学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Characterizations of RC Beams Intervened by ICCP-SS System with Externally Bonded Carbon-FRCM Composites
(炭素 FRCM 複合材の外部接着により ICCP-SS 工法を施した RC はりの特性評価)

The development of alternative techniques for structural rehabilitation is of critical importance to the safety and sustainability of concrete structures suffered from corrosion of steel. The structural strengthening (SS) and impressed current cathodic protection (ICCP) are conventional methods to improve the safety and sustainability of corroded concrete structures at different perspectives. The SS can recover the load-carrying capacity of deteriorated concrete structures, while the ICCP can retard the corrosion of steel in concrete. Currently, a new strategy to integrate ICCP with SS has been proposed that is termed as ICCP-SS intervention system. Fabric reinforced cementitious matrix (FRCM) composites have emerged as an alternative reinforcement material to fiber reinforced polymer (FRP) composites for structural strengthening and rehabilitation. The carbon-FRCM composite can be adopted as the dual-functional material in the ICCP-SS system in which carbon-FRCM plays the role of reinforcement material in the SS system and of anode material in the ICCP system. To this end, an experimental program was undertaken to propel the application and optimization of the ICCP-SS intervention system.

This study aims to clarify the characterization of RC beams with externally bonded carbon-FRCM under static and cyclic loading. Two carbon-FRCM composites were considered for this research, one with multilayer carbon-FRCM (M/C-FRCM) intended for understanding the effectiveness of carbon-FRCM in strengthening beams and one with anodically polarized carbon-FRCM (AP/C-FRCM) for evaluating the mechanical degradation caused by anodic polarization in the ICCP on the strengthening characterization of RC beams. From the material perspective, the mechanical properties of both M/C-FRCM and AP/C-FRCM composites were also studied.

The first study investigates the static performance of RC beams with externally bonded M/C-FRCM. The static tensile tests of M/C-FRCM were conducted followed by the four-point bending tests of beams with externally bonded M/C-FRCM under static loading. Nine M/C-FRCM specimens were prepared for tensile tests and four beams were prepared for bending tests. The prediction model of apparent strain of carbon fabric (CF) mesh in the M/C-FRCM was proposed based on the global strain of carbon-FRCM in tension. The load-carrying capacity of beams with externally bonded M/C-FRCM improved that was largely dependent on the number of layers of CF mesh. An analytical study on the prediction formulas in flexure for RC beams with externally bonded carbon-FRCM was performed by using the model of apparent strain of CF mesh. Prediction results agreed well with the experimental results.

The second study explores the fatigue performance of RC beams with externally bonded M/C-FRCM.

The cyclic tensile tests of M/C-FRCM were performed and followed by the four-point bending tests of beams with externally bonded M/C-FRCM under cyclic loading. Nine M/C-FRCM specimens were prepared for cyclic tensile tests and twelve beams were prepared for cyclic bending tests. The fatigue life model and fatigue strength model of M/C-FRCM composites were proposed. The fatigue life performance of carbon-FRCM was compared with steels and CFRP composite materials. In addition, the fatigue stress limit of M/C-FRCM is recommended to 35 percent of the ultimate tensile strength. Carbon-FRCM composites significantly improve the fatigue performance of RC beams comparing with un-strengthened beams. The S-N curve for beams with externally bonded M/C-FRCM was proposed.

The third study examines the influence of anodic polarization on the static performance of RC beams with externally bonded AP/C-FRCM. An accelerated electrochemical (AC-EC) test was performed to introduce the anodic polarization to the carbon-FRCM making the AP/C-FRCM. Then, the static tensile tests of AP/C-FRCM were conducted and followed by the four-point bending tests of beams with externally bonded AP/C-FRCM under static loading. The tensile strength of carbon-FRCM reduced after suffering from anodic polarization. Effectiveness of carbon-FRCM suffering from anodic polarization in strengthening did not change prior to the yielding of steel, and weaken slightly as increasing the intensity of anodic polarization.

The last study detects the influence of anodic polarization on the fatigue performance of RC beams with externally bonded AP/C-FRCM. The identical AP/C-FRCM composites were adopted in this study. The cyclic tensile tests of AP/C-FRCM were performed and followed by the four-point bending tests of beams with externally bonded AP/C-FRCM under cyclic loading. The combined damage effect of the anodic polarization and cyclic loading caused acceleration of reduction of stiffness and decrease of fatigue life of carbon-FRCM. Based on the total experimental data, the S-N curve for beams with externally bonded fabric reinforcement by inorganic matrix was proposed.

Overall, the constitutive behavior of both M/C-FRCM and AP/C-FRCM were assessed by static tensile tests, and the fatigue degradation characterizations of both carbon-FRCM were evaluated through cyclic tensile tests. The fatigue life prediction models of M/C-FRCM and AP/C-FRCM were proposed based on the experimental data. The strengthening behaviors of RC beams with externally bonded M/C-FRCM and AP/C-FRCM were investigated under static and cyclic loading. The prediction formulas in flexure for RC beams with externally bonded carbon-FRCM was proposed. In addition, the fatigue life of strengthened beams was predicted well based on the proposed S-N curve. However, in the future studies, the further optimization design of carbon-FRCM is necessary to improve the mechanical behavior of itself and bond behavior with concrete substrate. Moreover, the fatigue performance of bond between carbon-FRCM and concrete needs to be investigated to improve the fatigue life prediction of RC beams with externally bonded carbon-FRCM composites.