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Numerical modeling of the double punch test for plain concrete

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ABSTRACT

Double punch test is used to indirectly assess the tensile strength of plain concrete, f_t. For this normalized test, the tensile strength is obtained as a function of the failure load, P, which is expressed as $f_t = \mathcal{F}(P)$. Different authors have proposed different expressions for the relation $\mathcal{F}(\cdot)$, yielding scattered values of f_t. None of these alternatives is universally recognized as being more suitable than the others. In fact, these expressions are mainly based on elastic models considering the maximum tensile stress under the load P and f_t is obtained as an output of the linear model. A numerical simulation allows using models in which f_t is an input of the material model and the corresponding failure load P is obtained associated with each value of f_t. In the present work, double punch test is simulated numerically considering two alternatives for modeling plain concrete accounting for damage and cracking: (a) the nonlocal Mazars damage model and (b) an heuristic crack model including joint elements in an *a priori* defined crack pattern. Numerical results are validated with experimental data and compared with the analytical expressions available in the literature.

1. Introduction

The double punch test (DPT) (Chen, 1970; Chen and Yuan, 1980; Chen and Ttumbauer, 1972) is used to indirectly measure the tensile strength of plain concrete, f_t. Indirect measures of tensile strength (Brazilian test, DPT, 3 and 4 point bending test, etc.) are often preferred to direct uniaxial tests because (1) they are much easier to perform, particularly for controlling material production (for plain concrete, for example, the Brazilian test is of common and standard use) and (2) they show a reduced scattering of the results. The main focus of this work is proposing numerical models for the DPT in which f_t is an input parameter. The idea is to replace the naif linear elastic model by a more realistic one that has the tensile strength, f_t, already as one of material parameters and to identify the value of this material parameter that better fits the experimental results. These models are validated using experimental results and other analysis available in the open literature (Chen and Yuan, 1980; Bortolotti, 1988; Marti, 1989; Molins et al., 2007).

The information extracted from the experimental tests is translated into the parameters characterizing the mechanical properties of the analyzed concrete. In this case, the parameter to be assessed is precisely the tensile strength, f_t. Essentially, the data provided by the experimental setup is a force–displacement curve in which the peak points corresponding to the collapse are easily identified. The force corresponding to the peak point, P, is readily translated into the tensile strength value using a theoretical model simulating the mechanical behavior of the test, $f_t = \mathcal{F}(P)$. Currently, the underlying theoretical model used in this framework is an analytical solution of the linear elastic problem (Chau and Wei, 2000,). These models are a crude approximation of the actual behavior of the specimen close to the collapse regime but they still provide a good approach to the tensile strength by selecting a characteristic tensile stress in the linear elastic solution for the peak force, P.

Two different approaches are considered in order to model the mechanical behavior of the concrete in the DPT. Firstly (option A), a continuous model which has been successfully used modeling the common Brazilian test (Rodriguez-Ferran and Huerta, 2000), the nonlocal Mazars damage model (Mazars, 1986; Bažant, 2002; Jirásek, 2007; Pijaudier-Cabot and Huerta, 1991; Rodriguez-Ferran and Huerta, 2000). Secondly (option B), a model which introduces discontinuous fracture at the surfaces corresponding to an *a priori* defined cracking pattern, based on the experimentally observed fracture mechanisms (Díez and Pegon, 2002; Beer, 1985; Snyman et al., 1991). On the fracture surfaces, joint elements with cohesive dilatant behavior are used to model the interfaces. In the rest of the specimen, the mechanical behavior is assumed to be linear elastic because the relevant deformation is concentrated in the fracture surfaces. Here, 3D finite element approximations are used complemented (for option B) with 2D joint elements. Both options A and B are solved using 3D finite elements.

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