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Title：

Behavior of Reinforced Concrete Beams Strengthened by Prestressed UFC Panel in Flexure and Shear

(プレストレスト UFC パネルによって補強された RC はりの曲げ及びせん断挙動)

Content of the Dissertation:

The new application of UFC (Ultra high strength fiber reinforced concrete) for strengthening to RC beams is proposed in this study. It is named as the prestressed UFC panel. UFC is a well-known high performance in strength, durability, and ductility. However, it has low tensile performance comparing to its compressive strength, because of its high cementitious material. In order to increase the tensile performance of UFC and control the crack opening, the idea to apply prestressing force in to the UFC panel is introduced. The outcome of this new method is expected to bring about the high strengthening performance and induce better durability to RC beams. There are two main objectives, which are the investigations of strengthening effect in shear and flexure to RC beams by using prestressed UFC panel. In addition, the evaluation methods for flexural and shear capacity of strengthening system also proposed in this study.

Chapter 1 introduces the research background and research motivation in this study. The idea to create the new strengthening method by using prestressed UFC panel is indicated. The scopes of research, outline of dissertation are summarized in this chapter.

Chapter 2 reviews the basic knowledge of UFC and other strengthening methods. The innovation of UFC in various applications is also presented including the studies of UFC development in the strengthening utilization.

Chapter 3 focuses on the flexural strengthening performance of the RC beams strengthened by pre-tensioned UFC panel. The prestressing force was horizontally introduced into the panel for

enhancing the flexural performance before strengthening on the bottom side of RC beam. The bonding between a RC beam and a pre-tensioned UFC panel was supplemented by undercut anchor bolts. Due to the new composite system of pre-tensioned UFC panel, the exact prestressing level in the panel needed to be verified firstly. Based on experimental results, the satisfied prestressing level were obtained by considering the loss compensations from elastic shortening loss and shrinkage loss. In second part, the experimental results of RC beams strengthening by pre-tensioned UFC panel showed that the panel enhanced the flexural capacity of RC beams more than twice, and the load significantly increased with higher amount of PC strands in the UFC panel. The higher prestressing level affected the delay of crack opening and caused the lower number of crack. Besides, the panel could recover the loading capacity of 70% of damaged RC beam.

Chapter 4, the failure mechanism of RC beams strengthened by pre-tensioned UFC panel is discussed in this chapter. Afterwards, the evaluation method for flexural capacity of strengthened beams was proposed. The strain compatibility along the cross section in the mid span was achieved by using the undercut anchor bolt as validated by the calculated and experimental results. The conventional method for flexural section analysis has successfully applied for evaluating the flexural capacity of strengthened RC beams as the confirmation between the calculations and experiments.

Chapter 5 focuses on the shear strengthening performance by post-tensioned UFC panel. As the utilization of stirrup in RC beams for restraining the diagonal crack, the comparative idea has been applied by introducing the prestressing force to the UFC panel in vertical. Hence, the bonded post-tensioning system should be adopted for discarding the problem of insufficient transfer length. The prestressing level in the UFC panel was directly confirmed by the average strains on prestressing rods. The results of RC beams strengthened by post-tensioned UFC panel are identified that the panel can improve the shear capacity of RC beams more than 1.5 times. The higher prestressing level influenced the delay of crack opening and yielding of stirrups in RC beams.

Chapter 6, the failure mechanism of shear strengthening by the post-tensioned UFC panel revealed that the compatibility can be achieved for a while by using bolts and nuts for anchoring system. However, the strengthening by post-tensioned UFC panel can provide high stiffness to RC beams and substantially resists the load even after all stirrups yielding in RC beams. The bridging

effect inside the UFC panel and the PC rods also prevent the brittle failure. Eventually, the evaluation of shear carried by post-tensioned UFC panel was proposed. Based on the crack pattern from experiments, the imaginary diagonal crack can be drawn and uses for evaluating shear carried by post-tensioned UFC panel. Consequently, the evaluation of shear carried by post-tensioned UFC panel is proposed by using the force equilibrium along the imaginary diagonal crack and the shear equation for UFC from the recent recommendation of JSCE. The effect of prestressing level is included in the diagonal angle. The recommended angle based on experiments was proposed in this study.

Finally, the findings in this research and the recommendations for further studies are concluded in **chapter 7** for further development of the new strengthening system by prestressed UFC panel.