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SIMULATING MONOTONIC AND CYCLIC BEHAVIOUR BY MEANS OF AN ELASTOPLASTIC MULTIMECHANISM LAW

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EXTENDED ABSTRACT

The analysis of ballasted railway structures still demands many improvements to achieve an accurate estimate of its global behaviour, i.e, towards reproducing the real performance of the materials and the structure. Furthermore, in the design process, ultimate/serviceability limit states and life cycle costs should be attended. As a result, a wide range of research works are being introduced.

In this context, a research entitled *High-speed trains on ballasted railway track. Dynamic stress field analysis*, was performed and contributes to the improvement of these processes throughout laboratory and numerical experiments aiming to investigate (with particular emphasis) on the dynamic stress field analysis, particularly the characteristic stress paths followed by granular elements below a typical track structure under the passage of a High-Speed Train (HST). The numerical experiments were carried out using an elastic frequency domain model and an elastoplastic time domain model, validated with in situ data obtained by vibration measurements in a HST railway line.

To perform these elastoplastic numerical experiments, 3 geomaterials were calibrated in a complex constitutive law since geomaterials and soils have special deformation characteristics such as: anisotropy, dilatancy/contractancy, hardening/softening and complex behaviour under cyclic loading. Wu *et al.* (1996) performed an inspection on the relevant literature and detect that the capacity of plastic laws is gained by sacrificing its simplicity. In some cases the rheological models have even non-physical parameters impossible to identify directly from laboratorial characterization. In this context, a powerful constitutive law was defined and enhanced by Aubry and co-workers since the early 80's (Aubry *et al.*, 1982; Hujeux, 1985) at Ecole Centrale Paris, using a continuum approach, to allow the simulation of clay, sand or gravel, under monotonic and cyclic testing. The law uses a multimechanism approach with four plastic elementary mechanisms: three plastic mechanisms for the deviatoric deformations and one plastic mechanism for the isotropic deformation

To demonstrate the capacity of the multimechanism law to simulate experimental results obtained in monotonic and/or cyclic tests, two distinct materials were study. The first one consist on a natural crushed aggregate used currently as base course layer and the second one a foundation clayey soil study under a cooperation protocol between REFER and TecMinho, as the representative consortium UM/LNEC/IST/FCT-UNL (project POCI/ECM /6114/2004: Interaction soil-rail track for high speed trains). The law was developed to be able to simulate all relevant deformation characteristics (in opposition to the simplified equivalent-linear approach), without excessively time and computational effort (as the micromechanical model approach). For that, it demands the calibration of 19 parameters. Regarding the calibration of the clayey soil, a minimization algorithm was implemented to assist on the process and also to validate the quality of the set of parameters found with a classical calibration procedure (Modaressi and Lopez-Caballero, 2001). This ESs algorithm was developed in University of Minho and, as all ESs algorithms, it mimic the natural evolution of the species that occurs in natural systems. It works directly with the real representation of the parameter set, searching from an initial population (a set of points) generated at random inside a defined valid interval (boundary constraints), requiring only data based on the objective function and constrains, and not derivatives or other auxiliary knowledge (Miranda, 2007).

The law was calibrated by means of two distinct processes (a classical one and by means of a minimization algorithm) in order to simulate both monotonic and cyclic testing. Along the process it was detected that the model presents high capacity to reproduce monotonic behaviour with respect to all test results (Fig. 1). Regarding cyclic testing, limiting cumulative strain was not so simple, even with the incorporation of a new parameter that induces the variation of model parameter along cyclic testing. Consequently, even if global behaviour during consolidation and reversible cyclic testing is well represented, studies with imposed variation of other model parameters. Regarding the use of a new calibration procedure one becomes aware that the chosen ESs algorithm was able to provide a quality set of

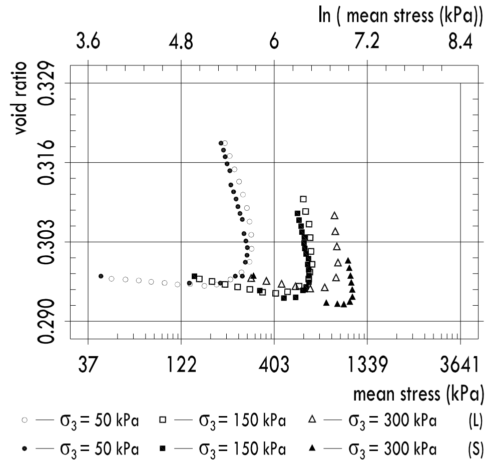

Fig. 1. Comparison between the data obtained from a drained monotonic triaxial test performed over a natural crushed aggregate (L) and those resulting from the use of Hujeux law (S)

parameters if suitable valid intervals for all parameters were chosen (Fig. 2). This cannot be considered as a true limitation since expected set of parameters are known as function of the material type (e.g., clay, sand or gravel) and short valid parameter intervals can be

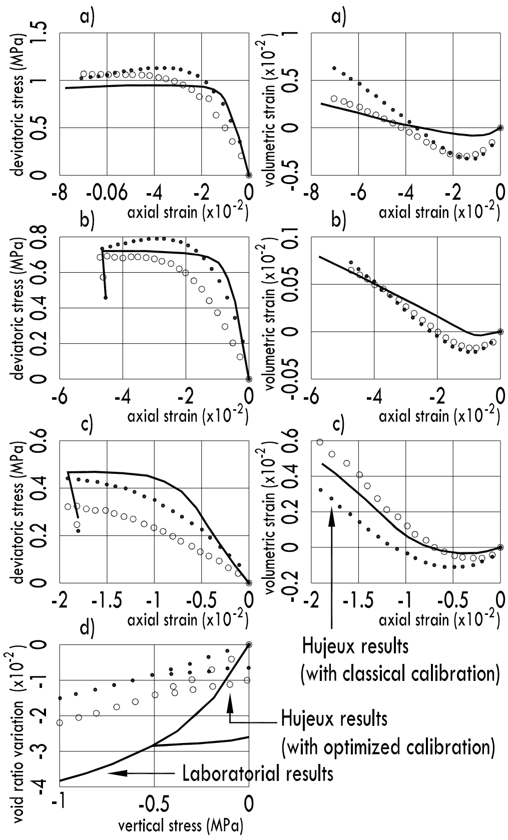

Fig. 2. Comparison between Hujeux results obtained with the conventional calibration (closed dotted points), optimized calibration (open dotted points) and laboratorial results (continuous line) for a clayey soil in terms of a) drained triaxial monotonic test with σ_3 = 100 kPa, b) drained triaxial monotonic test with σ_3 = 200 kPa, c) drained triaxial monotonic test with σ_3 = 300 kPa and d) eodometric test

defined. Nonetheless, it is intended to tune and improve ESs algorithm to tackle efficiently this particular optimization problem. To summarize the combined use of this multi-mechanism constitutive law and ESs algorithm was found to be a powerful solution to improve geotechnical design.

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