EFFECT OF ANALYTICAL AND EXPERIMENTAL BOND SLIP CURVES ON SHEAR BEHAVIOR OF CIRCULAR RC BEAMS STRENGTHENING BY CFRP BARS

Kobe University Student Member ○Mamy A. RABOTOVAO
Kobe University Regular Member Tomohiro Miki

1. Introduction

In an aggressive environment, the lifespan of steel reinforced concrete members is limited due to the corrosion of steel reinforcements. Fiber reinforced polymer (FRP) rebars can be considered as an alternative solution to that matter since their non-corrosiveness, high tensile strength, lightness, fatigue resistance and small creep deformation. However the force transfer between FRP rebars and concrete is still ambiguous since the lack of research regarding the bond slip between FRP bars and concrete. This article presents the effect of analytical bond slip curves which take into consideration the deformed shape of CFRP bars, on the behavior of Circular cross-sectionnal CFRP reinforced concrete (RC) beams.

2. Analytical program

(1) Representative model for pull-out test

This representative model for pull-out test, shown in Fig.1, is targeted for experimental results performed by Solyum et al. (2020). It takes into consideration two different shape of deformed CFRP rebars namely ribbed bar and dented bar, as shown in Fig.1. For the FE analysis, CFRP bar is modeled with an elastic model characterized by a moduls of elasticity of 141,000 N/mm^2. Regarding constituve models for concrete, an ideal models are considered for both compressive behavior and tensile behavior. The compressive strength and tensile strength of concrete are 36 N/mm^2 and 2.5 N/mm^2 respectively. Based on parametric analysis, the shear stiffness and normal stiffness moduli of the interface element between concrete and CFRP bar are 0.005 N/mm^3 and 5 N/mm^3, respectively.

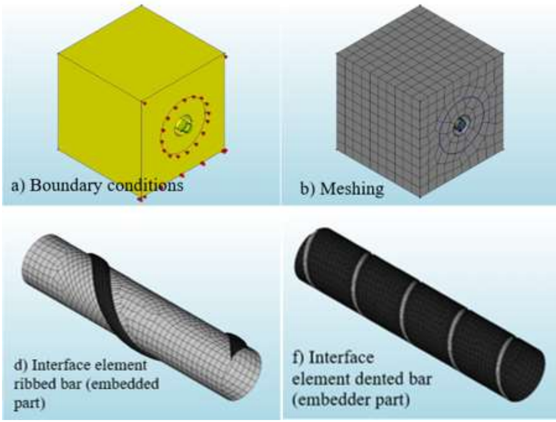

Figure 1: Representative model for pull-out test

(2) Circular cross sectionnal CFRP RC beam under shear

This part of the analysis, shown in Fig.2, consists of circular beams reinforced with CFRP bars. Each specimen was 3000 mm in length with a diameter of 500 mm. Moreover, each specimen is simply supported over a length span of 2400 mm. The parabollic model with a compressive strength of 38 N/mm^2 is considered for the compresive behavior of concrete. on the other hand, the tensile behavior of concrete is represented with the Hordjick model. The tensile strength of concrete was 2.5 N/mm^2 and the tensile fracture enrgy was 0.1 N/mm. Regarding the CFRP bars and spirals, the linear elastic model was used.

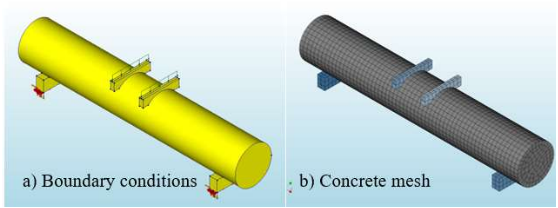

Figure 2: CFRP RC beam under shear

3. Results

(1) Bond slip curves

Fig.3 presents different bond slip curves used for the analysis. Analytical bond slip curves of dented bar and ribbed bar are characterized by a uniform post-peak curve in both cases. However, the initial stiffnesses of those analytical bond slip curves are 336 N/mm^3 and 13 N/mm^3 for ribbed model and dented model respectively. Their bond strengths are 8.27 N/mm^2 and 7.90 N/mm^2 respectively. In contrast to those analytical bond slip curves, a fitted bond slip curve of sand coating surface based on experimental results is also considered. It is characterized by an initial stiffness of 88 N/mm^3 and a bond strength of 12.865 N/mm^2. Moreover, this sand coating bond slip curve presents a post softening part.

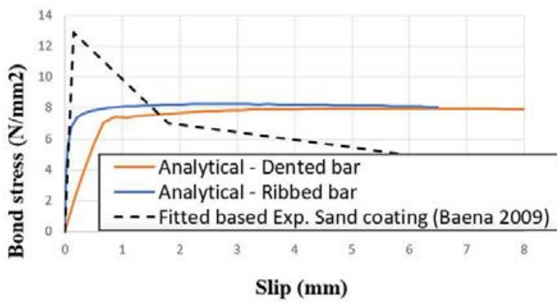

Figure 3: Bond slip curves

Apart from those three models, a perfect bond model is also associated to one specimen. A perfect bond model is defined as no

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Contact address: 1-1 Rokkodai, Nada, Kobe 657-8501, Japan, Tel: +81-78-803-6094

slip occurs between CFRP reinforcing bars and concrete. Somehow those materials are merged perfectly and adopted the same behavior.

(2) Load carrying capacity of CFRP RC beams

As shown in Fig. 4, in case of BC100, analytical specimens present a lower load carrying capacity at a larger deflection than experimental specimen. This leads to a lower flexural stiffnesses of those latter ones.

Perfect bond model and sand coated bond model lead to the highest load carrying capacity among analytical specimens. On the other hand, ribbed model presents a little drop in term of load carrying capacity if compared to Perfect and sand coated bond models. And dented model leads to the lowest load carrying capacity among all analytical specimens.

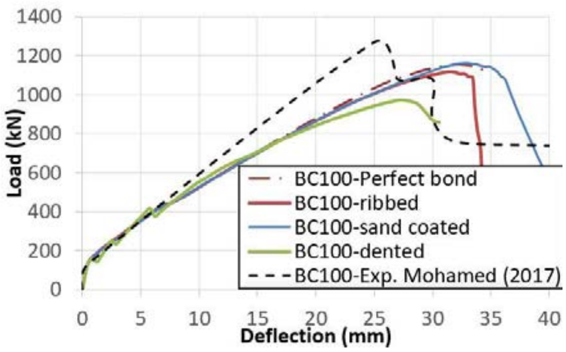

Figure 4: Effect of bond slip curves on the load carrying capacity of BC100

4. Discussion on the cracking pattern of each specimen at Pmax

Fig. 5 shows the different cracking pattern of each specimen at Pmax for BC100. Ecw1 is the maximum crack width in the principal direction.

Ribbed bar and perfect bond models present similar cracking patterns expect the fact that diagonal cracks are more concentrated for perfect bond model. However, ribbed bond model shows very few flexural cracks if compared to ribbed model and perfect model, leading to steep diagonal crack. This steep diagonal crack can be the effect of a lower initial stiffness leading to larger slip and impairing the contribution of reinforcements leading to a brittle failure.

Sand coated bond model presents the highest bond strength, its cracking pattern show some flexural cracks and some concentrated diagonal cracks. However, if compared to ribbed model Ecw1 of sand coated model is lower. It confirms that this specimen shows more resistance than other specimens except perfect bond RC beams. That can be the effect of bond strength which is somehow dominant than initial stiffness regarding the force transfer between concrete and reinforcements.

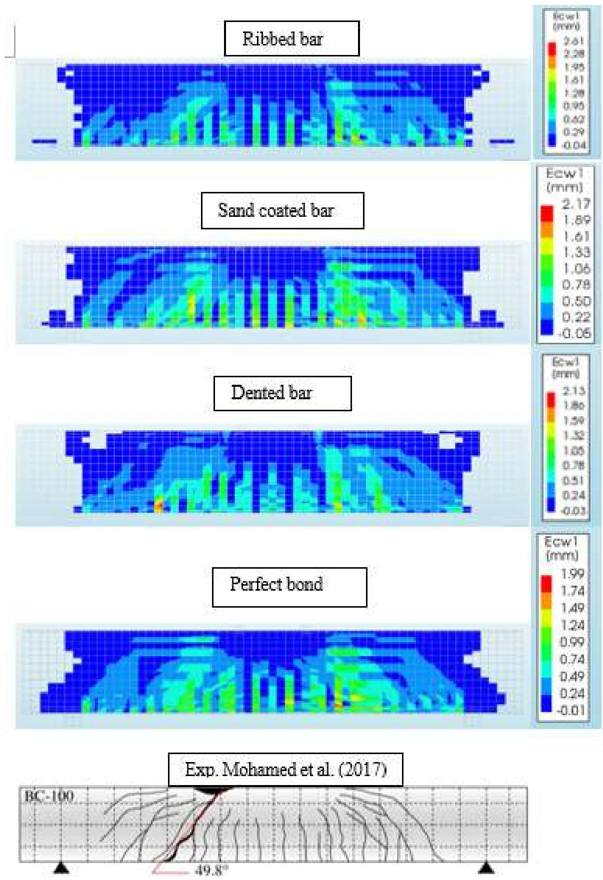

Figure 5: Cracking patterns for BC100 - Pmax

5. Conclusions

The main finding of this investigation can be summarized as follows:

(1) Deformed surface characteristics leads to bond slip curves with a uniform post-peak. However, post peak curve does not affect the affect the behavior of CFRP RC beams. Bond strength and initial stiffness are the prevalent parameters that decide the strength of CFRP RC beams.

(2) Regarding the force transfer between concrete and reinforcements which ensure the resistance of a specimen after apparition of diagonal cracks, bond strength is somehow dominant over initial stiffness.

(3) Adjustment is needed regarding the normal and shear stiffnesses moduli of analytical bond slip curves since it tends to underestimate totally the load bearing capacity of CFRP RC beams. Moreover, those shear and normal stiffnesses moduli lead when associated with the surface characteristics of CFRP bars lead to a low bond strength if compared to experimental results.

References

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