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DETERMINATION OF ENERGY RELEASE RATE FOR A MIXED-MODE DEBONDING TEST FOR □COMPOSITE□PAVEMENTS

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Abstract: The main purpose of the article is to present a mixed-mode test to characterize debonding in □composite□ pavement consisting of superimposed layers of processed materials (cement concrete and bituminous materials). The energy release rate is calculated by the Multi-particle Modelling of Multi-layered Material with 5 kinematic fields per layer (M4-5n). The classical virtual crack closure technique helps to separate analytically the two individual fracture modes. The crack propagation mainly depends on interface stress fields. During the four-point bending test, by means of image analysis techniques, M4-5n values have been compared successfully to Dundurs□ expressions.

Keywords: interface stresses, debonding, mixed-mode test, multiparticle modelling, Dunder, pavement

Due to the structural heterogeneity of multilayer systems, debonding between pavement layers can occur during its service life. This phenomenon happens especially near the edges or vertical cracks through one layer as observed for instance during an accelerated loading test made on a specific □composite□ pavement composed of a cement concrete overlay on a bituminous material layer [1]. The interface behaviour between pavement layers near shrinkage cracks or joints need to be characterized. For being used by engineers in charge of rehabilitation problems a specific model and experimental device has to be proposed.

As opposed to other classical models, the family of multi-particle models of multilayer materials (M4) yield finite stresses at a free edge or crack tip at the interface point location of two different layers [2]. For the pavement bending problem, the M4 selected herein contains five kinematic fields per layer. This so-called M4-5n (n is the total number of the layers) is based on a polynomial approximation of degree 1 in z (vertical direction) per each layer for the in-plane stress fields. According to the equilibrium equations, this set-up provides, for each layer, a 2nd degree and a 3rd degree polynomial equation in z for shear and normal stresses respectively. The coefficients of the polynomial approximations are expressed via the classical Reissner generalized (x, y) fields per layer i . These approximations offer the advantage of defining the out-of-interface plane normal $v^{i,i+1}(x, y)$ and shear stresses $\tau_{\alpha}^{i,i+1}(x, y)$ at interface $i, i+1$, between layers i and $i+1$. The Hellinger-Reissner's formulation [3] reduces the real 3D problem to a determination of regular plane fields (x, y) per each layer i and interface $i, i+1$ (and $i-1, i$). All these modelling assumptions accelerate the equation resolution process compared to other modelling approaches. For crack initiation problems, two delamination criteria in the angle-ply laminates have been proposed [4]. The first one is based on the maximum value of interface stresses. Using the virtual crack closure technique (VCCT), the second criterion is based on an analytical calculation of the individual strain energy release rates (G_I, G_{II} and G_{III}).

Applied to the 4-point bending test under plane strain assumptions, the M4-5n solutions computed into the Scilab software are obtained very quickly [5]. It allows making several parametric studies as illustrated on Fig.1 (beam length: $L=420\text{mm}$; width: $b=120\text{mm}$, Young modulus ratio: $E_2/E_1 \approx 17,4$). Both experimental and analytical results have been compared on bi-layered pavement specimens. The results show that the elastic model is really efficient to design the geometry of the specimen. Significant crack at the interface in mixed mode conditions is obtained. The mode I should be recognized as the main failure mode (Fig.1b).

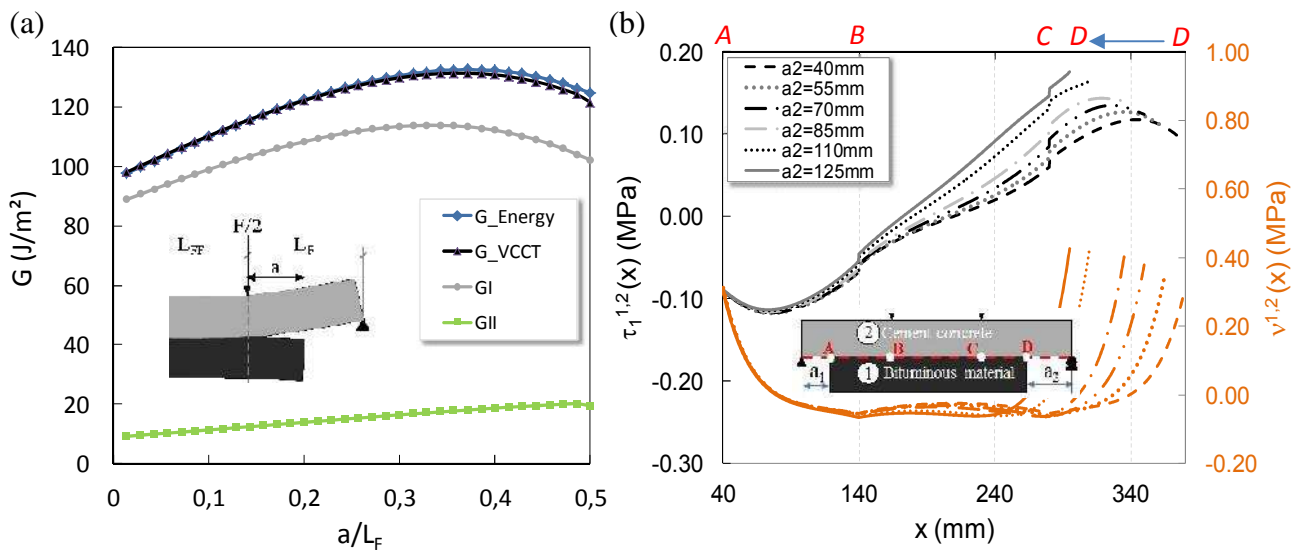


Figure 1: M4-5n results - (a) Energy release rates ($a_2=70\text{mm}$, $F=12\text{kN}$) - (b) interface stress fields ($F=4\text{kN}$).

Digital image correlations techniques are used to determinate the crack length and the displacement field. Energy release rates of the M4-5n have been validated successfully compared to Dundurs's approach [6].

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