Concrete Cracks by Expansion Agent Filled Pipes in Bond Test Specimens

Regular Member ○Toshiyuki Kanakubo *
Regular Member Juan Jose Castro **
Regular Member Amadou Sakhir Syll ***
Regular Member Togo Aburano ***

Concrete crack Rebar corrosion Crack width
Expansion agent Bond test

1. INTRODUCTION

Rebar corrosion basically causes bond deterioration between rebar and concrete which directly affects the serviceability and durability of RC structures. Indeed, the surface crack width provides the clearest visual manifes-tation of reinforcement corrosion. Easily measurable, it can be a key parameter to solve this problem by directly correlating the bond deterioration of the surface crack width. Moreover, corrosion-induced crack has been clarified to be more dominant than corrosion product and change of rebar profile in bond deterioration mechanism [1]. In our previous study [2], the simulation of the cracking of concrete due to corrosion of reinforcing bars by using an aluminum pipe embedded in concrete and filled with an expansion agent has been proposed as a method to simulate reinforcing bars which volume expands due to corrosion. In this paper, a novel crack simulation method to investigate the bond behavior of concrete corrosion-induced cracks is presented and test specimens are prepared for the pull-out test using expansion agent filled pipes.

2. PULL-OUT SPECIMENS OVERVIEW

2.1 Aluminum pipe with ribs

Fig. 1 shows an overview of a processed aluminum pipe with ribs set according to JIS G 3112. An aluminum pipe with 21.7 mm as outer diameter and 2.5mm thickness was used to imitate D19 rebar. The fundamental properties of the aluminum pipe and the expansion agent filled pipe have been reported by authors [3].

2.2 Pull-out specimen

Pull-out specimen was designed as shown in Fig. 2. Dimensions of specimen are 260×260×82mm and the aluminum pipe with ribs was embedded at 38mm from the specimen side. The bond length of 51.6mm was chosen to avoid the rupture of the pipe by tensile force. Moreover, adhesive tape was used to make unbonded part to avoid cone failure of concrete. A M6 coupler was fixed 100×100 mm at up left position to set a LDVT for measuring the slip of pipe. A π-type displacement transducer was placed on the concrete cover to measure the opening of crack during loading. Table 1 shows the mechanical properties of concrete obtained from concrete cylinder test at the day of filling of expansion agent.

2.3 Loading and measurement

Fig. 3 shows the test set-ups for pull-out test. The specimen was set on the Teflon sheet, and the loading plate on which the hole with the same diameter corresponding to concrete cover in order

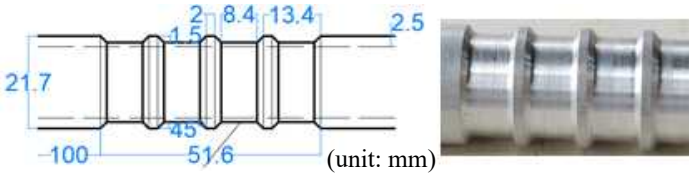


Fig. 1 Aluminum pipe with rib

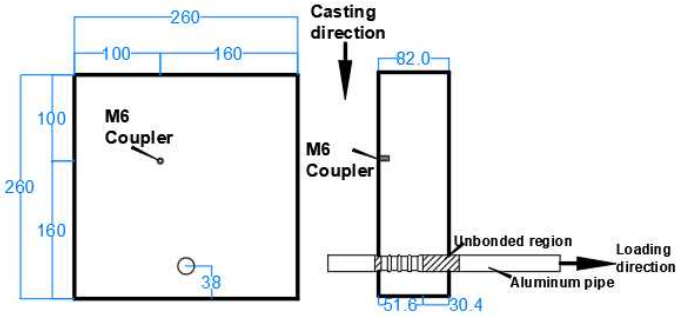


Fig. 2 Specimen detail

Table 1 Concrete mechanical properties

Compressive strength (MPa)	Young's modulus (GPa)	Splitting tensile strength (MPa)
17.8	22.8	1.78

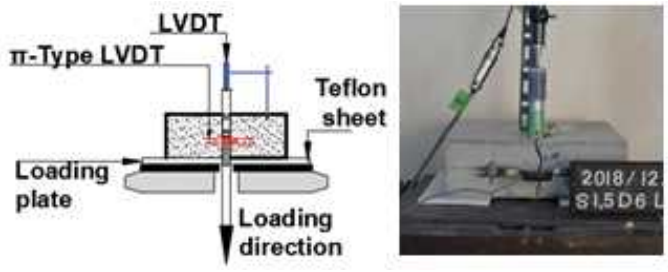


Fig. 3 Loading and measurement in pull-out test

to not restrict the lateral deformation of concrete. The pipe was subjected to monotonic pull-out loading at a speed of 0.5mm/min. The measurement items are pull-out load, crack opening and slippage of the pipe at the free end.

3. CRACK SIMULATION BY ALUMINUM PIPE FILLED WITH EXPANSION AGENT

3.1 Filling of expansion agent

Expansion agent is mainly used for destruction of rocks and RC structures, in powder form, and it expands when humified. Due to this expansion, cracks are generated in the concrete (Fig. 4). The ratio of the water to expansion agent was set to 30%. The specimen was placed as the axial direction of the pipe was set vertically, and expansion agent was filled from the top of the pipe as shown in Fig. 5.

3.2 Cracking patterns induced by expansion agent

Fig. 6 shows examples of crack patterns after filling the expansion agent. The reaction of the expansion agent was heavily influenced by the ambient temperature around the specimens. To control the width of induced crack, specimens were placed in variable temperature conditions such as in an air-conditioned room or in the testing laboratory with same temperature of outside. Also, because of the increasing of crack width over elapsed time from filling of expansion agent, maximum crack width was measured by a crack scale after a full stop of crack width increasing. Crack width as parameter is organized into 3 levels as shown in Table 2. The maximum crack width in every specimen is summarized in Table 3. As the results, crack width ranges from 0.1mm to 3.0mm.

4. CONCLUSIONS

This study describes a crack simulation method to investigate the bond behavior of reinforcing bars in corroded reinforced concrete. Ribbed aluminum pipe filled with an expansion agent can simulate concrete cracks due to bar corrosion.

ACKNOWLEDGEMENT

This study was supported by the JSPS KAKENHI Grant Number 17K18917.

REFERENCES

[1] Yang ,Y., Nakamura, H., Miura, T., Yamamoto, Y., Effect of Corrosion-Induced Crack and Corroded Rebar Profile on Bond Stress and Slip Relationship, Proceedings of the Japan Concrete Institute, Vol. 40, No. 1, pp.927-932, 2018

[2] Syll, A. S., Kawamura, Y., Kanakubo, T., Simulation of Concrete Cracks due to Bar Corrosion by Aluminum Pipe Filled with An Expansion Agent, Summaries of Technical Papers of Annual Meeting, AIJ, Structure IV, pp.55-56, 2018.9

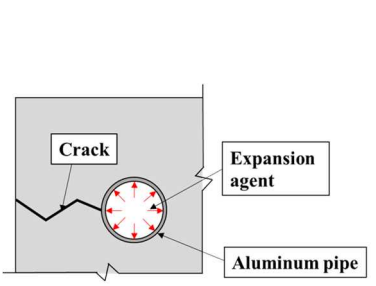
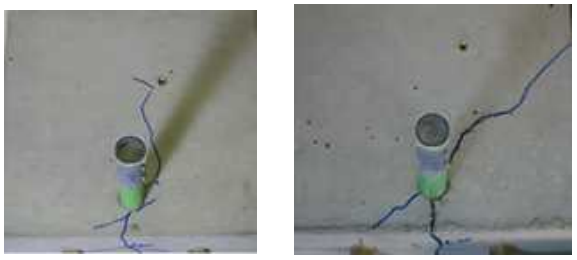


Fig. 4 Concrete cracking with expansion agent

Fig. 5 Filling of expansion agent



(a) Bottom view (free end)

(b) Side view (cover side)

Fig. 6 Cracking of concrete before pull-out test

Table 2 Crack level

Level	Crack width range
Level 1	≤ 0.5mm
Level 2	0.5mm to 1. 0mm
Level 3	> 1. 0mm

Specimen name explanation

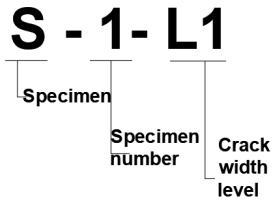


Table 3 Maximum crack width

Specimen name	Maximum crack width (mm)
S-1-L1	0.15
S-2-L1	0.1
S-3-L1	0.2
S-4-L1	0.35
S-2-L2	0.5
S-1-L2	1.0
S-1-L3	1.5
S-2-L3	3.0
S-3-L3	2.0
S-4-L3	1.8
S-5-L3	2.0
S-6-L3	2.6

[3] Aburano, T., Syll, A. S., Castro, J. J., Kanakubo, T., Tensile Characteristics of Expansion Agent Filled Pipes for Simulation of Concrete Cracks due to Bar Corrosion, Summaries of Technical Papers of Annual Meeting, AIJ, 2019.9

* Prof., Dept. of Eng. Mechanics and Energy, University of Tsukuba, Ph.D.

** Prof, Architecture and Building Engineering Program, University of the Ryukyus, Ph.D.

*** Master Program in GSSIE, University of Tsukuba