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学位論文題名	SHEAR BEHAVIOR OF REINFORCED CONCRETE BEAMS STRENGTHENED WITH CFRP GRID (CFRP 格子筋で補強された RC 梁のせん断耐荷機構)
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【論文の内容の要旨】

Carbon Fibre Reinforced Polymer (CFRP) has been applied for strengthening concrete structures for several recent decades on over the world. CFRP grid has been proved that it is useful for the strengthening of bridge decks, tunnels, and beams. Numerous studies on CFRP grid have been conducted to examine the properties and take advantage of it. But there is almost no research on CFRP grid in analytical approach and detail investigation for the behavior of the material in a large structure. The objective of this thesis is to investigate the behavior of materials working in composite specimens and in shear-strengthened RC beams, and to study the shear strength of strengthened beam basing on the mechanical analysis. The doctoral thesis has been arranged in seven chapters with the main content is summarized as bellow:

Chapter 1 introduces the statement of the problem, the objectives, the significance as well as the organization of thesis.

Chapter 2 reviews the related studies and backgrounds of the issues be presented in the dissertation.

Chapter 3 is about the investigation of the capability of four materials: concrete, steel, CFRP grid, and mortar, working together in a strengthened structure. In the experiment, three concrete prisms (500 mm in length) are reinforced by different schemes of steel bars and/or CFRP (CR5, interval 50mm, section area 13.2 mm^2) grid in the axial direction. Specimen 1, the control one, with a square section (100 x 100 mm) of concrete, axially reinforced by rebars. Specimen 2 is reinforced by CFRP grid, and Specimen 3 is reinforced by both rebars and CFRP grid. The strengthened specimen 2 and 3 have the same dimensions (100 x 100 mm) as specimen 1, they were applied the axial tensile force until failure. According to the test results, good combination of four materials has been proved. Both strengthened specimens perform the very high bearing capacity comparing to the specimen 1. The behavior of reinforcing materials and the capability of CFRP grid strongly influenced by the bonding interface between concrete and mortar. In this study, although the bonding surfaces are repaired by an common method such as sandblasting (the roughness of surface after sandblasting is0.16 mm) and epoxy primer applying. In both specimens, the fracture still occurs at the bonding surface (the average shear stresses is 1.1 MPa), and CFRP grid only perfoms 76% of tensile strength. It is consider that, a better condition of surface roughness of more than 0.3 mm is necessary to make use the full capacity of CFRP grid.

Chapter 4 shows the effectiveness of CFRP grid in enhancing the shear capacity of RC beams under four-point bending test. Three large beams (200 x 500 x 2750 mm) were fabricated, which are same in the longitudinal reinforcement but different in transverse reinforcement. RC beam 1, the reference one, shear-strengthened by stirrup D10, RC beam 2 has stirrup D6 and CFRP CR8, and RC beam 3 has CFRP CR8 only. The cross-sectional area of reinforcing materials in RC beam 2 and RC beam 3 is equivalent to 120% and 75%, respectively, compared with the cross-sectional area of stirrups in RC beam 1. The result shows that CFRP grid and sprayed mortar could significantly improve the shear strengthening. RC beam 2 and RC beam 3 attains 10% higher and 10% lower of ultimate load comparing to RC beam 1. In general, the stiffness, ductility characteristic, and the cracking load of the strengthened RC beams are upgraded. When the load increased, variations of the stirrup strains and the CFRP grid strains at the same position in a strengthened RC beam have similar tendencies. After stirrups yielded and cracks developed, the behavior of CFRP grid and stirrups was considerably affected. In this application, CFRP grid didn't work at full capacity. The maximum stress of CFRP grid was 85% of the tensile strength. When calculating the shear strength of RC beam, the material factor for CFRP sheet in JSCE's guideline is 1.3, but for CFRP grid, this factor of 1.5 is proposed.

Chapter 5 studies the crack propagation of strengthened beams using CFRP grid. Acoustic emission (AE) sensors were attached on the two beams to monitor the development of cracks from the starting point till the ultimate state. The actual observed fact is combined with AE result to conclude the better understanding of the formation and propagation of diagonal cracks. According to the test data, micro-cracks occur and develop so early, even when the load is low and in the compressed area also. Chapter 5 also discusses the contribution of the horizontal and vertical bar of CFRP grid to the shear strength. The analysis indicates that the vertical component of CFRP grid plays the key role for shear strength contribution when comparing with the horizontal part. And horizontal CFRP bars work as anchors supporting the vertical movement between CFRP grid and spray mortar, especially, at the tip of the critical crack.

Chapter 6 presents the simplified formula to estimate the shear strength of strengthened RC beams based on the mechanical model. The problems are solved in two cases, RC beam shear-strengthened by CFRP grid and/without stirrups. The contribution to the shear strength is assumed to be the sum of the shear transferred by un-crack concrete compression zone, by stirrups, by CFRP grid, by residual tensile and frictional stresses of the critical crack. Applying the input data from the chapter 4, shear strength of RC beams can be calculated. These calculating values consist with the ultimate load from the test. Therefore, these formulas are applicable for estimating the shear strength of RC beams strengthened with CFRP grid.

Chapter 7 summaries all results and conclusions of the overall dissertation.