CERIS Civil Engineering Research and Innovation for Sustainability

SSHM4DAMS – Seismic and Structural Health Monitoring of Large Concrete Dams

Summary

Due to climate change, characterized by periods of prolonged drought followed by periods of heavy rainfall, large concrete dams are assuming an increasingly important role in the management of water resources. Being structures with high potential risk [DSR18], according to ICOLD it is fundamental to ensure the safety of dams for any type of hazards from the natural and man-made environment [Wi16]. In order to verify the structural safety of dams located in seismic areas, it is essential to invest (i) in finite element (FE) programs and models for numerical analysis and (ii) in monitoring of the dynamic behaviour of dams under ambient/operational vibrations and during seismic events. With that aim, Seismic and Structural Health Monitoring (SSHM) systems must be used [LiÇe19], which should be equipped with sensors for continuousl measuring vibrations and with appropriate software for automatic analysis of recorded data. The installation of SSHM systems has been proposed for new dams, to evaluate their dynamic behaviour since the first filling of the reservoir, and for some older dams in operation [OlAl19]. However, the companies that provide and install these systems cannot present comprehensive software solutions as all dams have unique features, and therefore solutions can only be worked out in close cooperation with dam owners and engineers responsible for safety control.

Therefore, the goal of this project is to continue the work that has been developed by the research team in the design and development of SSHM systems, namely in what concerns the software component [OlAl19, AlCaMaMeOlPr19]. In particular, the aim is to improve and optimize the existing software for: (i) automatic modal identification [BrVe15], to obtain natural frequencies, vibration mode shapes and modal damping ratios, using the frequency domain approach with innovative techniques for selection of spectral peaks and Artificial Intelligence (AI) models for pattern recognition and clustering techniques in order to distinguish vibration modes with close frequencies; (ii) automatic detection of seismic vibrationsin the dam body and foundation, using pattern analysis and AI algorithms in order to distinguish the seismic vibrations from those induced by the operation of gates and turbines of generator sets; and (iii) numerical analysis of the dynamic response of dam reservoir-foundation (DRF) systems [ZiBe78], based on finite element (FE) coupled formulations [ZiTaZh05] to perform: a) complex modal analysis of the DRF system with generalized damping; and b) linear and non-linear seismic analysis, considering damage in concrete and opening/closing/sliding of block joints. The aim is also to contribute to the development and improvement of graphical tools to facilitate: (i) the analysis of the evolution of modal parameters over time, enabling to study their correlation with the deterioration and ageing of dams, taking into account thermal and reservoir level variations, and the automatic comparison of recorded data with results from the calibrated numerical models; and (ii) the analysis of vibrations induced by seismic events and the comparison with the seismic response predicted in numerical calculations.

The main objectives of this project are as follows: (i) to increase knowledge on the dynamic behaviour of DRF systems, with focus on complex modal analysis and seismic response analysis; (ii) to support studies for structural safety verification over time, by controlling the effects of time-dependent deterioration of concrete, and studies for seismic safety evaluation; (iii) to provide information for dam owners and engineers responsible for safety control, to help in informed decision making in face of regular maintenance needs or emergency cases; (iv) to disseminate experimental and numerical results on the dynamic response of large dams through the scientific community, by providing measured data to the DamQuake platform [RoHu19] and collaborating in its further development; and (v) create a webpage SSHM for Dams, in order to: a) disseminate the most recent scientific studies on the dynamic behaviour of DRF systems; b) share the numerical modelling software developed in this project and the main results; and c) promote and grant access to DamQuake, in order to ensure general access to recorded data on the seismic response of as many dams as possible, and to encourage the provision of seismic acceleration records for large concrete dams subject to strong earthquakes.

The research team includes researchers from institutions of excellence, with extensive experience in the installation and operation of SSHM systems and in numerical modelling of the dynamic behaviour of dams, granting access to high-value experimental and numerical data from several large dams. As consultants, the project can count on the remarkable experience of two world-renowned experts.

Project Reference

PTDC/ECI-EGC/5332/2020

Leading Institution

LNEC – National Laboratory for Civil Engineering (Portugal)

Partners

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal), ISEL – Instituto Superior de Engenharia de Lisboa (Portugal)

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