学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Bond behavior and degradation mechanisms of Multi-functional Fabric Reinforced Cementitious Matrix (MFRCM) composites used for ICCP-SS
(ICCP-SS 工法に用いる多機能型繊維補強セメント系複合材料 (MFRCM) の付着挙動と劣化メカニズム)

A sustainable repair method, which is called ICCP-SS (impressed current cathodic protection and structural strengthening), has been proposed for deficient reinforced concrete structures caused by corrosion of steel in concrete. In implementation of the proposed method, a material that plays a dual functional role as structural reinforcement and impressed current anode should be used and applied on concrete substrate. A multifunctional fabric reinforced cementitious matrix (MFRCM) composite in which carbon fabric is incorporated is chosen as such a functional material. While the MFRCM composite works in an ICCP-SS system the embedded carbon fabric is subjected to not only anodic polarization that is related to electrochemistry but also the stress transferred from the surrounding matrix. Thus, there is a need to investigate the bond behavior and degradation of carbon fabric embedded in the matrix under anodic polarization, which helps gain an in-depth understanding on the global behavior of MFRCM composites and the effectiveness and efficiency of the ICCP-SS method.
A systematic research work was carried out, with a major aim at clarifying the bond behavior at the interface between carbon fabric and cementitious matrix within MFRCM composites under anodic polarization. At the beginning, the bond behavior of carbon yarn embedded in a range of cementitious matrices was investigated. The bond slip relationship was determined for the carbon yarn embedded in various matrices. The results show that the carbon yarns embedded in various matrices show a similar bond behavior that can be represented by a trilinear bond slip relationship. Once the tensile strength is attained, fracture of the embedded carbon yarn can take place. An anchorage length model was derived based on the bond slip relationship. Afterwards, the effect of matrix impregnation on the bond behavior between carbon fabric and matrix was studied. The outer (impregnated) part and inner (unimpregnated) part can be distinguished within a single carbon yarn due to limited matrix impregnation. The percentage of the impregnated part was estimated as 30 percent based on the image process and analysis results. In addition, the respective bond slip relationship for the outer (matrix-outer part) and inner (outer part-inner part) interfaces was determined based on the pullout test results. With carrying out finite element modelling that incorporates the evaluated bond slip relationships, good agreement can be achieved between numerical and experimental results. Besides, the stress transfer at the outer and inner interfaces and the contribution of the outer and inner parts to carrying the applied force were also discussed based on numerical simulation.
With introducing anodic polarization, MFRCM composites were investigated with respect to the electrochemical performance, the mechanisms of degradation and the bond behavior between carbon fabric

and matrix. Stabilized electrochemical performance can be maintained for MFRCM composites polarized up to 125 mA/m2, while an exponential grow of cell voltage can be seen for larger current densities. By means of SEM, EDS, FTIR and XPS, the polarization induced changes in the chemical composition and morphology of carbon fabric and the surrounding matrix were analyzed. The results reveal that the carbon fabric in the matrix showed a clear sign of deterioration featured by multiple transverse cracks on the carbon filaments and significant changes in the surface functional groups. The changes in the morphology of carbon fabric within MFRCM composites were also discussed. Finally, the effect of anodic polarization on the bond behavior between carbon fabric and matrix was examined. The respective bond slip relationships for the outer and inner interface were determined based on test results obtained from anodically polarized MFRCM composites. The results show that anodic polarization compromises the bond behavior for both interfaces, depending on the extent of anodic polarization. With increasing the extent of anodic polarization, the local bond strength and the residual bond stress for the outer interface decreases, while the local bond strength is reduced for the inner interface.