Distributed Fiber Optic Sensing for Micro- and Macro-Crack Quantification: An Interfacial-fracture-energy-based Model

Dao-Yuan TAN[1]

[1]School of Earth Sciences and Engineering, Nanjing University, China

Clarifying strain transfer between the host material with a crack opening displacement (COD) and the optical fiber after interfacial debonding remains a critical challenge for crack quantification. Interfacial debonding induces a triangular strain profile around the crack due to residual shear stresses at the interface. This study investigated the interfacial shear stress–slip relationship between the bare fiber and its coating layer through a plate splitting test. Based on these findings, we proposed an interfacial-fracture-energy-based analytical model to convert distributed fiber optic strains before and after interfacial debonding into CODs of micro- and macro-cracks. The model's accuracy under a single crack was validated through plate splitting tests and experimental data reported in the literature. Additionally, experimental results from a four-point beam test were utilized to investigate the model's feasibility under multiple cracks. The model, assisted by a strain superposition strategy, accurately quantified the CODs of multiple cracks before interfacial debonding but failed when interfacial debonding occurred. Furthermore, we proposed a simplified method based on the linear relationship between debonded lengths and the corresponding CODs, facilitating the evaluation of CODs after debonding. The investigation into the interfacial shear stress–slip relationship between the bare fiber and its coating layer, as analyzed in plate splitting tests, served as the basis for our proposed interfacial-fracture-energy-based analytical model. This model enhances the accuracy of evaluating micro-CODs (where no interfacial debonding occurred) compared to the previous study using an empirical strain lag parameter. Crucially, the analytical model accounts for residual interfacial strength, filling the research gap in evaluating macro-CODs (where interfacial debonding occurred). Additionally, assisted by a strain superposition strategy, the proposed analytical model accurately quantified CODs of multiple cracks before the occurrence of interfacial debonding. The clarification of interfacial debonding behavior and the practice of COD quantification for multiple adjacent cracks will promote the application of distributed fiber optic sensing in crack detection and quantification for structural health monitoring.