第V部門　Nonlinear Analysis of Circular Cross-Sectional RC Beams Strengthening by CFRP Under Shear

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1. Introduction

Circular cross-sectionnal 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 specimen 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%.

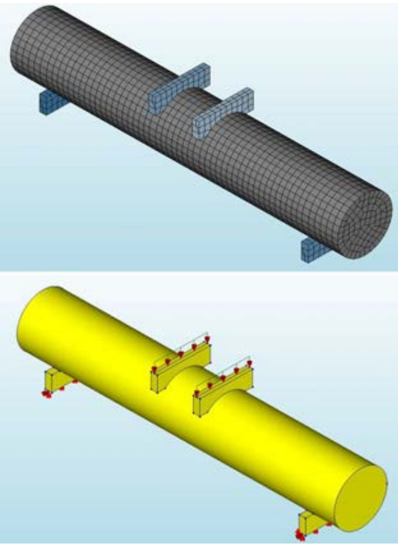

Figure 1: Analytical model

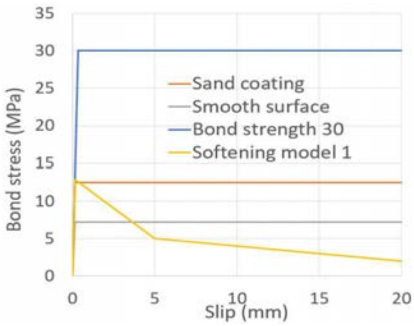

Figure 2: Example of bond models

3. Sensitivity analysis of Bond Model parameters

The overall behavior in shear of circular CFRP RC beam was observed under different bond models. This research focused mainly on how the bond properties between CFRP rebars and concrete affect the load carrying capacity, load-deflection relationship, cracking patterns and concrete strain distribution of CFRP RC beam. Different parameters of these bond models including different surface conditions, different initial stiffness and different post-peak softening curve were analyzed as shown in Fig.2.

- The bond model with low maximum shear stress will reduce the maximum load and stiffness of the specimen, while the bond model with high maximum shear stress will reduce the maximum load but increase the stiffness as shown in Fig.3.

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- The sand-coated model increase the load carrying capacity of the beam. After the apparition of the first diagonal crack, a reduce in stiffness is observed.

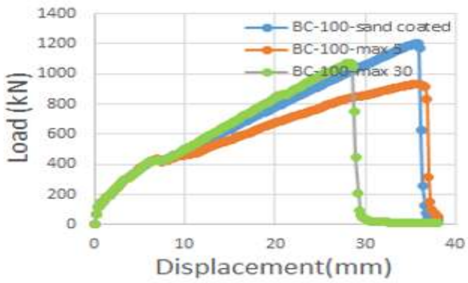

Figure 3: Load - deflection curve

4. Discussion on Internal strain distribution of concrete

Figure 4 shows the effect of the different bond model on the internal concrete strain distribution of concrete. The BC specimens (without stirrups) show a narrow strain distribution joining the support and the loading point, however BC200 show a wide strain distribution covering a large part of the midspan of the beam. This represents the ability of stirrups in withstanding the shear stresses and preventing shear failure.

Regarding the surface treatment, both sand coated bond model and smooth surface bond model present a wide strain distribution covering a large part of the midspan of the beam. The only difference is that, specimen with smooth surfaced bond model shows higher tensile strain. This phenomenon can be attributed to the lack of friction between the smooth surfaced CFRP rebars and concrete, which prevent the reinforcement from distributing the shear stress.

Specimen with initial shear stiffness 200 tends to increase the tensile strain of the concrete next to the supports. This can be explained by the fact that a higher initial stiffness, requires higher shear stress and a smaller slip displacement between CFRP rebars and concrete. Therefore, as the loading increase small slips occur next to the supports and the distribution of shear stress is more concentrated next to that region. In other words, diagonal cracks occur at an early stage for specimen with initial shear stiffness. On the other hand, an increase in the bond strength reduces considerably the tensile strain in the mid-span of the beam.

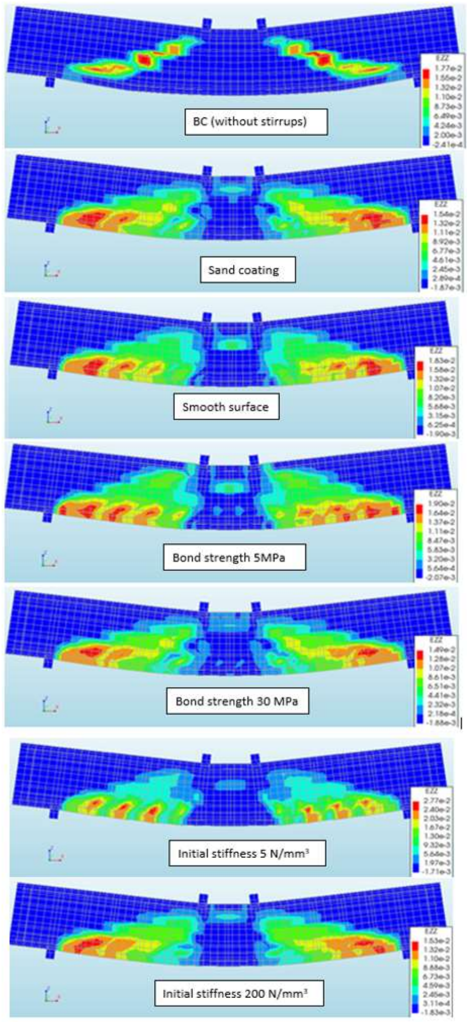

Figure 4: Effect of bond model on the internal concrete strain distribution at the middle axial section

5. Conclusions

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

1) Regardless of the bond model, the specimens without stirrups shows several shear cracks, however specimens with stirrups tend to show more flexural cracks. In other words, modeling the stirrups as spirals is representative of their contribution in preventing shear failure of the specimen.
2) 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.
3) An increase in the initial shear stiffness favorizes the opening of diagonal cracks at an early stage of the analysis.

References

1) 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.