Analysis of debonding of CFRP from concrete using Global Energy Balance and Fracture Mechanics

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Synopsis

Reinforced Concrete beams retrofitted with FRP plates commonly fail, before the target flexural capacity has been reached, in a sudden manner by premature debonding. Failure typically takes place in the concrete layer immediately next to the adhesive. Most attempts to analyse this phenomenon rely on providing more and more complex finite element models of the adhesive layer and the concrete between the surface and the internal reinforcement. The problem with this is that it relies on information that is inherently unknowable: what is the state of micro-cracking, where are the aggregate pieces, how are they aligned? Instead, we argue that debonding failure is a fracture process: micro-cracks almost certainly exist everywhere and they can extend if more energy is input by the load than is required to propagate the crack.

The problem with this approach is that we have to know the fracture energy of a debonding crack, and we have to have a good model for the moment-curvature response of the beam, and how it responds to cracking. The adhesive layer is loaded in shear, and most people who have tackled this problem assume that it is a Mode II failure, but we argue that there is almost no resistance to movement of the FRP plate away from the concrete surface and, at least locally, the final failure is in Mode I. We show that the debonding load depends on the location of the end of the plate and that the debonding load can be accurately predicted using our model. Tests to measure the fracture energy of concrete in Mode I, and to determine the size of the associated Fracture Process Zone will be described.

Our analysis can be used to back-analyse tests, but is too complicated for designers to use because it requires extensive computation. By making certain simplifying (and conservative) assumptions, design charts can be produced that can be used in design office.

Chris Burgoyne background

Chris Burgoyne is head of the Structures Research Group in the University of Cambridge. He has extensive experience of the design and analysis of prestressed concrete structures and was one of the first to use high-strength fibres for prestressing tendons, and for other tension elements. This in turn led to research into the properties of those materials for other applications of high strength fibres such as aramids and polyesters. Of particular relevance is research into the effects of long term loads, high temperatures, bundle theory effects, both with and without the presence of resin, and techniques for anchoring both the fibres themselves and ropes made from the fibres. This also led to his work on the fracture mechanics of plate debonding since this governs the behaviour of structures reinforced with CFRP. He has recently been involved in the SPICE geoengineering project where he studied the construction of a 20km long umbilical connection to a balloon from which particles can be injected into the stratosphere.