 2020. Experimental evaluation of punching shear capacity of reinforced concrete slabs with horizontal crack due to compression rebar corrosion. Structural Concrete.