ICOLD European Club

EWG Dams and Earthquakes

Proposed Terms of Reference

Guillaume VEYLON, Chairman

Context

The effective application of the demanding regulations for the seismic safety of dams requires advanced and robust models and methods of analysis. There are many outstanding issues, namely those related to the definition of seismic hazard, the dynamic behavior of materials and structures, or the numerical techniques, which need to be tested and validated.

The EWG *Dams and Earthquakes* was created under the impulse of Jean-Jacques FRY in 2015. Since then, three symposiums were organized in Saint-Malo (2016), Roma (2017) and Lisbon (2019). The deliverables of the symposiums consisted in fundamental packages of qualification of seismic analyses: case studies of comparison of model results with experimental data, measurements of dam response under seismic events, dynamic monitoring , probabilistic assessment of seismic hazard in Europe or lessons learned from recent earthquakes(Fry & Matsumoto, 2018 ; Lemos et al., 2019).

Object and objective

The EWG Dams and Earthquakes intends to occupy an important place as a structure promoting mutual exchanges between engineers and researchers working in the field of seismic analysis applied to dams. On the one hand, it aims to facilitate the transfer between academic work and their practical application in real projects. On the other hand, its work should highlight the needs of engineering to allow the setting up of new research projects. The EWG may also be the place for discussions and comparisons of recommendations or guides developed by national committees.

Selected topics

The last 10 years have seen rapid changes in practices and regulations in the field of seismic risk assessment of dams, especially in Europe. The calculation of concrete and earth structures has been the subject of state of the art syntheses and recommendations which deserve to be valued on a European scale (DGPR, 2014 ; Abbasiverki et al., 2017). The assessment of the seismic hazard is constantly evolving, methodologies for taking this hazard into account in the justification of certain types of structures were proposed, simplified approaches have emerged, new models were developed and conditions of use of these numerical tools were specified. It now appears important to evaluate the impact of the results obtained from research, to transfer this new knowledge into operational practice by adapting it to dams. Based on the engineering needs identified today, the EWG intends to focus on the following topics regarding the issues for the determination of relevant

input ground motions to introduce at the base of the numerical models and issues concerning specific aspects of structural modeling.

A. INPUT GROUND MOTION

A1. Assessment of the impact of the new seismic hazard assessment on a European scale

The revision of the seismic hazard map in Europe, drawn up on the occasion of the H2020 SERA project, is about to be published. Based on partially published results, it appears that it may lead to significant changes in hazard estimates (Danciu et al., 2021), with decreasing trends in weak to moderate seismicity areas, and increasing trends in higher seismicity areas. Part of the decreasing trends could be related to newly developed GMPES (Kotha et al., 2016, 2020) which are more reliable for weak to moderate events. Moreover, significant advances have recently been made in the evaluation of round motions in the case of very rigid rock foundations (Laudendeau et al., 2018); Shible et al., 2021).

One objective of the EWG could be **to assess the impact of the revised hazard map** on the seismic security assessment of some dams located in European countries. Comparison of national regulations of seismic hazard assessment at borders of member states would also be of great interest. Such work may be very useful for the national authorities' reflections on the relevance of a review of regulatory requirements in terms of seismic risk applied to dams.

A2. Deconvolution of ground motion

The regulations define the seismic hazard against which dams must be justified in the form of a response spectrum at the "standard" bedrock. The introduction of ground motion at the basis of numerical models requires the deconvolution of the signal (Reimer, 1973). This deconvolution is, in principle, trivial when the constitutive law of the soil foundation is linear elastic, and the incident wavefield assimiliated to vertically incident plane S-waves. In the case of a subgrade soil made up of several layers with contrasting properties (altered rock foundation at the surface), anisotropic or strongly nonlinear behaviors (fractured rock, residual soils for example), and realistic wavefield mixing body and surface waves with various azimuth and incidence angles, there is no widely shared methodology or tool allowing to reconstruct the seismic signal to be introduced at the base of the numerical model. Some recent results (Berge-Thierry et al., 2017) suggest the use of a more robust methodology avoiding important drawbacks such as frequency related divergence.

The purpose of this work could be to provide a state of the art of existing practices and research work on the subject in order to **propose and validate a robust deconvolution doctrine** adapted to operational issues making it possible to deal with all the cases encountered in practice.

A3. Influence of seismic intensity measures (IMs) on the seismic performance of dams

The regulations define the seismic hazard against which dams must be justified in the form of a response spectrum at the bedrock. The generation of synthetic accelerograms is carried out from real recordings according to elaborate procedures which naturally lead to a significant variability of seismic intensity measurements, even for a given response spectrum. To cover the uncertainties associated with this variability, the seismic analysis of the dams is carried out using several ground motions, the choice of which is left to the expert judgment of engineers.

Following the approach developed in recent studies concerning other fields (Liang et al., 2020), the evaluation of the influence of IMs on the seismic response of dams could be carried out on the basis of a few well chosen structures and for response spectra corresponding to the standards of the participating European countries. The objective of the EWG contribution could be to provide recommendations, expressed with regard to relevant IMs of ground motion at ground surface, for

the choice of natural or synthetic accelerograms for a safe evaluation of the seismic performance of dams.

B. STRUCTURAL MODELING

B1. Comparison of numerical models simulations with dynamic field measurements

In recent years, the EWG has endeavored to promote the publication of case studies enabling field measurements to be compared with the results of numerical models (Fry & Matsumoto, 2018). This theme still seems very topical to us. It could also be envisaged to produce the **feedback of simulations compared to measurements** with a synthesis of the material collected during the various symposia which were the subject of proceedings.

B2. Simplified methods for the seismic performance assessment of dams

Several simplified methods for analyzing the seismic performance of gravity and embankment dams have been developed in recent years (Papadimitriou et al., 2014 ; Veylon et al., 2018 ; Durand, 2018 ; Frigo et al., 2017 ; Goldgruber et al., 2015). The purpose of the EWG's work could be to **evaluate the performance of these simplified analyses on real dam** examples encountered by dam engineers. This will be an opportunity to promote these methods to dams and levees systems owners or managers for whom the rapid and cost-effective assessment of their dams is an important issue in terms of asset management and prioritization of post-event visits.

B3. Earthquake-induced damage in old masonry dams

In Europe, a significant proportion of old dams were built in masonry in the 19th century. These dams have aged and the evolution of regulations have led some of them to the need to assess their seismic performance. The masonry dams are often made up of large blocks (several decimeters in diameter) initially embedded in a mortar of variable quality. In addition, the upstream faces of these dams are often made of paired and jointed stones which ensure the dam waterproofing.

Modeling tools should therefore adapt to these peculiarities which differentiate them from more recent concrete dams. Engineering needs constitutive models allowing the modeling of crack propagation under seismic loading taking into account: i) for the dam body: the heterogeneity of the dam body, scale effects related to the size of the blocks, ii) for the upstream and downstream facings : the mechanical anisotropy of the walls and iii) for the entire dam, the hydro-mechanical coupling which leads to the propagation of the interstitial pressure concomitant with the opening of the cracks.

The purpose of the EWG work could consist in formulating **recommendations for the calculation of these old masonry structure**s in terms of constitutive laws, methodology for taking into account scale effects and hydro-mechanical coupling. This work could be extended to the structures strengthened by earth backfills or post-tensioned anchors.

The list of topics is not limitative. The selected topics are simple proposals in which we hope that as many people as possible will find their interest. The EWG is obviously open to any other suggestion of topics such as seismic behavior of roller compacted hardfill dams, seismic performance of equipment, seismic monitoring and seismic surveys of dams performance, etc.

For each of the topics covered, the identification of existing scientific barriers could lead to the **definition of research projects** allowing for deeper and continued collaboration between the members of the EWG.

Activities

The activities will be powerpoint presentations, writing reports and organizing symposiums on a selection of the topics listed above (additional topics may be identified). General activities for the working group:

- Organizing benchmarks, documenting and sharing best practices,
- Organizing and running symposiums on the specific topics to provide a context networking of professionals and for the coaching and training of young and senior professionals;
- Promotion of related research and development by the redaction of synthesis or recommendations.

The ambition of the Working Group of the European club of ICOLD is to organize a workshop for the 2024 ICOLD Congress and write a synthesis report with the main achievements and perspectives of the Working Group.

Participants

In order to be representative of the know-how of all the european club members of ICOLD, the list of participants will be established after a call for applications sent to all national organizations.

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