

FRP Debonding Fracture and Design for Flexural Retrofitting

Abstract

This work studies Fibre-reinforced polymer (FRP) plate debonding from flexurally-retrofitted Reinforced Concrete (RC) beams using fracture mechanics, and proposes design methods to prevent debonding. The global energy balance approach (GEBA) is used to predict debonding, which compares the energy release rate needed to propagate a debonding fracture with the fracture energy of concrete. The computation of the energy release rate and the justification of the fracture energy used are explained, followed by a parametric study on debonding and the development of a unified retrofitting design method.

The energy release rate is determined using moment-curvature models. Five existing and three proposed models are studied for their appropriateness in describing FRP-RC beam loading response, and five are then selected for further study. The FRP-RC section can be treated as a whole section or as an external FRP force acting on the RC section. This work focuses on the whole-section models due to its simplicity and potential for use in design. The accuracy of the whole-section models is validated and compared with the model using a separate treatment. The characteristics needed in a whole-section model for an accurate prediction are discussed. An accurate whole-section model enables the development of the debonding parametric study and design method.

The conventional concrete-opening fracture energy is used as the debonding fracture energy in the global energy balance approach, and it is assumed to remain constant during debonding fracture propagation. Although this assumption leads to an accurate debonding prediction, it goes against the conventional wisdom and needs to be justified. There is very limited test evidence for the variation of the debonding fracture energy with crack length, so wedge-split peel-off tests were conducted to study this effect, using three types of specimens with different plating conditions.

Digital image correlation techniques were developed for detailed fracture investigation and to provide evidence for the source of fracture resistance and the fracture process zone identification. This technique has special features for interface fracture measurement and was validated using different tests to ensure its accuracy and ability to capture the fracture process zone. Using a simple fixed-ended cantilever beam model for the debonded plate, the debonding fracture energy is determined for different fracture propagation lengths.

Fifty five concrete specimens were tested, and the similarity between the debonding fracture and the conventional concrete opening fracture are discussed. The size of the fracture process zone (FPZ) and the nature of fracture resistance are also covered. Specimens made of timber were also tested for a contrast to demonstrate the feature of small-sized and localised debonding fracture. It is shown that the conventional understanding of size effect in concrete fracture is irrelevant in the localised debonding fracture, and also that the constant fracture energy assumption in GEBA is justified. The scatter in fracture energy is shown to relate to concrete heterogeneity and the interface flaws, which are inevitable, rather than to the fracture propagation length.

A debonding parametric study is then conducted using GEBA, and the effects of the important factors are presented using debonding contour plots. A unified design method considering both retrofitted strength and debonding prevention is developed, based on the debonding contour plots, and compacted concise design charts are provided.