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Probabilistic seismic assessment of existing concrete gravity dams

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ABSTRACT

Assessment of the current safety level of existing dams is a main concern for owners and reclamation agencies. It is often observed that old dams were designed employing out-of-date analysis methods and/or assuming seismic actions that are nowadays considered as unacceptably underestimated. A reliable tool for the seismic assessment of existing dams is then required to support cost-effective decisions on rehabilitation and retrofitting strategies. Such a method should be able to face both the complexity of the dam-foundation-reservoir system and the several uncertainties affecting the problem. These uncertainties are a consequence of the lack of knowledge of “physical” data, such as dam geometry, rock mass profile, material properties as well as of inaccuracies of the models employed to evaluate the system failure modes.

In the present work, motivated by the above considerations and following concepts similar to those proposed for the seismic assessment of building and bridge structures, the performance of a probabilistically-based methodology for the seismic assessment of existing dams is investigated. We use finite elements to discretize dam body, foundation rock mass and reservoir water in order to effectively simulate their interactions and corresponding effects on dynamic response of the dam body. The seismic response is estimated from a reduced number of dynamic time-history analyses and the fragility curves of the system are derived according to a standard Monte Carlo simulation procedure. The method is capable of accounting for uncertainties not only in the seismic action but also in the height of reservoir water and in the system properties, typically due to the lack of data regarding for example dam geometry and site geology.

The procedure is applied in the analysis of Kasho Dam, a 46.4 m high concrete gravity dam constructed in 1989. On October 6, 2000, this dam experienced the Western Tottori Prefecture Earthquake (M. 7.3) without any serious damage. Available monitoring data allow a calibration of the several parameters involved in the analysis, especially those related to the definition of failure mechanisms. A number of these mechanisms are in fact considered to investigate the operational limit state (sliding at the dam-rock interface, material failure in the dam body, excessive deflection/drift deformation, material failure at the neck, etc.). These selected “critical” failure mechanisms have been numerically evaluated, both in terms of demand definition and capacity evaluation.

Results of the seismic assessment are presented and discussed in terms of fragility curves for the whole system and for each failure mechanism.