Bond Strength Degradation due to Corrosion Cracking in Concrete Specimens without Stirrups

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1. INTRODUCTION

Rebar corrosion can deteriorate the bond between the rebar and the concrete, directly affecting the serviceability and durability of RC structures. The surface crack provides the clearest visual manifestation of reinforcement corrosion. Easily measurable, it can be a key parameter in solving this problem by directly correlating the bond deterioration of the surface crack width. However, due to the ambiguity related to corrosion, the bond deterioration remains unclear.

This study aims to cast deep sight on the bond strength of concrete cracked by corrosion. To investigate the isolated influence of cracks on bond strength degradation, specimens cracked by electrical corrosion or by expansion agent-filled pipe (EAFP) are subjected to a pull-out test. The relationship between the bond strength and surface crack width as a variable is discussed.

2. PULL-OUT SPECIMENS OVERVIEW

2.1 Pull-out specimen

The pull-out specimen is designed as shown in Fig.1. The dimensions of the specimen are 260×170×170 mm, and the D19 rebar is embedded at 47.5 mm from the specimen cover side. A short bond length of 4 times the diameter of the rebar equal to 76 mm is chosen to focus on the local bond behavior. Two rebars or EAFPs are set to 50 mm from the main tested rebar to simulate the cracking of surrounding concrete. In addition, an unbonded part was set to avoid cone failure of concrete. The compressive and splitting strengths of the concrete were 22.4 MPa and 2.2 MPa, respectively.

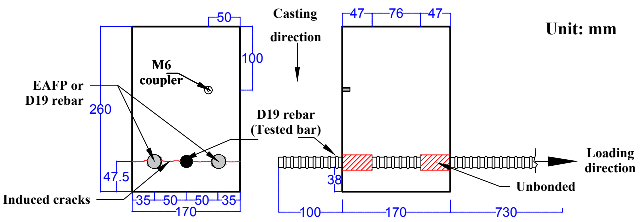


Fig. 1 Specimen detail

2.2 Loading and measurements

Fig. 2 shows the test set-ups for the 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 to not restrict the lateral deformation of concrete. The D19 rebar is subjected to monotonic pull-out loading at 0.5mm/min.

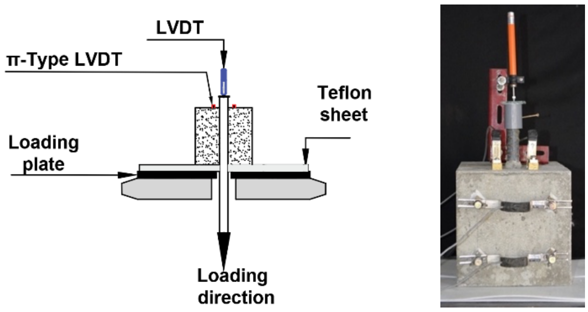
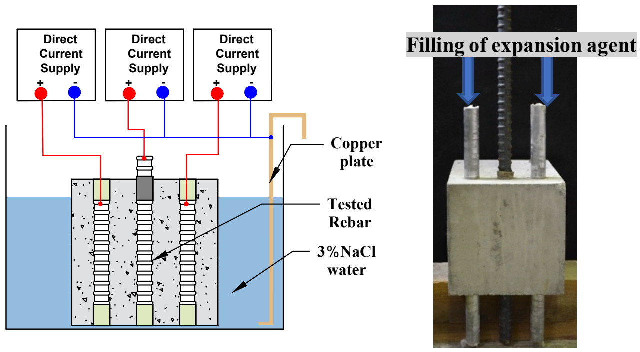


Fig. 2 Loading and measurement of pull-out test



(a) (b)

Fig. 3 Crack simulation: (a) electrical corrosion; (b) EAFP

3. CRACK SIMULATION METHOD

3.1 Crack simulation by electrical corrosion

Fig.3 (a) shows the setup for electrical corrosion. The specimen was immersed in a 3% NaCl solution and a direct current was separately impressed in the three rebars using three different current supplies. An intensity of 0.3 A was applied to simulate cracking in a reasonable time.

3.2 Crack simulation by EAFP

Fig.3 (b) shows the setup for crack simulation by EAFP. It consists of inserting an aluminum pipe into the concrete and then filling it with an expansion agent to simulate the volumetric expansion of the bar due to corrosion. More details can be found in a previous paper [1].

Keywords　Pull-out test, Bond strength, Induced crack width, Electrical corrosion, Expansion agent filled pipe
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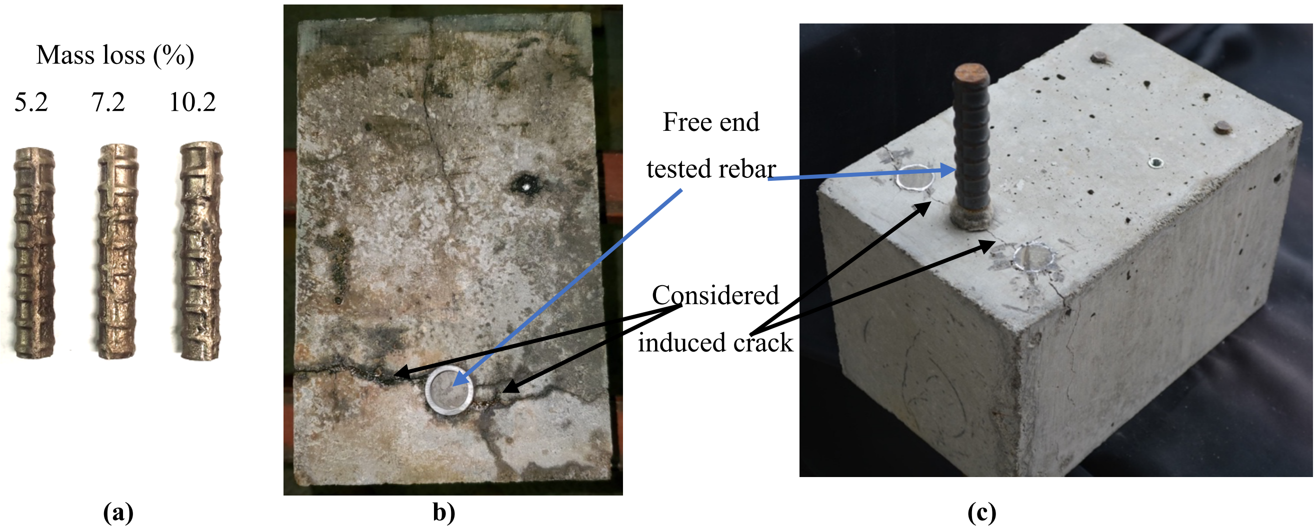

Fig. 4 Crack simulation :(a) Rebar after corrosion (b) Electrical corrosion; (c) EAFP

3.3 Crack simulation result

Fig. 4 (b) and (c) shows an example of crack patterns by electrical corrosion and EAFP, respectively. The side split type cracks took place in all specimens. The considered crack width ranged from 0.15 to 1.10 mm in specimens cracked by EAFP and from 0.15 to 0.65 mm in specimens cracked by electrical corrosion. After loading, the mass loss due to corrosion was calculated for electrically corroded specimens. An example of the change in the rebar surface can be seen in Fig.4(a). Moreover, Fig.5 shows that the relationship between the mass loss and induced crack width is unclear.

4. BOND DEGRADATION IN CRACKED SPECIMEN

The residual bond strength ratio associated with the induced crack width is obtained by normalizing the bond strength of the cracked specimens to that of the uncracked reference specimen. Fig. 6 shows the relationship between the residual bond strength ratio and the induced crack width. With increasing induced crack width, residual bond decreases in most specimens. Also, the residual bond strength ratio can be correctly estimated by considering the single effect of cracking, ignoring the rebar profile change. This demonstrates that the bond mechanism through interlocking ribs is predominant with respect to frictional influence after cracking. Furthermore, it is confirmed that a direct relationship between interlock reduction and crack width can ignore ambiguity related to the accumulation of corrosion products. The result also suggests that a crack-based approach can lead to more accurate results because corrosion-induced surface cracks represent the net amount of corrosion. In addition, it is practical to have a direct and visible damage indicator that can be measured on the outer concrete surface. However, more research is necessary to investigate the influence of other involved parameters such as concrete strength, cover/diameter ratio, confinement effect, and so on, to develop a predictive model for general applicability.

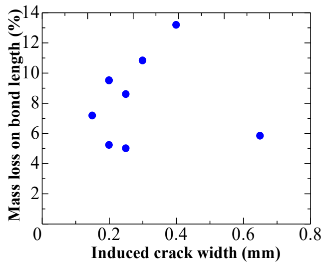

Fig. 5 Mass loss versus crack width

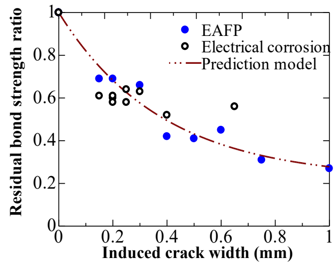

Fig. 6 Residual bond strength ratio versus crack width

5. CONCLUSIONS

To investigate the bond degradation in cracked concrete without stirrup, pull-out bond test was conducted on specimens cracked by electrical corrosion or EAFP. The results showed that the deterioration trend is almost identical in both induced crack method (electrical corrosion and EAFP). The reduction in bond strength can be related directly to induced crack width while ignoring the ambiguity resultant from corrosion (rebar shape change or rust accumulation).

ACKNOWLEDGEMENT

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