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Numerical Simulation of Composite's Interface Failure – Delamination

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ABSTRACT

The paper deals with the behavior of composite structures subjected to a load considering damage evolution. Within the interest of the authors are especially the textile reinforced concrete (TRC), the composite consisting of fine-grained concrete with textile reinforcements made of alkali resistant (AR) glass. The material is used for strengthening of existing concrete structures or for the construction of new light-weight structures. One of the most dominant and dangerous failure phenomena in layered structures is the loss of continuity between adjoining layers, e.g. between the existing concrete structure and the strengthening layer, called delamination.

In a numerical simulation of the interface failure two stages can be distinguished: the onset and the progression of delamination. Three delamination modes can be identified in the three-dimensional model. The three different modes of separation are taken from fracture mechanics, whereby one is normal to the interface and the two others are parallel to it. Delamination is initiated, when the interlaminar stress state reaches the maximum interfacial strength. To take into account the complex stress state, which influences the delamination initiation, stress-based interactive failure criteria can be used, e.g. HASHIN [2] and PUCK [5]. The simple criteria, that compare the stresses with experimental strength parameters, are suitable for the prediction of the delamination onset [3, 4]. However the structure can still sustain a load after the delamination onset, therefore effective tools for the prediction of the delamination progression are needed. In this work the crack growth is modeled taking into account the internal contact and friction in the interface. The composite structure is modeled with a multi-layer shell element based upon the geometrically nonlinear surface-related shell theory. Linear elastic orthotropic material behavior is assumed in the constitutive relation of the composite layers. The complete three-dimensional stress state is considered in the numerical simulations. The behavior of the interface, after delamination has occurred, is modeled by using contact mechanics' conditions within the multi-layer shell elements. The conditions prevent a self-penetration of the debonded areas as well as they take into account the friction between layers. The tangential slip strongly depends on the normal pressure in the delaminated interface producing friction. The presented model for the delamination process simulation into the multi-layer shell element can be generally applied to problems where small relative displacements between adjacent layers are expected.

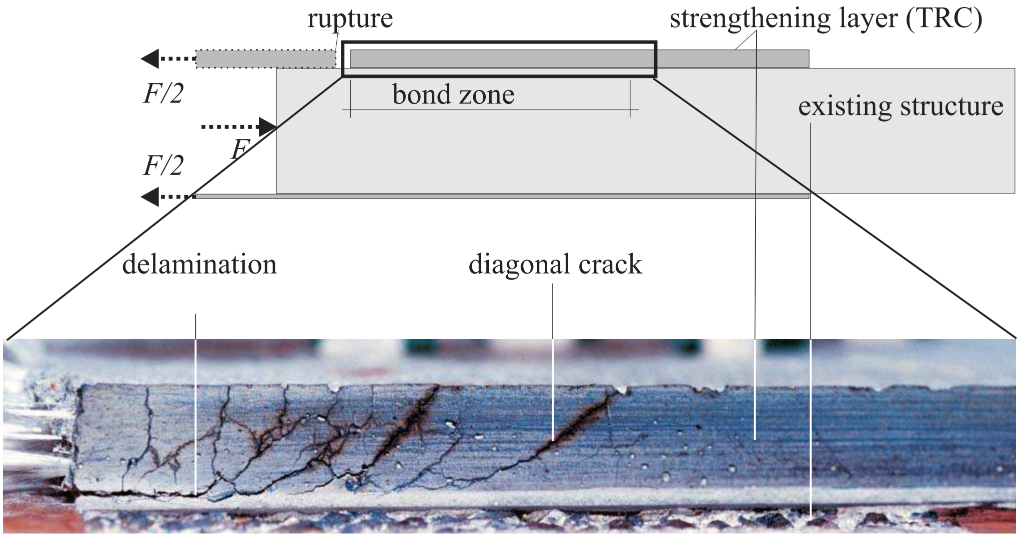

Figure 1: Sketch of the specimen (top) and picture from the experiment after the rupture (bottom).

Finally, the pull-off test shown in Fig. 1 is considered for the comparison of the simulation with the results from experiment. The test was performed in the subproject C1 of Sonderforschungsbereich SFB 528 (Collaborative Research Center). A sketch of the experiment is presented on the top and a picture from the experiment after the rapture is shown at the bottom of Fig. 1. The crack pattern in the strengthening layer and debonding between the layer and the existing structure are visible in the picture. The geometry data for this and other experiments as well as material parameters of textile reinforced concrete can be found in the report [1]. The numerical results will be presented during the conference.

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