Bond Strength Degradation in Cracked Concrete by Expansion Agent Filled Pipes

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1. INTRODUCTION

Bond at the steel-concrete interface is a critical property of reinforced concrete. Rebar corrosion causes bond deterioration between rebar and concrete which directly affects the durability of RC structures. Evidence suggests that the surface crack width is among the most important factors for solving this problem by directly correlating it to the bond deterioration. In previous research [1] [2], the simulation of the cracking of concrete due to corrosion of reinforcing bars by using an expansion agent filled pipe (EAFP) was proposed as a novel method. Moreover, a pull-out test was carried out to establish a simple formula for predicting the bond degradation with surface crack width as a variable. Despite the importance of the induced crack width, there remains a paucity of evidence on the influence of other parameters (concrete strength and cover).

In this paper, a concrete cracked by an EAFP in bond test specimens has been designed with a smaller concrete cover. Those specimens with different crack width are subjected to a pull-out test. This study sets out to investigate the influence of the concrete cover on bond deterioration.

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 [1].

2.2 Pull-out specimen

Pull-out specimen was designed as shown in Fig. 2. Dimensions of the specimen are 260×260×82mm and the aluminum pipe with ribs was embedded at 28.5mm from the specimen side. A concrete cover as 28.5mm (1.5D_b) have been used in the previous study [2], here a 19mm (D_b) cover was adopted to investigate the effect of cover on bond deterioration. 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. Table 1 shows the mechanical properties of concrete obtained from concrete cylinder test on the day of filling of expansion agent.

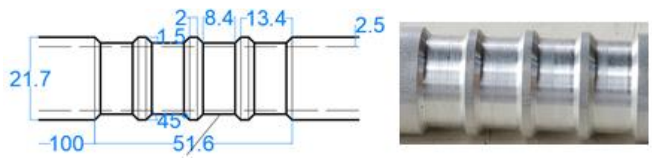

Fig. 1 Aluminum pipe with rib

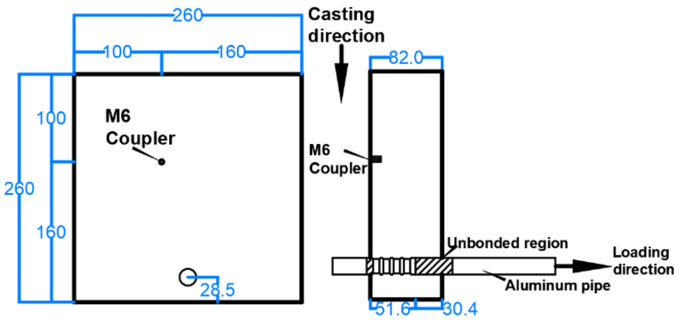

Fig. 2 Specimen detail

Table 1 Concrete mechanical properties

Compressive strength (MPa)	Young's modulus (GPa)	Splitting tensile strength (MPa)
28.2	22.8	2.17

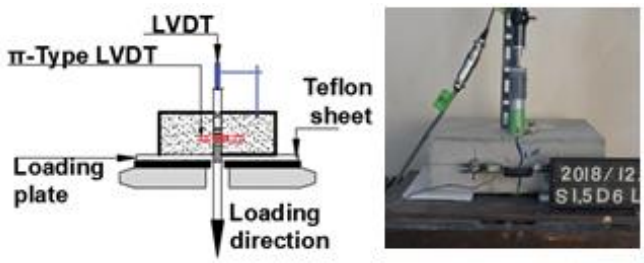

Fig. 3 Loading and measurement in pull-out test

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

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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, slippage of the pipe at the free end, and crack opening. . A π-type displacement transducer was placed on the concrete cover to measure the crack opening as shown in Fig.3.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Crack simulation by EAFP

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. The details of the EAFP simulation method have been reported by authors [1]. The results of the cracking simulation and pull-out test are summarized in Table 2.

Initially, the influence of concrete cover on crack propagation is insignificant, but later there exists a tendency that the crack width increases at a faster rate for specimens with a smaller concrete cover. This has contributed to the difficulty to obtain a crack width between 0.3mm and 0.85mm. Also, in some specimens with 19mm cover presented multiple cracks. These results are likely to be related to the fact that larger concrete cover offers more resistance to the formation of cracks due to the volumetric expansion of rebar.

3.2 Influence of the concrete cover on bond degradation

All specimens failed by splitting of concrete in pull-out loading. A group of specimens failed by newly generated splitting crack despite existing longitudinal crack due to EAFP and other specimens failed by the widening of existing crack.

The results, as shown in Table 2, indicate that the maximum load decreases exponentially as the crack width increases when new crack did not occur at failure.

To better observe the deterioration of the bond, the maximum pull-out load is normalized by calculated bond splitting strength reported in previous study [3].

Fig. 4 shows the normalized maximum pull-out load versus crack width relationship. It can be seen that the concrete cover shows no significant influence on the relationship between bond deterioration and the surface crack width. This result may be explained by the fact that once cracking develops, appreciable loss of bond strength may be due to the lack of confinement. The opening of cracks during the loading severely affects the confinement. Therefore, the crack width may be the most important parameter when evaluating bond deterioration.

Table 2 Experimental result list

Specimen	Max. crack width (mm)	Max. load (kN)	Failure mode
S-1	0.30	5.55	Crack opening
S-2	0.85	3.75	Crack opening
S-3	0.95	4.47	New crack
S-4	1.00	4.92	New crack
S-5	1.10	5.78	New crack
S-6	1.50	2.50	Crack opening

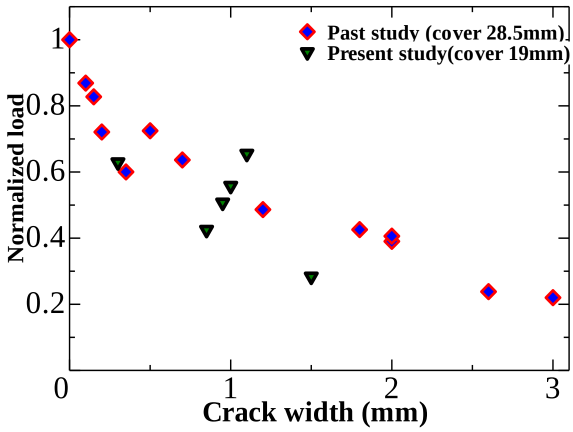

Fig. 4 Max. load vs. crack width

4. CONCLUSIONS

The maximum pull-out load reduces exponentially as surface crack width increases even in the case of small concrete cover. The concrete cover has no significant influence on the bond deterioration due to cracking of the cover. However, it plays a fundamental role in limiting the cracking due to corrosion.

ACKNOWLEDGEMENT

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