第V部門 Effect of different bond slip curves on the behavior of Circular Cross-Sectional RC Beams Strengthening by CFRP Under Shear

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1. Introduction

The lifespan of conventional steel reinforced concrete members in an aggressive environment 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 a lack of research regarding the bond-slip relation between FRP bars and concrete. This article presents the effect of analytical bond-slip curves which take into consideration the deformed shape of carbon FRP (CFRP) bars, on the behavior of circular cross-sectional CFRP reinforced concrete (RC) beams.

2. Analytical program

(1) Representative model for pull-out test

Presented in Fig.1, the pull-out specimen consists of a cubic mould with an edge of 150 mm . The embedment length was taken as 5ø (ø-nominal diameter of CFRP bar). CFRP bar was modeled with an elastic model characterized by a moduls of elasticity of 141 GPa. Regarding constitutive models for concrete, ideal models were considered for both compressive and tensile behaviors with a Young's modulus of 30 GPa. The interface between is modeled as the interface element with a fine mesh discretization. The mesh size of the ribbed and dented part was 0.5 mm, while that of the smooth part was 1.5 mm of the interface. Based on several parametric analysis, the shear stiffness and normal stiffness moduli of the interface element between concrete and CFRP bar were set as 5 N/mm^3 and 0.005 N/mm^3, respectively.

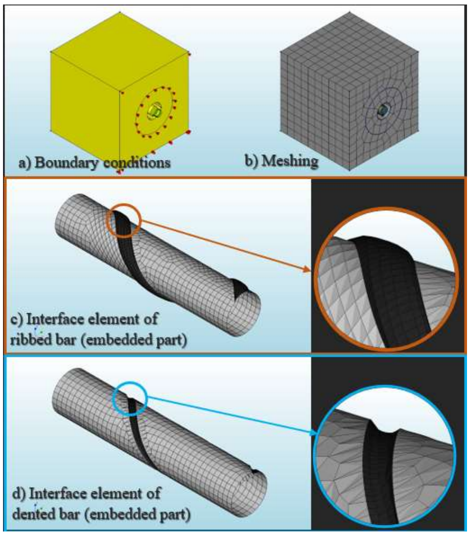

Fig.1: Representative model for pull-out test

(2) Circular cross sectionnal CFRP RC beam under shear

This part of the analysis consists of circular beams reinforced with CFRP bars as shown in Fig.2. Each specimen was 3000 mm in length with a diameter of 500 mm of the cross section. The elemental size of concrete was 50 mm. The bondslip interface between concrete and rebar was modeled as a line interface element characterized by a shear stiffness and normal stiffness moduli. The shear stiffness modulus was taken as the initial stiffness of bondslip curves provided by previous analysis, and the normal stiffness was taken as thousand times the shear stiffness modulus.

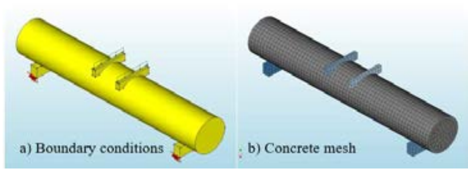

Fig.2: Model for CFRP RC beam under shear

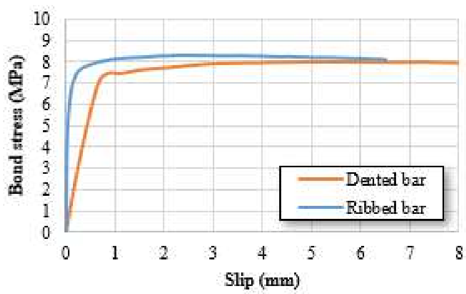

Fig.3: Analytical bond slip curves

The parabolic model with a compressive strength of 38 N/mm^2 was considered for the compresive behavior of concrete, while the Hordjick model was used for concrete in tesnsion. The tensile strength and the tensile fracture energy of concrete were set as 2.5 N/mm^2 and 0.1 N/mm, respectively. The CFRP rebar and spiral were represented with an elastic model where elastic

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moduli were 141 GPa and 124 GPa for rebar and spirals, respectively.

3. Results

(1) Analytical bond slip curves

Fig.3 presents the effect of the two different shapes of deformed CFRP bar on the bond slip between concrete and CFRP rebar with a diameter of 16 mm. It is observed that the surface characteristics of CFRP bar affect mainly the initial stiffness of the bond slip curves. The initial stiffnesses of those bond slip curves are 336 N/mm^3 and 13 N/mm^3 for ribbed model and dented model respectively.

(2) Load carrying capacity of CFRP RC beams

In the case of specimen with a spiral spacing of 100 mm or BC100, analytical results present a lower load-carrying capacity at a larger deflection than the experimental specimen as shown in Fig.4. This leads to lower flexural stiffness of those latter ones. On the other hand, the specimen with a ribbed bond model presents a better strength performance than the specimen with the dented model.

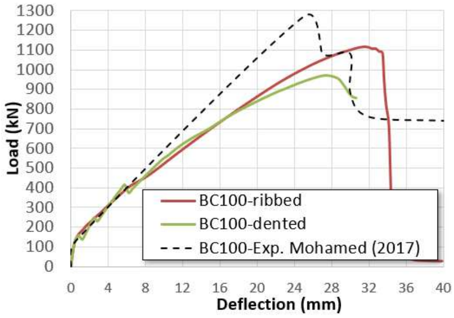

Fig.4: Effect of bond slip curves on the load carrying capacity of BC100

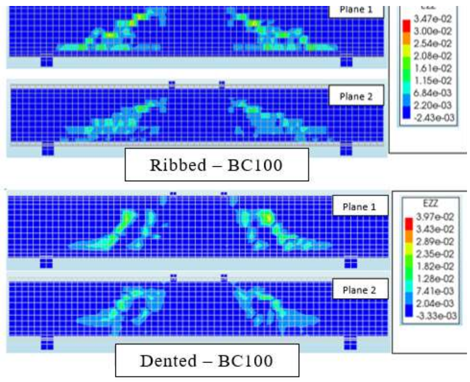

Fig.5: Internal strain distribution of concrete for BC100

4. Discussion on Internal strain distribution of concrete

Fig.5 shows the effect of the different bond models on the internal strain distribution of concrete in the case of BC 100. The ribbed model leads to an internal strain distribution of concrete EZZ which is widely distributed in the shear span of the beam. The internal strain distribution starts at the support point and increased gradually towards the loading point, creating a triangle-shaped area of the internal strain distribution. This shape is observed at the two different section planes namely plane 1 which is the middle axial section of the beam and plane 2 which is a vertical section of the beam located at D/4.

The dented bond model leads to a triangle shape distribution concentrated in the middle of the shear span. Moreover, a line-shaped internal strain distribution is clearly observed in the middle of the shear span. The dented model leads to a higher tensile strain of 0.039 as compared to the ribbed model's tensile strain of 0.034. This difference in internal strain distribution explains the higher load-carrying capacity of specimen with the ribbed model. This is because the larger area of concrete contributes to the resistance of the specimen.

5. Conclusions

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

(1) Among the two different surface characteristics (dented and ribbed surfaces), the ribbed surface characteristics present the highest bond strength and initial stiffness. It provides a better force transfer than the dented model.

(2) The surface characteristics of longitudinal reinforcements decide the ability of CFRP RC beams to sustain high loading. The ribbed model results in better performance since its better force transfer leads to a larger area of concrete contributing to the strength of the specimen under loading. On the other hand, the specimen with the dented model failed at a lower loading and present steep diagonal cracks.

References

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2) Mohamed HM, Ali AH, Benmokrane B. (2017) Behavior of circular concrete members reinforced with carbon-FRP bars and spirals under shear. J Compos Construct, 21(2): 04016090.