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Inelastic Parameter Identification for Local Diagnosis Analysis of Concrete Dams

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Inverse analysis procedures provide more and more frequently computational mechanics contributions to structural diagnosis in civil engineering and in various other technologies. The contribution presented in this communication consists of a technique for calibration by flat-jack tests of the simple inelastic constitutive models frequently employed for limit state analyses of concrete dams. The parameters, never identified so far by this nondestructive experiment, are: tensile and compressive strengths and fracture energy of concrete. The other novelties with respect to recent research results published in [1, 2] are (see Fig. 1): (i) two slots according to a "T geometry"; (ii) displacements measured by Digital Image Correlation (DIC) (instead of extensometers which are employed in the state-of-the-art practice) on the "region of interest" between the two slots ; (iii) Proper Orthogonal Decomposition combined either with Radial Basis Functions interpolation and the (first order mathematical programming) Trust Region algorithm (its convergence in a typical exercise is visualized in Fig. 2) or, alternatively, with Artificial Neural Networks (ANNs). The parameter identification processes (iii) require a set of repeated finite element (FE) simulations (generation of "snapshots" for POD and truncation; ANN "training" and testing) to be performed "a priori" (here by the commercial code Abaqus), once-for-all, in a computing laboratory; afterwards, inverse analyses can be carried out routinely, rapidly and economically by a portable computer in situ for parameter assessment in several locations of a large dam, possibly deteriorated by diverse events (such as alkali-silica reaction).carried out in situ by a portable computer.

The technique presented herein, developed and validated so far only computationally, can be outlined as follows. (a) Two usual slots are cut according to a "T geometry" (namely: one horizontal and the other vertical, distant from each other of about a jack radius). (b) A standard three-dimensional FE model is generated of a domain containing the jack pair, with suitable boundary on which elastic constraints can be enforced by statical condensation. The material models are simple and traditional in civil engineering practice: isotropic Drucker-Prager (DP) elastoplasticity, assuming normality as a practical approximation; cohesive crack (CC) model, with linear softening, on the straight line which extends the vertical slot up to the intersection with the horizontal one. (c) Digital image correlation is employed to measure displacements on the surface in many nodes (say 100) of a standard grid around the slots. (d) Relative displacements induced during the slot cutting phase are recorded for later use. (e) Relative displacements due to low pressurization of the jack are measured and employed for inverse analysis apt to identify Young modulus and Poisson ratio of concrete. (f) Using the elastic parameters, experimental data gathered at stage (d) are employed to identify the two normal components and the tangential one in the local (plane) stress state. (g) Pressurization of the jacks is increased in order to generate plastic strains around the slot end points and a crack propagating upward from the top end of the vertical slot. Inverse analysis based on the measurements provided by DIC in this stage leads to the estimation of fracture energy and of tensile and compressive strength (the latter indirectly from the parameters contained in the DP model).

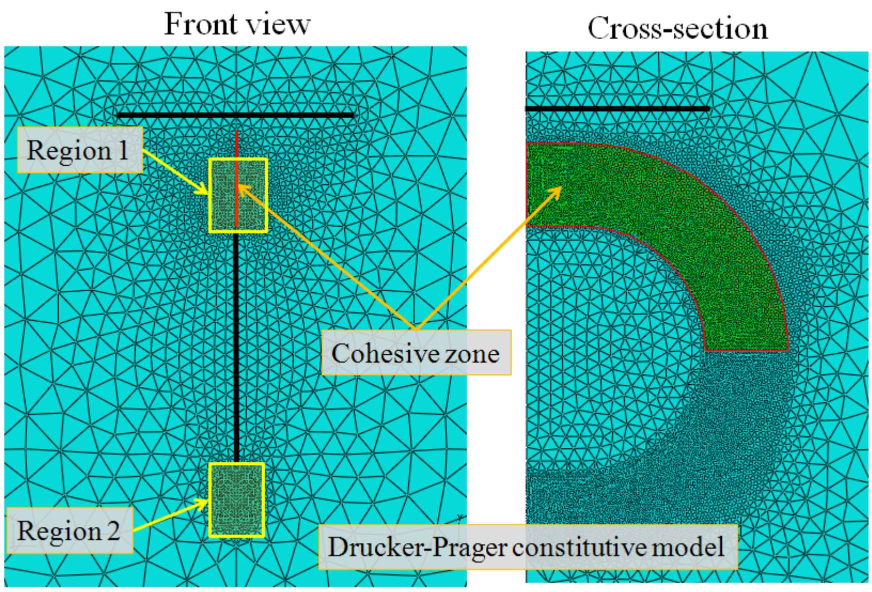

Figure 1: T-configuration of the slots and mesh of the 3D FE model

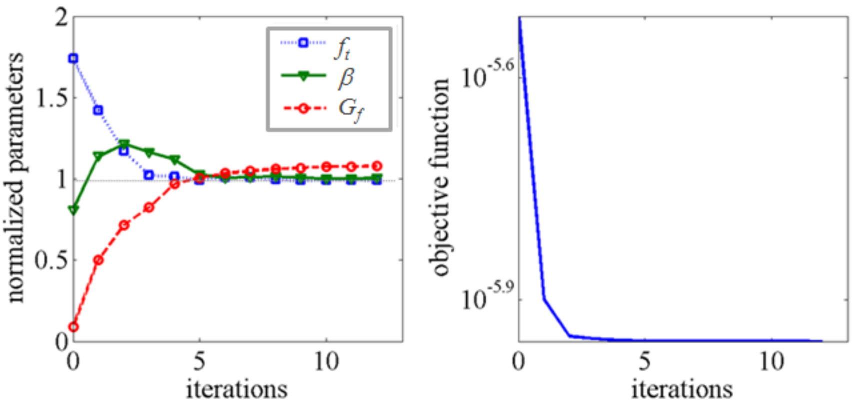

Figure 2: Identification of the inelastic parameters (f_t = tensile strength, G_f = fracture energy, β = internal friction angle correlated to compressive strength f_c through the other parameters) and convergence of the discrepancy function

References

[1] *Identification of elastic stiffness and local stress in concrete dams by in situ tests and neural networks*, R. Fedele, G. Maier, B. Miller, Structure and Infrastructure Engineering, 1 (3), 165-180, 2005.

[2] *Flat-jack tests and inverse analysis for the identification of stress and elastic properties in concrete dams*, R. Fedele, G. Maier, Meccanica, 42, 387–402, 2007.