Nonlinear Analysis for Shear Performance of Circular Cross-sectional RC Beams Reinforcing by Carbon Fiber Reinforced Polymer

Civil Engineering: Yan Haoran

Supervisor: Associate Prof. Tomohiro Miki

1. Introduction

Fiber-reinforced-polymer (FRP) bars are considered alternatives to conventional steel bars for reinforced concrete structures in severe environments. There are some experimental studies introducing the shear performances of circular cross-sectional carbon FRP (CFRP) RC beams with different reinforcement type, shear reinforcement ratio and sectional dimension. However, there are still rooms that influence shear performances not mentioned in the experimental study, such as the bond properties between the CFRP reinforcement and surrounding concrete. This study aims to investigate the following three points; 1. Reproduce the experiment of circular cross-sectional CFRP RC beams by carry out finite element analysis to evaluate the shear performance, 2. Comparing analytical results with experimental results in order to evaluate how bond properties affect the shear performance of circular cross-sectional CFRP RC beams, and 3. Evaluate the effect of the bond model with different parameters on the internal concrete strain distribution.

2. Analytical Model

The specimens used in this study were mainly those of Mohamed et al (2017). The section diameter of the specimens is 500 mm and the total length is 3000 mm. Figure 1 shows the finite element mesh of analytical model, the model is divided to grid by size of 50 mm. The RC specimen with circular section was modeled in three dimensions and the crack model based on total strain was used to simulate concrete with compression strength of 36 N/mm^2. For CFRP bars and spirals, the linear elastic model was used. The Von Mises model was used to model steel reinforcement with yield strength of 460 N/mm^2.

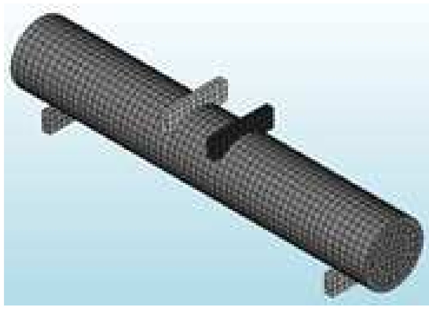

Fig. 1 Analytical model

The shear performance of the circular CFRP reinforced concrete beams was evaluated by finite element analysis. The load in analysis has been set as displacement control with step of 0.2 mm. The Newton-Raphson method is used as the iterative calculation method.

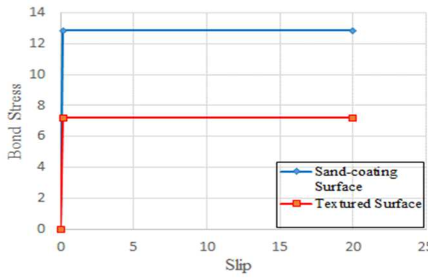

Fig. 2 Bond model with different surface condition

3. Sensitivity Analysis of Bond Model Parameters

The sensitivity analysis for the bond model parameters was performed. Through comparing analytical results with experimental results, we evaluate how bond properties affect the shear performance of circular cross-sectional CFRP RC beams. This research focused on the analytical results of shear performance such as load carrying capacity, load-displacement relationship, crack patterns, and concrete strain distribution.

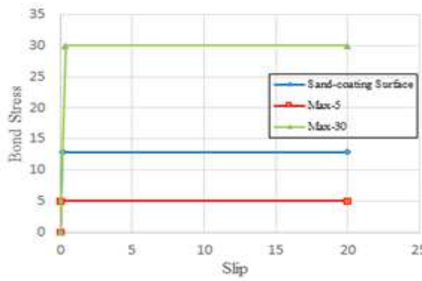

Fig. 3 Bond model with different maximum bond stress

In the chapter 3, four series of bond property models were used for analysis, as shown in Fig. 2, 3, 4 and 5. The parameters of these bond models include different surface conditions, different maximum shear stress, different initial shear stiffness and different post-peak softening parts.

- The bond model with smooth surface in analysis, leading to the decrease of maximum load and stiffness of the specimens. As the smooth surface bond model shows larger relative bond slip compare with the sand-coated bond

Keywords：Nonlinear analysis, Circular CFRP RC beams, Bond property model, Internal concrete strain distribution

model, the crack patterns and concrete strain distribution show more obvious crack at the area where bond slip is occurred.

- 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.
- The bond model with low initial shear stiffness results in a soft load-displacement stiffness after the formation of diagonal crack.

4. Discussion on Internal Strain Distribution of Concrete

In this research, the analytical results of three vertical sections at different positions are used to evaluate the internal strain distribution of concrete. The results of different bond models are compared. Through the comparison, the effect of the bond model with different parameters on the internal concrete strain distribution of circular cross sectional CFRP RC beams under the same load level is evaluated.

For the bond models with different parameters, the analytical results indicate that the main difference in the internal concrete strain distribution is the maximum value of strain. The analytical results of all specimens indicate that the maximum value of internal concrete strain corresponding to the cross section decreases with the decrease of the distance from the cross section to the surface.

5. Conclusion

1) The bond property model of CFRP bars has a great effect on the shear performance of circular cross-sectional CFRP RC beams. The analytical results indicate that the maximum load and the displacement at which the maximum load of the specimens with shear reinforcement is reached are significantly increased when the sand-coated bond model is used. It can be concluded that the contribution of shear reinforcement to load carrying capacity can be reproduced by using appropriate bond model in the analysis.
2) The analytical results of the crack patterns and the concrete strain distribution show more obvious diagonal shear cracks with sand-coated bond model is used. It is indicated that the bond model can make the specimens tend to fail with diagonal tensile failure.
3) The bond models with smooth surface condition, low maximum shear stress and low shear stiffness will show a large maximum value of the internal concrete strain. However, for the case that the specimen BC with low shear stiffness bond model, the maximum value of internal concrete strain is smaller than that of the high shear stiffness bond model.

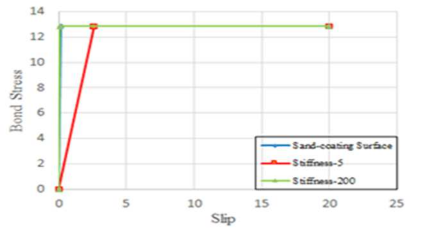

Fig. 4 Bond model with different initial shear stiffness

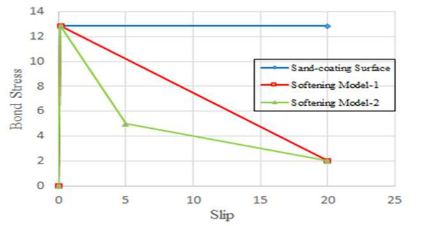

Fig. 5 Bond model with different softening parts

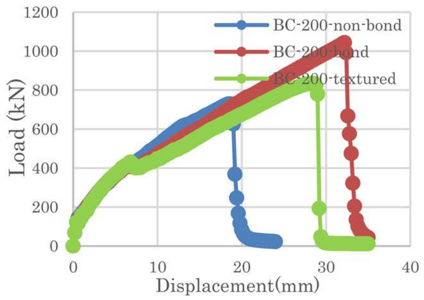

Fig. 6 Load-displacement relationship

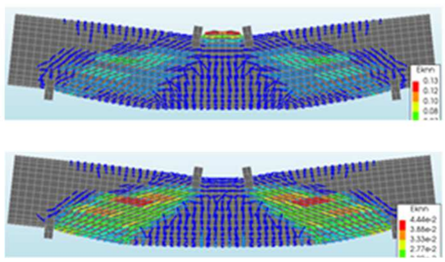
Fig. 7 Cracking patterns

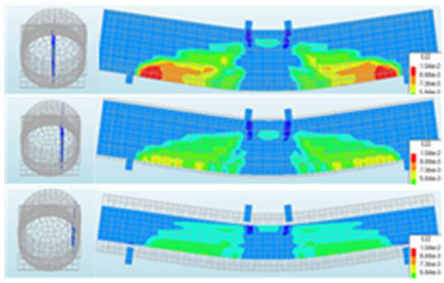
Fig. 8 Internal concrete strain distribution

4) As the decrease of the distance from the cross section to the surface of specimen, the distance between the center of the cross section and the longitudinal reinforcement of top and bottom side also decreases. This seems to increase the resistance during the formation of diagonal crack, leading to the decrease in the maximum value of internal concrete strain.

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.