CERIS : Civil Engineering Research and Innovation for Sustainability

Modelling and monitoring the dynamic behaviour of concrete dams. Modal analysis and seismic response

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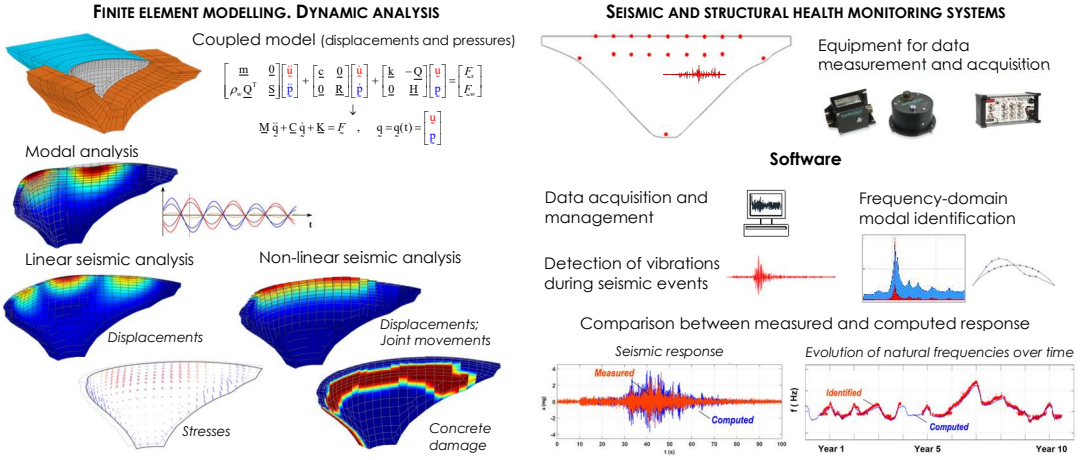
Summary

The present work begins with the development of a finite element model for dynamic analysis of arch dam-reservoir-foundation systems. A formulation in displacements and hydrodynamic pressures is adopted, considering the dam-water dynamic interaction and the propagation of pressure waves in the reservoir. The proposed model is implemented into a finite element program and, besides pre- and post- processing tools, it includes three modules, namely for: (i) complex modal analysis, based a new state-space approach that allows to consider generalized damping; (ii) linear seismic analysis, using a coupled time-stepping formulation based on the Newmark method; and (iii) non-linear seismic analysis, by combining the time-stepping method with a stress-transfer method, considering a) the non-linear behaviour of concrete up to failure, using on a strain-softening constitutive damage model with two independent damage variables (d+ and d-), and b) the opening/closing and sliding movements of joints, using a constitutive model based on the Mohr-Coulomb failure criterion and on appropriate relative displacement-stress laws. After that, the work dedicates to the development of computational tools to integrate and complement the software component of Seismic and Structural Health Monitoring (SSHM) systems installed in large dams, in particular for: (i) automatic analysis and management of dynamic monitoring data, in order to assess data quality, automatically detect vibrations induced by seismic events, and perform the maintenance of the database; and (ii) automatic modal identification, based on the classic frequency domain decomposition method, and using new techniques proposed to automate peak selection and to enhance the modal parameter identification for dams over time. Application studies are presented for Cabril dam (132 m high), in Portugal, and Cahora Bassa dam (170 m high), in Mozambique, two double curvature arch dams which have been under continuous dynamic monitoring since 2008 and 2010, respectively. The provided results are mainly focused on: (i) the analysis of the evolution of identified natural frequencies over time and the comparison with numerical values, in order to evaluate the influence of reservoir level variations and to perform evolutive damage detection; (ii) the study of the response during real seismic events, based on the comparison between measured and computed accelerations in the dam body, aiming to investigate the influence of the seismic input and damping ratios used in the models; (iii) the simulation of the non-linear seismic behaviour under a strong earthquake, with a view to evaluate influence of joint movements in the structural dam response (displacements and stresses), and (iv) the seismic safety assessment of large concrete dams based on the Endurance Time method, by analysing the progression of tensile and compressive concrete damage under intensifying seismic accelerations.

Keywords

Dynamic behaviour of concrete dams, coupled finite element modelling of dam-reservoir-foundation systems, seismic and structural health monitoring, state-space complex modal analysis, linear and non-linear seismic response (joint movements and concrete damage).



Finite element modelling (dynamic analysis) and SSHM systems for large concrete dams.