

Bond Behavior in Cracked Concrete by Expansion Agent Filled Pipes

Regular Member
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Concrete crack
Bond strength

Rebar corrosion
Bond test

Expansion agent

1. INTRODUCTION

A rough correlation between bond strength reduction and surface crack width is suggested by fib Model Code 2010 [1], also an overview the current research indicates that existing studies has achieved a primary knowledge regarding the potential correlation between bond and the surface crack width. However, there still a research gap in this respect.

In our previous works [2], concrete cracked by expansion agent filled pipes in bond test specimens has been presented. In this paper, those specimens are subjected to pull-out test and a relationship between the maximum pull-out load of bar and surface crack width as a variable is discussed.

2. PULL-OUT TEST RESULT

Test results of pull-out tests are shown in Table 1. All specimens failed by splitting of concrete. A group of specimens failed by newly generated splitting crack despite existing longitudinal crack due to corrosion and other specimens failed by widening of existing crack induced with the expansion agent. The pull-out load versus free end slippage relationships are shown in Fig. 1. The maximum pull-out load versus crack width relationship is shown in Fig. 2. It can be seen that the maximum load decreases as the crack width increases. The maximum pull-out load is normalized by calculated pull-out splitting strength reported in previous study [3] as non-corroded specimen using following equation:

$$\tau_{b,max} = 0.601 \cdot \sigma_t \cdot (r_u d_b) \cdot \cot \alpha$$

Where, $\tau_{b,max}$: bond splitting strength, σ_t : splitting tensile strength of concrete, $r_u \cdot C + d_b / 2$, d_b : diameter of pipe (19mm), C : thickness of cover concrete, α : angle between longitudinal axis and splitting force (=34 degree).

To calculate the pull-out splitting strength, splitting surface in the entire embedded bar length (82mm) is assumed.

Table 1 Test result list

Specimen name	Biggest crack width (mm)	Maximum Load (kN)	Slippage at maximum load (mm)	Remarks
S-1-L1	0.15	7.985	0.088	New crack
S-2-L1	0.1	8.386	0.146	Crack opening
S-3-L1	0.2	6.959	0.218	New crack
S-4-L1	0.35	5.793	0.144	New crack
S-2-L2	0.5	6.142	0.198	New crack
S-1-L2	1.0	6.994	0.890	New crack
S-1-L3	1.5	4.110	0.262	Crack opening
S-2-L3	3.0	2.123	0.804	Crack opening
S-3-L3	2.0	3.767	0.572	Crack opening
S-4-L3	1.8	4.693	0.658	Crack opening
S-5-L3	2.0	3.919	0.768	Crack opening
S-6-L3	2.6	2.298	1.380	Crack opening

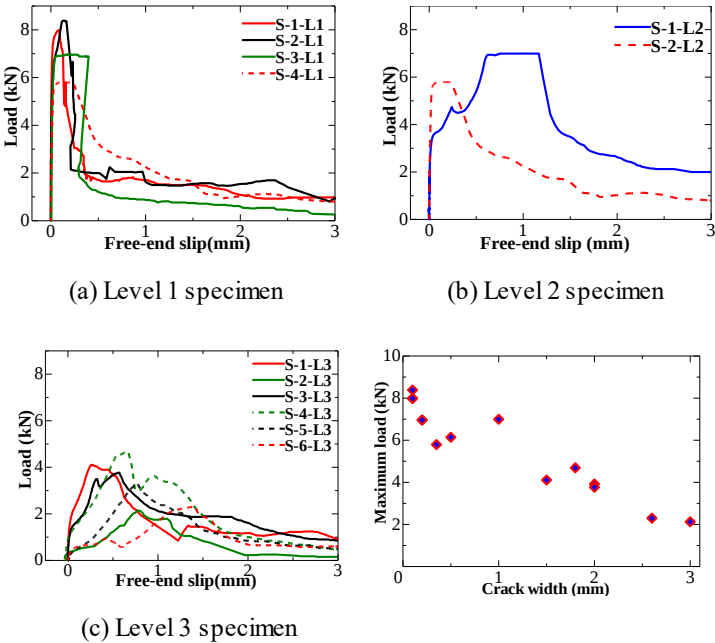


Fig. 1 Pull-out load vs. slip

Fig. 2 Max load vs. crack width

3. BOND STRENGTH DEGRADATION

In fib Model Code 2010[1], the reduction in bond strength depending on the surface crack width was introduced. For a certain range of surface crack width, the possible variation of the pull-out load degradation can be predicted. In this study the suggested relationship is compared with the test results in Fig. 3. The prediction with Model Code 2010 is in good agreement with Level 1 (crack width $\leq 0.5\text{mm}$) and for specimen with 2.6 and 3mm as crack width as an extrapolation. However, for Level 2 (crack width 0.5mm to 1.0mm) fib Model Code gives underestimation.

As can be seen from regression analysis results in Table 2 exponential equation gives the better correlation than linear or logarithmic fitting. Therefore, the following equation can be used for prediction of the maximum pull-out load:

$$P_{(W_{cr})} = P_0 \cdot e^{-0.46W_{cr}}$$

Where $P_{(W_{cr})}$: Pull-out load; P_0 : Pull-out load of specimen without crack; W_{cr} : Crack width.

Fig. 4 shows the experimental result and the prediction model comparison. The calculated and experimental results are compared in Table 3. The ratios of the experimental to calculated values are close to one, which indicates that the concrete crack width can potentially be a good indicator to characterize bond strength degradation.

4. CONCLUSIONS

It is clarified that the maximum pull-out load reduces exponentially as surface crack width caused by the corrosion of rebar increases. A simple formula to predict the bond degradation is proposed by using the surface crack width as a variable. More research is necessary to investigate the influence of other involved parameters (e.g. cover/diameter ratio, confinement, bar profile) to develop a predictive model for general applicability.

ACKNOWLEDGEMENT

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[3] Yasojima, A., Kanakubo, T., Bond Splitting Strength of RC Members Based on Local Bond Stress and Slip Behavior, 11th International Conference on Fracture, No.4486, 2005 .

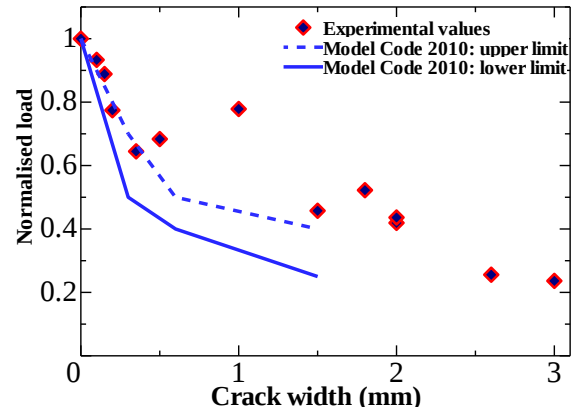


Fig. 3 Result in comparison with Model Code 2010

Table 2 Regression analysis results

Analysis	Equations	R ²
Linear	$-0.28 W_{cr} + 1$	0.79
Logarithmic	$-0.17 \ln(W_{cr}) + 0.54$	0.83
Exponential	$e^{-0.46 W_{cr}}$	0.90

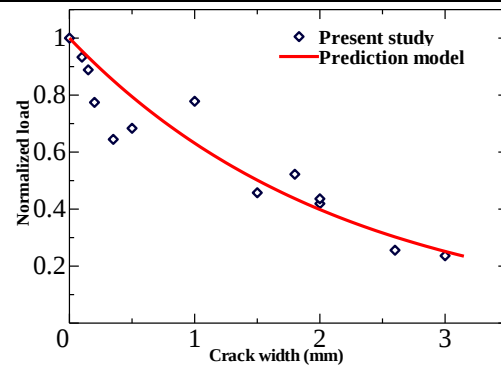


Fig. 4 Result and prediction model

Table 3 Comparison of the calculated and experimental values

Specimen name	Biggest crack width (mm)	Experimental maximum load (kN)	Calculated maximum load (kN)	Exp /Cal
S-1-L1	0.15	7.985	8.386	0.95
S-2-L1	0.1	8.386	8.582	0.97
S-3-L1	0.2	6.959	8.196	0.85
S-4-L1	0.35	5.793	7.649	0.76
S-2-L2	0.5	6.142	7.139	0.86
S-1-L2	1.0	6.994	5.672	1.23
S-1-L3	1.5	4.110	4.507	0.91
S-2-L3	3.0	2.123	2.260	0.94
S-3-L3	2.0	3.767	3.581	1.05
S-4-L3	1.8	4.693	3.926	1.19
S-5-L3	2.0	3.919	3.581	1.09
S-6-L3	2.6	2.298	2.717	0.84

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