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DETERMINATION OF THE CONCRETE COHESIVE LAW UNDER MODE I LOADING USING AN INVERSE METHOD

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ABSTRACT

An inverse method based on an optimization strategy involving a genetic algorithm is used to determine the cohesive law under pure mode I loading of concrete using the single edge notched-three point bending test. The method is based on the minimization of an objective function that quantifies the difference between the numerical and the experimental load-displacement curves resulting from the application of a given law. A tri-linear law with bilinear softening relationship was assumed. The optimization procedure involving a genetic algorithm was used to identify three cohesive parameters. A validation procedure involving numerical analysis was performed.

Keywords: concrete, cohesive law, mode I loading.

INTRODUCTION

Cohesive zone modeling (CZM) is being used to simulate damage onset and propagation in different materials [Gonçalves et al., 2003; de Moura et al., 2008]. These models establish a relationship between tractions and relative displacements at a given interface. The method is particularly adequate when crack path is confined to a given plane and presents several advantages: does not require the definition of a pre-crack, reveals mesh independency from a given mesh refinement and it is not restricted to linear fracture mechanics analysis. This last aspect is particularly relevant namely in materials that present non-negligible fracture process zone, which is typically a field of nonlinear fracture mechanics.

One of the crucial aspects of the CZM is the use of a material representative cohesive law. Previous studies have shown that the tri-linear cohesive law presenting a bilinear softening relationship (Figure 1) is appropriate for concrete [Petersson, 1981].

The objective of this work is to evaluate the cohesive parameters by an inverse method involving a genetic algorithm that provides a good agreement between the numerical and experimental load-displacement curves. The parameter w_0 (relative displacement corresponding to damage onset) can be obtained by the relation between initial stiffness and σ_u. The G_{Ic} corresponds to the energy circumscribed by the cohesive law which leads to the following relationship:

$$w_u = w_0 + \frac{2G_{Ic} - \sigma_u w_1}{\sigma_1} \tag{1}$$

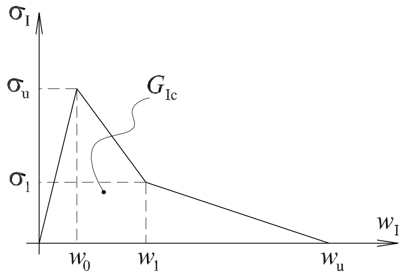

Fig. 1 - Tri-linear cohesive law.

The remaining cohesive parameters (σ_u, σ_1 and w_1 in Figure 1) are obtained through the optimization strategy. The objective of the procedure is to minimize an objective function that quantifies the difference between the numerical and the experimental load-displacement curves resulting from the application of a given law.

The single edge-notched beam under three-point bending test (SEN-TPB) was used to get the cohesive law of concrete under mode I loading. Experimental tests (Figure 2a) were performed considering the following specimen dimensions: span L=1680, width B=80, pre-crack a_0=140, height h=280, all dimensions in mm. The experimental results were treated in order to obtain the resistance-curve (R-curve) allowing the definition of the fracture energy (G_{Ic}=0.049 N/mm), which is used in the optimization procedure as an input parameter.

Finite element simulations of the test were performed using the inverse method. The optimization strategy propitiated good agreement between the numerical and experimental load-displacement curves (Figure 2b), thus allowing the identification of the unknown cohesive parameters (σ_u= 2.0MPa, σ_1= 1.4MPa and w_1= 0.007692mm).

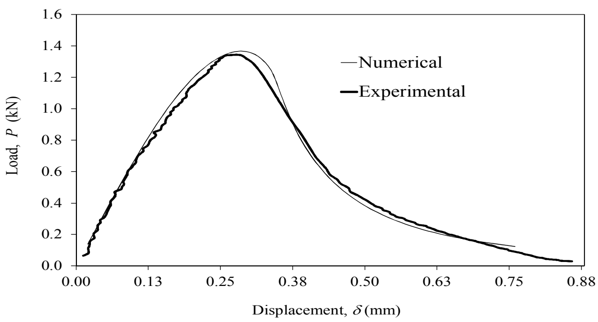

Fig. 2 - Photography of the SEN-TPB test and load-displcament curves.

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