Diagnosis of structures by inverse analyses: novel procedures applied to concrete dams and membranes

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Abstract

Meaningful contributions to progress in technologies and sciences, and hence in the society at large, usually arise from interactions between practical engineering environments and research institutions. Problem formulations, stimuli and orientations are expected to go from practice to research; novel methodological results in the opposite direction. In this lecture such interactions is considered with reference to the following two structural problems: (a) diagnostic examination of concrete dams possibly deteriorated in time; (b) mechanical characterization of anisotropic free-foils, particularly of membranes for tension structures, but similarly of geomembranes for dams and of laminates for food containers.

Advantageous innovative applications to the solution of both the above practical problems are here described with reference to the following techniques recently developed by general methodological researches: (α) full-field measurements through "digital image correlation" (DIC), which provides through digitalized photos many experimental data (much more than by traditional instrumentation) and, hence, makes mathematically "well-posed" the inverse analysis problems; (β) "proper orthogonal decomposition" (POD), namely a mathematical and computational procedure which leads to fast and economical inverse analyses for parameter identification.

The novel approach, described in this lecture, to the engineering problem (a), i.e. diagnosis of concrete dams on the basis of flat-jack experiments, exhibits the following practical advantages with respect to the state-of-the-art: (i) less "destructive" tests because of the limitation to two slots with "T geometry"; (ii) more estimates, namely three stress components, three orthotropic elasticity moduli and three inelastic parameters governing Drucker-Prager model of plasticity and a simple cohesive crack model of fracture; (iii) estimation achievable fast, "in situ", by a small computer equipped either by an "artificial neural network" (ANN) or by a "trust region algorithm" (TRA), in both cases with inputs provided by a POD procedure exploiting preparatory computations performed once-for-all "a priori".

As for problem (b), i.e. mechanical characterization of membranes, the following advantageous novelties are achievable by DIC and by POD approaches to inverse analysis: (i) a rather complex anisotropic elastic-plastic model (i.e. a simplified Xia-Boyce-Parks (XBP) model originally proposed for paper) can be calibrated for tensile stress states by a single biaxial tensile test on a "cruciform" specimen; (ii) the parameters governing the foil behavior under dominant compression in the simplified XBP model can be identified by means of a novel kind of experiment intended to avoid instability and wrinkling of the specimen; (iii) the positive features of the computational procedures based on POD mentioned above with reference to flat-jack tests are shown to hold also with experiments for free-foils mechanical characterization.

Keywords

structural diagnosis, concrete dams, membranes

Theme

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