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Title(English)	ESTIMATION OF SHEAR CAPACITY OF SLENDER AND SHORT REINFORCED CONCRETE BEAMS WITH STEEL FIBER CALCULATED BASED ON FAILURE MECHANISMS
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Estimation of shear capacity of slender and short reinforced concrete beams with steel fiber calculated based on failure mechanisms

(鋼繊維で補強された鉄筋コンクリートスレンダービームおよびショートビームのせん断耐荷力の破壊メカニズムに基づく推定)

Concrete is a widely famous construction material in the world that can be formed into any shape and gives a high compressive strength but has a low tensile resistance. Steel fiber reinforced concrete (SFRC) is a concrete mixing with steel fiber to improve concrete tensile resistance. This research aims to estimate the shear capacity of slender and short reinforced concrete beams with steel fiber (RSF beams). Four-point bending tests of RSF slender and short beams were conducted to investigate their shear failure mechanisms. The estimation methods for the shear capacities were proposed based on the failure mechanisms. The estimation for RSF slender beams was based on the residual tensile stress perpendicular to the surface of critical diagonal crack and the angle of critical diagonal crack. In the case of RSF short beams, digital image correlation (DIC) was utilized to determine the width of compressive strut necessary for strut-tie model. Finally, the proposed methods were verified with the experimental data including the literature.

Chapter 1 introduces background, objectives, and outline of this research. The background of RC and RSF beams were included. The objectives were described with details of experiments. The main objectives of this study are to investigate the shear capacity of RSF slender and short beams and to propose the simple and accurate estimation methods for the shear capacities. The outline includes the content of each chapter. There are totally 7 chapters, including the introduction, literature review, experiments and discussions, and conclusions.

Chapter 2 describes the literature review from previous researches. The background of concrete, SFRC, shear capacity of RC and RSF beams, and DIC are shown in this chapter.

Chapter 3 illustrates the experimental program of RSF slender beams. At first, three-point bending tests of SFRC notched beams were conducted in order to investigate the tension softening behavior of SFRC. The parameters were concrete compressive strength, shape of steel fiber, and volume fraction of steel fiber. The load-mid-span displacement curves, fracture

energy, and tension softening curves were obtained. It was found that the shape of hooked-end of steel fiber has a more significant effect in high strength SFRC than that of normal strength SFRC. Then, the four-point bending of RSF slender beams were conducted. RSF slender beams were fabricated with various concrete compressive strength, volume fraction of steel fiber, and stirrup ratio. The concrete compressive strength has a significant effect on shear capacity of RSF slender beams. And the peak load was increased in high strength RSF beams due to the increases in bonding and bridging effect in high strength SFRC according to the results of three-point bending tests of notched beams.

After the experimental program of RSF slender beams, in Chapter 4, the estimation of the shear capacity of RSF slender beams was proposed according to shear failure occurred along the critical diagonal crack. The data from various background was used which has different materials, geometry, mechanism, etc. The range of parameters were expanded for the safety of an estimation. The estimation is based on the estimations of residual tensile stress along the critical diagonal crack and the angle of the critical diagonal crack. Various parameters were investigated which are concrete compressive strength, volume fraction of steel fiber, shear span ratio, and tensile reinforcement ratio. Finally, the estimation of the shear capacity of RSF slender beams was proposed. The proposed method was compared with the equations from previous researches. The proposed method gave the highest accuracy with the lowest variation compared to the other equations.

Chapter 5 illustrates the experimental program of RSF short beams. Four-point bending tests and DIC were applied. The aim is to investigate the shear capacity and compressive strut of RSF short beams. DIC was used to analyze the minimum principal strain (\mathcal{E}_2) in compression for the investigation of the width of compressive strut. The width of compressive strut will be used for the estimation of the shear capacity of RSF short beams. The parameters were concrete compressive strength, volume fraction of steel fiber, and shear span ratio. The results showed that the increase in volume fraction of steel fiber is more significant in normal strength RSF short beams than that of high strength RSF short beams in terms of the shear capacity. Moreover, the shear span ratio affected the shear capacity of RSF short beams significantly especially in high strength cases.

In Chapter 6, after the four-point bending tests of RSF short beams were conducted and the data from DIC was obtained, the shear capacity of RSF short beams was proposed. This chapter shows the attempt to use \mathcal{E}_2 captured directly by DIC to determine the width of compressive strut for the estimation of the shear capacity of RSF short beams. The results showed that the shear span ratio has a significant effect on the width of compressive strut followed by concrete compressive strength. In the case of volume fraction of steel fiber, the effect was likely to be small. \mathcal{E}_2 was concentrated near the loading point and showed the distribution similar to the parabolic shape which was used to determine the width of compressive strut. The compressive strut can be used for the estimation of the shear capacity of RSF short beams. This also shows that DIC can be used to estimate the width of compressive strut.

Chapter 7 concludes the experimental results and findings in this research. The conclusions and recommendations are described. This research estimates the shear capacity of RSF slender beams and RSF short beams which provides the further understanding and new information for the design of RSF beams.