INFLUENCE OF BOND PROPERTY BETWEEN CFRP BARS AND CONCRETE ON OVERALL BEHAVIOR OF CIRCULAR RC BEAMS STRENGTHENED BY CFRP UNDER SHEAR

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1. Introduction

Circular cross-sectional reinforced concrete (RC) members are often used in bridge foundations and a marine infrastructure systems as piers and/or piles because they are easy to build and provide equal strength characteristics in all directions under external lateral loads. Fiber-reinforced polymers (FRP) are considered as the modern material owing to its characteristics such as high tensile strength, lightness and corrosion resistant properties. Previous studies introduced the shear performances of circular cross-sectional RC beams with different reinforcement type and shear reinforcement ratio of carbon FRP (CFRP) strengthening. However, no research seems to have investigated the effect of bond propreties between CFRP bars and concrete, on the overall behavior of CFRP RC beam. This research aimed to evaluate an influence of bond propreties on the shear strength of RC beams strengthening by CFRP bars and sprirals by comparing experimental and analytical results.

2. Analytical model

For the analysis, a 3D FE model for Mohamed et al. (2017) specimens was created with DIANA10.3. The specimens were 500 mm in diameter and 3000 mm in length. As shown in Fig. 1, each model was divided in mesh with a grid size of 50 mm. Moreover, the specimens were simply supported over 2400 mm span and the load is applied through two loading plates. The concrete material was modeled with a total strain-based crack model, a compressive strength of 36 N/mm^2 and an elastic modulus of 28000 N/mm^2. Regarding the CFRP bars and spirals, the linear elastic model was used.

The analysis is controlled by displacement with a step of 0.2 mm. As an iterative procedure, the Regular Newton-Raphson method is used, with an energy convergence criterion of 0.0001 and the maximum number of iterations was set at 30 to reach an average convergence rate of 95%.

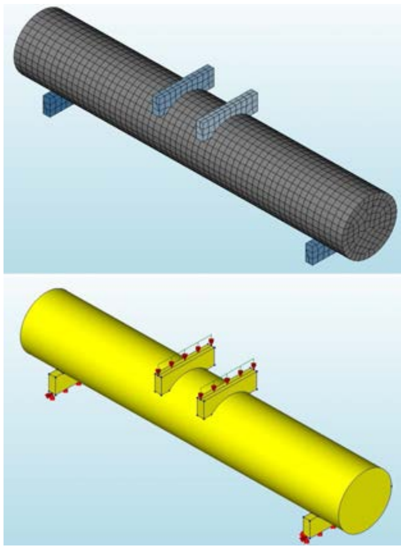

Figure 1: Analytical model

3. Sensitivity analysis of bond model parameters

The bond property between CFRP rebars and concrete is closely related to the behavior of the specimen in shear. This research focuses on how parameters of different bond models such as the texturing of CFRP rebars, the initial stiffness and the bond strength affect the performance of the specimens under shear, as shown in Fig.2.

Figure 3 shows the effect of bond models' parameters on the load carrying capacity of the specimen BC150.

- The sand coated bond model presents the highest peak load of 1203 kN.
- Compared to the specimen with a sand coated bond model, the specimen with a smoothed surface shows a lower peak load. This phenomenon is due the loss of friction between CFRP rebars and concrete.
- The perfect bond model neglects totally the contribution of the longitudinal reinforcements.

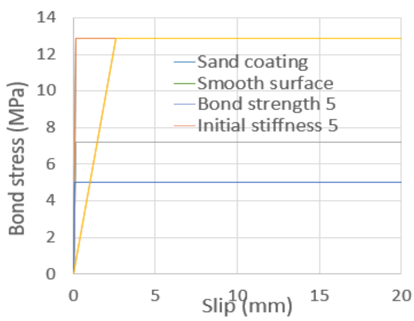

Figure 2: Example of bond models

Keywords: CFRP, bond model, bond property, Circular cross-sectional reinforced concrete beams, Shear
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4. Discussion on internal strain distribution of concrete

Figure 4 shows the effect of the different bond model on the internal concrete strain distribution at the middle axial section of specimens. For the specimen BC100, both sand coated bond model and smooth surface bond model almost present the same strain distribution. However, the smooth surface bond model favorizes a higher tensile stress next to the supports of the beam. This phenomenon can be attributed to the lack of friction between the smooth surfaced CFRP rebars and concrete, which hindrances the transmission of shear stress from the concrete to the longitudinal reinforcements and stirrups.

The comparison between the sand coated bond model, which has an initial shear stiffness of 200, and the specimen with initial shear stiffness 5, it was observed that a smaller initial shear stress tends to decrease the tensile strain of the concrete next to the supports. This can be explained by the fact that a higher initial shear stiffness, requires a smaller slip displacement between CFRP rebars and concrete, leading to a more concentrated tensile strain in the region of supports.

On the other hand, a comparison between specimen with sand coated bond model, which has a bond strength of 12.865 MPa, and a specimen with a bond strength of 5 MPa, showed that an increase in the bond strength reduces considerably the tensile strain in the shear-span of the beam.

The BC specimen (without stirrups) show a narrow strain distribution joining the support and the loading point, if compared to specimen BC100. This difference is representative of the contribution of stirrups in withstanding shear stresses and preventing shear failure.

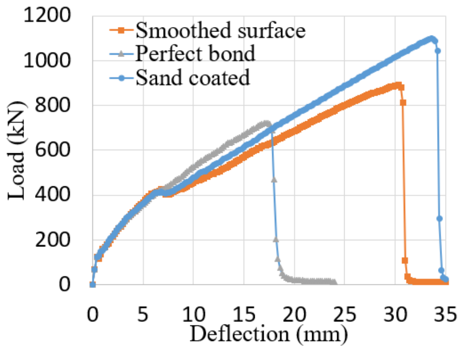

Figure 3: Load - deflection curve of BC150 with different bond models

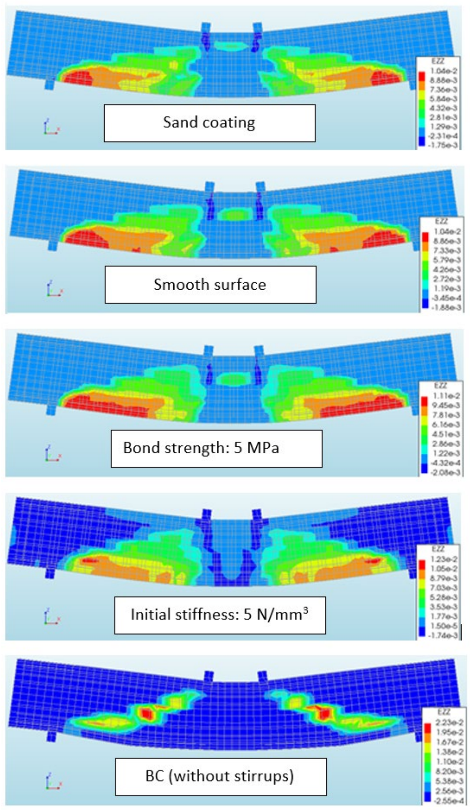

Figure 4: Effect of bond model on the internal concrete strain distribution at the middle axial section

5. Conclusions

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

1) Sand-coated bond model is more representative of the friction between CFRP rebars and concrete. In other words, the sand-coated bond model enhances the shear strength of the beam by allowing the distribution of tension shear cracks and tensile stresses through the CFRP rebars.
2) An increase in the initial shear stiffness tend to create more tensile strain next to the support, favorizing the opening of diagonal cracks at an early stage of the analysis.
3) Regardless of the bond model, modeling the stirrups as spirals is representative of their contribution in preventing shear failure of the specimen.
4) Regarding the load carrying capacity, the perfect bond model neglects completely the contribution of the longitudinal reinforcements leading to a failure at an early stage of the analysis. Whereas, the use of the sand coated bond model tends to improve the performance in shear of the specimen by increasing its load carrying capacity.

References

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