第V部門
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[V-515] Effect of Stirrups on Bond Strength Degradation in Cracked Concrete by Expansion Agent Filled Pipes

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This study aims to cast deep sight on the bond strength of cracked concrete from the perspective of confinements by stirrups. To achieve this target, Concrete cracked by expansion agent-filled pipes in bond test specimens has been presented in the previous paper. Empirical formulas of the bond strength deterioration with crack width as the main variable, have been proposed from pull-out test results. These prediction formulas give a good correlation when compared to the available literature.

Effect of Stirrups on Bond Strength Degradation in Cracked Concrete by Expansion Agent Filled Pipes

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1. INTRODUCTION

This study aims to cast deep sight on the bond strength of cracked concrete from the perspective of confinements by stirrups. To achieve this target, Concrete cracked by expansion agent filled pipes in bond test specimens has been presented in the previous paper. Here, pull-out load vs slip curves and relationships between the maximum pull-out load and surface crack width are discussed.

2. PULL-OUT TEST RESULT

Fig. 1 shows example of bond stress versus slippage curves. The bond strength versus crack width relationship is shown in Fig. 2. It can be seen that the bond strength decreases as the crack width increases for most specimens.

3. BOND STRENGTH DEGRADATION

3.1 Proposed empirical formulas

Residual bond strength ratio, which is defined as the ratio of the bond strength of a cracked specimen to that of the uncracked specimen is evaluated to discuss the bond degradation. The bond strength for uncracked specimens in S1and S2 is calculated by the formula reported in a previous study [1] as follows :

$$\tau_{b,max} = \sigma_l \cdot \cot\theta \qquad (1)$$

$$\sigma_{l,max} = \sqrt{0.018 \cdot \frac{b \cdot p_w}{N \cdot db} \cdot \frac{h}{l_{we}} \cdot E_{St} \cdot \sigma_B} \qquad (2)$$

Where, $\tau_{b,max}$: maximum bond stress, σ_l: lateral confinement stress, θ :angle between the principal bond stress and the axis of reinforcement (= 45degrees), db: the diameter of the tested bar, b: width of member, p_w: lateral reinforcement ratio, h: rib height, N: number of reinforcing bar, l_{we}: bond effective length, E_{st}: Elastic modulus of lateral reinforcement.

The following equation form is used to evaluate the degradation of bond by regression analysis:

$$RB = 1 - a\left(1 - \left(e^{b \cdot w_{CR}}\right)\right) \qquad (3)$$

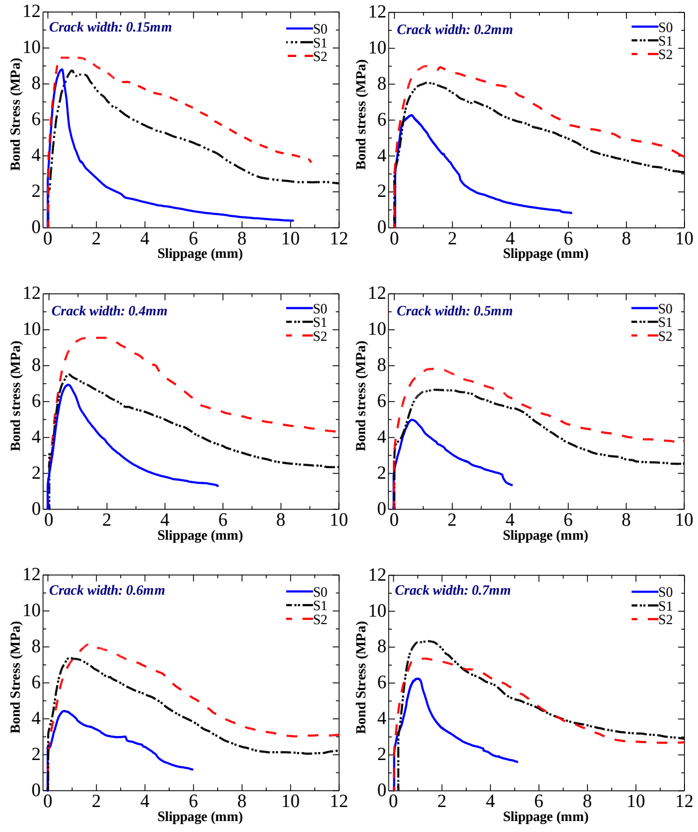

Fig. 1 Example of bond strength vs slippage

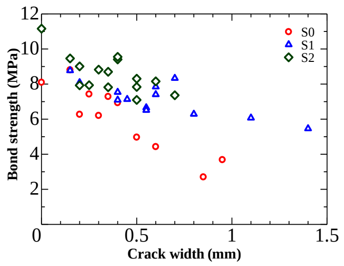

Fig. 2 Bond strength vs crack width

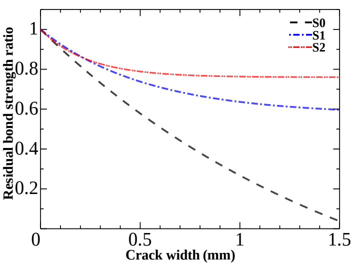

Fig. 3 Regression analysis result

Table 1 Regression analysis coefficient

Series	p_w (%)	*a*	*b*
S0	0	1.61	-0.61
S1	1.10	0.43	-1.89
S2	1.68	0.24	-4.23

Where RB: Residual bond strength ratio, W_{CR}: Crack width; a, b: Empirical coefficient.

Keywords　Rebar corrosion, Expansion agent, Crack width, Bond test , Stirrup.
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The empirical coefficient by regression analysis can be. seen in Table 1. Fig.3 compares the three formulas Until a crack width of 0.15mm, the influence of stirrup was not seen on the degradation of bond. This fine crack was still able to transmit the load from the bar to the surrounding concrete. However, when the crack width is more than 0.15mm, the stirrup can restrain the opening of the induced crack and limit the bond deterioration. The stirrups play an important role in terms of confinements after cracking. First, the concrete cracking was restricted by stirrups, which led to the increase of residual tensile strength of concrete. And then, once the concrete cover cracked, the bearing forces due to ribs transferred from the concrete to the stirrups, and the bond strength was partly maintained by stirrups.

The obtained formulas are compared with the fib model [2] in Fig.4. In absence of stirrup, the formula is in good agreement with the fib model until the crack width reaches 0.8mm. Also, for specimens with stirrup good agreement is obtained from 0.6mm as crack width.

3.2 Influence of stirrup on the empirical coefficient

The bond deterioration due to corrosion is closely related to the confinements provided by concrete cover and stirrups. The fitted coefficient a and b are plotted against the stirrup ratio p_w in Fig. 5. With the increase of stirrup index (in %), a and b decrease. Assuming an exponential decreasing, a and b can be evaluated by the following empirical equations:

$$a = 1.6e^{-0.8p_w} \quad (4)$$

$$b = 0.4e^{-1.3p_w} \quad (5)$$

Substituting Eq. (4) and Eq. (5) into Eq. (3), the empirical formulas for the bond strength of specimens with induced crack can be expressed as follows:

$$RB = 1 - 1.6e^{-0.8p_w}\left(1 - \left(e^{0.4e^{-1.3p_w}\cdot w_{cR}}\right)\right) \quad 6)$$

3.3 Experimental validation of the proposed formulas

To validate the effectiveness of the proposed formula, the predicted bond strength in cracked concrete is compared with the experimental data available in the literature [3]. In these specimens with different p_w values (0.33% to 1.33%), only the main rebars were electrically corroded.

Fig.6 shows the comparison between experimental and calculated RB by formula (Eq.6). The predicted values show a good agreement with experimental ones for some specimens.

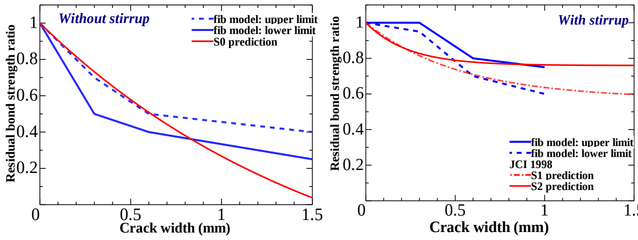

Fig. 4 Formulas compared with previous models

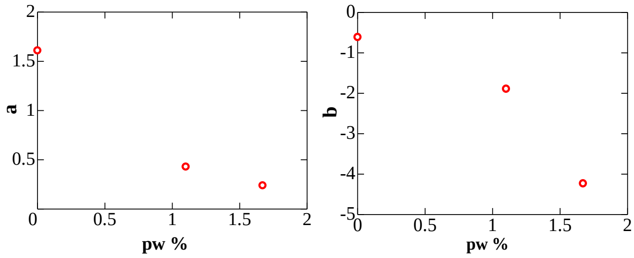

Fig.5 Influence of p_w on coef a, b

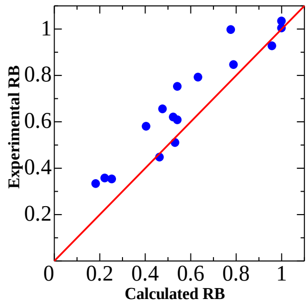

Fig. 6 Experimental and calculated results comparison

But others show a slightly higher value of experimental RB. This indicates that the change in rebar shape or rust accumulation can be beneficial for bond degradation.

4. CONCLUSIONS

To investigate the effect of stirrup on bond degradation of cracked concrete, pull-out bond test was conducted. Empirical formulas of the bond strength deterioration with crack width as the main variable, have been proposed. These prediction formulas give a good correlation when compared to the available literature.

REFERENCES

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[3] Lin et al. Bond strength evaluation of corroded steel bars via the surface crack width induced by reinforcement steel corrosion, Engineering Structures, 152(1), 506-522, 2017.