Simulation of Concrete Cracks due to Bar Corrosion by Aluminum Pipe Filled with An Expansion Agent

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Concrete crack Rebar corrosion
Expansion agent Aluminum pipe

1. INTRODUCTION

Many studies have been conducted about the effects of reinforcing bar corrosion on the structural performance of RC members using experiments that simulate cracks due to corrosion expansion of reinforcing bars by an electrolytic corrosion test or by slits in the previous research [1] [2], but the conformity to real cracks is unclear. In this study, an aluminum pipe embedded in concrete and filled with an expansion agent was proposed as a method to simulate reinforcing bars which volume expands due to corrosion. First, the possibility to simulate the cracking of concrete due to corrosion of reinforcing bars in the laboratory in a relatively short time was investigated. In addition, for grasping the mechanical properties of pipes filled with expansion agent to evaluate the structural performance of member when the pipe replace reinforcing bars, tensile tests and compression tests of those pipes were carried out.

2. CRACK SIMULATION BY ALUMINUM PIPE FILLED WITH EXPANSION AGENT

2.1 Specimen Overview

Fig.1 shows the specimen with a cross-section of 150 mm x 150mm and 400mm as the length. An aluminum pipe with 18 mm as outer diameter and 1 mm thickness was embedded in the concrete. The compressive strength of the concrete was 25.3 MPa and the ratio of the water to expansion agent was 30%.

2.2 Measurement Method

Till 140 hours after filling the expansion agent, the crack width was measured with π-type displacement transducers placed in three positions on the specimen. 250 hours later, the displacement transducers were removed, and the crack width was measured with a crack scale.

2.3 Experimental Results

a) Position of crack

Table 1 shows the average and maximum crack width after 250h. Average crack width is calculated using crack width measured by the 3 transducers. Fig.2 shows a typical crack occurred along the pipe after 250h. Cracks occurred from the top to the bottom on the coverside of the specimen along the aluminum pipe and almost stop increasing after 250 hours.

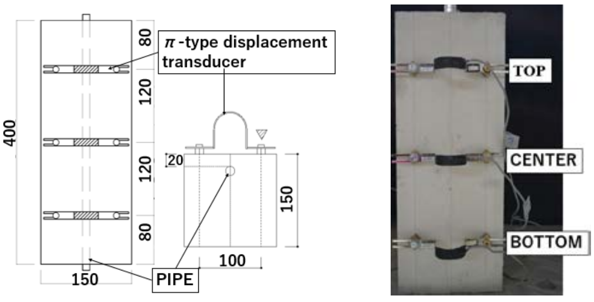

Fig. 1 Specimen overview

Table 1 Cracks width after 250h

Specimens	Average crack width (mm)	Maximum crack width (mm)
18-15-1	0.43	0.50
18-15-2	0.43	0.50
18-15-3	0.52	0.60

Fig.2 Crack after 250h

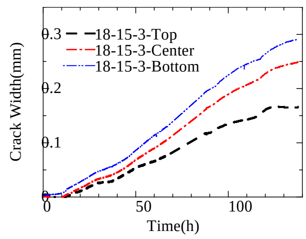

Fig.3 Crack width over time

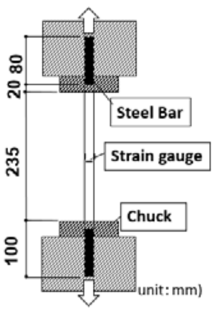

Fig.4 Tension test

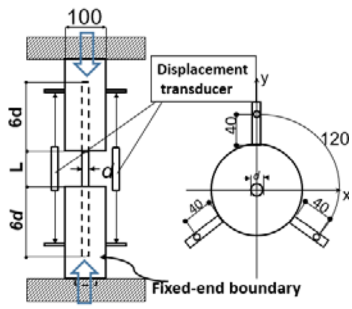

Fig. 5 Compression test

b) Crack width and elapsed time

Fig.3 shows the relationship between the crack width and elapsed time. In all specimens, the crack width increased over time. In addition, crack in the top part of the specimen is larger than that in the bottom.

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3. MECHANICAL PROPERTIES OF ALUMINUM PIPE FILLED WITH EXPANSION AGENT

3.1 Specimen Overview

Aluminum pipe with an outer diameter of 18mm (53.38 mm^2 as cross section) and 22mm (65.94 mm^2 as cross section) were used. The test length was 235 mm. Experimental factors were the outer diameter of the aluminum pipe and the elapsed time after filling the expansion agent (15, 65 and 300 hours). Experiments were conducted on three specimens with the same experiment factor.

3.2 Loading and Measurement

Monotonic loading was carried out using a universal testing machine of 500 kN capacity.

Fig.4 shows the loading and measurement method for tension test. To prevent deformation of the grasped part by the chuck, a round steel bar having a length of 80 mm was inserted into the specimen ends. Axial strain and the circumferential strain were measured.

Fig.5 shows the loading and measurement method for compression test. The jigs for fixing specimen were attached to the heads of the testing machine, so the boundary condition was to be fixed-end by inserting the ends of 6d (d: outer diameter) of the pipe in the jigs. Measurement items were compressive force and axial deformation at three points between jigs.

3.3 Experimental Results

a) Tension test

Tension test results as the average values of three specimens are listed in Table 2. The tensile stress was calculated dividing the load by the cross-sectional area of the aluminum pipe. The Young's modulus was calculated by the method of least squares in the section considered as a straight line in the tensile stress-axial strain relation. Fig.6 shows the relationship between tensile stress and axial strain.

The tensile strength and the yield strength do not have a clear influence on elapsed time after filling of expansion agent.

b) Compression test

Table 3 summarizes the compression tests results as the average values of three specimens. The compressive stress was calculated by dividing the load by the cross-sectional area of the aluminum pipe. The Young's modulus was calculated by the method of least squares in the section considered as a straight line in the compressive stress-axial strain relation.

As the buckling deformation begins to occur, the strain begins to decrease on one side, so the axial strain on the larger side is regarded as the strain at the maximum load.

Fig.7 shows the relationship between compressive stress and axial strain.

Table 2 Tension test result

Specimen	Max load (kN)	Tensile strength (MPa)	Yield strength (MPa)	Young modulus (GPa)
T18-0	12.3	230	211	66.9
T18-15	12.4	232	217	83.1
T18-65	12.5	235	219	101
T18-300	12.6	236	232	115
T22-0	14.4	218	198	64.3
T22-15	14.2	216	201	86.4
T22-65	14.6	221	213	107
T22-300	14.3	217	202	99.6

Table 3 Compression test result

Specimen	Max load (kN)	Max stress (MPa)	Max load strain (%)	Young modulus (GPa)
C18-0	11.0	206	0.52	53.2
C18-15	12.1	227	0.93	33.1
C18-65	16.6	311	1.63	33.8
C18-300	24.1	451	1.72	37.8
C22-0	12.8	194	0.58	53.0
C22-15	13.6	206	1.08	29.9
C22-65	22.8	345	2.18	26.5
C22-300	35.6	540	2.01	45.0

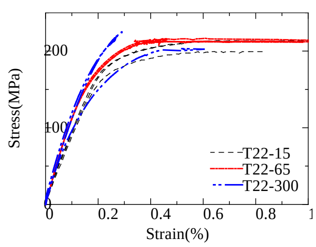

Fig. 6 Tension test result

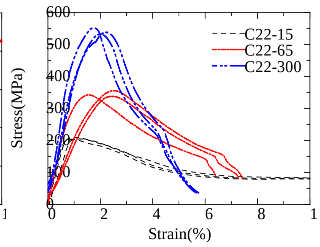

Fig. 7 Compression test result

The compressive strength becomes larger as elapsed time after filling the expansion agent. Regarding Young's modulus, there is no clear influence due to time.

4. CONCLUSIONS

This study shows that aluminum pipe filled with an expansion agent can simulate concrete cracks due to bar corrosion and crack width increased over elapsed time from filling of expansion agent. The tensile strength and the yield strength of the aluminum pipe filled with expansion agent do not have a clear influence on elapsed time after filling with expansion agent, however its compressive strength increases over time.

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