Lecture Notes in Civil Engineering

Gabriella Bolzon
Donatella Sterpi
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Antonella Frigerio *Editors*

Numerical Analysis of Dams

Proceedings of the 15th ICOLD International Benchmark Workshop

Springer

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ICOLD Technical Committee

Computational Aspects of Analysis and Design of Dams

ICOLD, the International Commission on Large Dams, appointed in 1988 the ad hoc Committee Computational Aspects of Analysis and Design of Dams that was converted into a permanent Technical Committee in 2005. The main objective assigned to the Committee was to fill the gap existing between the specialists of numerical modelling and the different professional figures involved in the dam sector, i.e. dam designers, authorities, and managers. A second objective was to contribute to the diffusion of engineering software in the field of dam engineering, introducing new approaches in a context traditionally refractory to innovations. The Committee is also strongly committed in the transfer of experience, skill and knowledge across generations.

The work done by the Committee during its long activity lead to the issuing of three Technical Bulletins (1–3).

Present and future activities of the Committee are oriented towards:

- creating a stronger link between the observed dam behaviour and the modelling process, with the aim to contribute to the preservation and maintenance of existing dams;
- making advanced tools increasingly available to the professional world, for improved design of new dams;
- promoting mathematical modelling improvements to approach safety-related problems that cannot at present be properly analysed.
- issuing guidelines to be used for educational purposes in the current practice.

The benchmarking program started in Bergamo (Italy) in 1991 and has continued over the time in different Countries, with the 15th event of the series organized in Milano (Italy) on 9–11 September 2019.

The active involvement in the benchmarking activities of technicians operating in the dam sector is visualized in Fig. 1. The examination of these data suggests the following considerations.

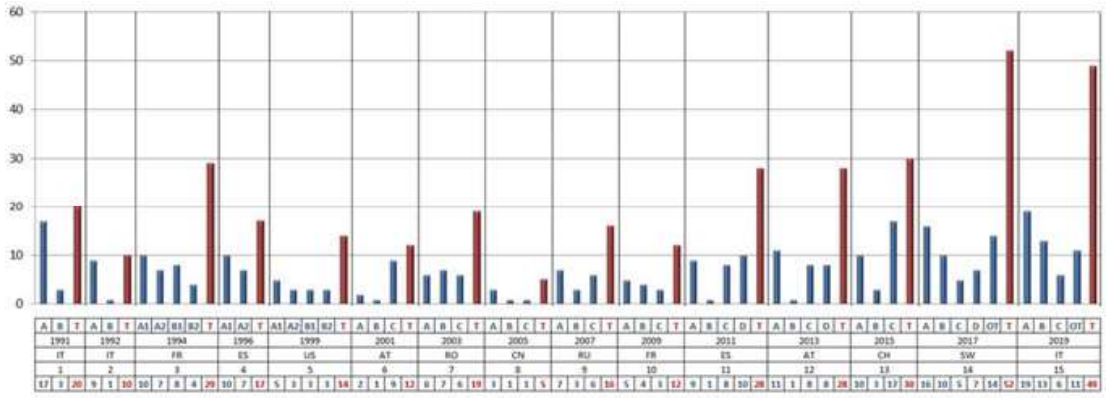

Fig. 1 Contributors to the 15 Benchmark Workshops held from 1991 to 2019 per theme and date (49 themes proposed in total); red figures and bars indicate the total number of contributors

- Until the 10th Benchmark Workshop (year 2009), the number of active participants (who provided a solution of the proposed problems) was mainly between 10 and 20; this number has been rapidly increasing in the subsequent editions.
- The total number of attendees has been always quite high, in the order of 100 people, with peaks of up to 190 participants in the last event in Milan.
- From a geographical point of view, the Benchmark Workshops took place mainly in European locations, with the exceptions of Denver (USA) in 1999 and Wuhan (China) in 2005. European centrality is partly linked to the prevalence of European members in the ICOLD Committee "Computational Aspects of Analysis and Design of Dams". However, the interest in the numerical modelling of dams has been increasing in the last few years in US and China, and these countries are prone to host these events soon.

The problem description together with the input data, and a report written by the formulator (about the individual results and their comparison) are collected by the proceedings that are available in ICOLD website.

A capitalization activity of the tremendous amount of data at disposal has been recently started with the aim to facilitate the accessibility and the critical review of the content of the Benchmark Workshops held so far. A new Bulletin—or an equivalent document—will provide a synthesis of the results, outlining the progresses made by numerical methods in dam engineering.

The benchmarking activities represent a reference for the whole dam community, and in particular for young engineers, engaged in the challenging task of ensuring dam safety.

Preface

This book collects the contributions presented at the 15th International Benchmark Workshop on Numerical Analysis of Dams held in Milano in September 2019.

These Benchmark Workshops are promoted by the Technical Committee on 'Computational Aspects of Analysis and Design of Dams' of ICOLD (International Commission of Large Dams) to provide an opportunity for engineers, researchers and operators to present and exchange their experiences and the latest developments related to the design, performance and monitoring of dams.

This series of almost biannual events was launched in Italy in 1991 and then hosted in several Countries all over the World. The topics and the approaches considered in the different editions reflect the evolution of the computer analysis tools and of the safety assessment criteria over the last decades.

The first benchmarks were focused on the validation of dedicated numerical codes, in their initial development phase. The predictive capabilities of available sophisticated computing facilities represent the challenges of the recent work. The main issues concern the selection of the most appropriate geometrical and constitutive models and the calibration of the parameters that define the conditions to be analyzed in reality.

The 15th International Benchmark Workshop on Numerical Analysis of Dams dealt with three main topics.

Theme A considers the earthquake response of a concrete gravity dam. The role of the foundation size and mass in the model, the interaction with the dam body and the non-linear material response represent the main debated aspects, with the ultimate goals of identifying the key uncertainties causing differences in results and developing the best practices in the advanced dynamic analysis of these massive structures. The benchmark problem has been formulated by: Jerzy W. Salamon and Christopher Wood (U.S. Bureau of Reclamation, USA); M. Amin Hariri-Ardebili (University of Colorado at Boulder, USA); Richard Malm (KTH Royal Institute of Technology, Sweden) and Giorgia Faggiani (Ricerca sul Sistema Energetico—RSE S.p.A., Italy).

Theme B refers to the seismic analysis of embankment dams. A case study is defined with the aim of understanding how different assumptions on the constitutive model of the rockfill material may affect the results. The stability conditions (in proximity to failure) of the dam after the assigned earthquake and, additionally, the potential damages of the bituminous facing represent problems to be specifically addressed in the proposal formulated by: Giacomo Russo (University of Napoli Federico II and University of Cassino and Southern Lazio, Italy); Manuela Cecconi, Alessia Vecchietti and Vincenzo Pane (University of Perugia, Italy); Andrea Fiorino and Sergio De Marco (So.Ri.Cal, Italy).

Theme C introduces to the pre-failure and failure behavior of a dyke on soft subsoil. The results of coupled hydro-mechanical analyses are compared with the monitoring data collected in a full-scale controlled failure test. The potential of current plane analyses to predict the failure and pre-failure response of the dyke is assessed. The improvement possibly provided by three-dimensional models taking into account the spatial variability of the soil layers is further evaluated. The benchmark formulation and the experimental information have been provided by: Cristina Jommi (Politecnico di Milano, Italy, and Delft University of Technology, the Netherlands); Tom de Gast, Elisa Ponzoni, Niccolò Valimberti and Stefano Muraro (Delft University of Technology, the Netherlands); Ludolph Wentholt and Henk van Hemert (STOWA, the Netherlands).

This volume contains both the problem definition (data concerning geometry, material properties, loading conditions, seismic input, etc.) and the throughout synthesis of the results, worked out by the formulators of each theme, together with the individual contributions by the benchmark participants.

Furthermore, the book introduces a series of topics relevant to the present practice in the computational analysis of dams and of the relevant appurtenant structures. The contributions collected in this volume focus on the study of dams with interesting features (Eberlaste, Grand Dixence, Nam Ngum 3, Ridracoli). Specific aspects of the numerical analysis of these infrastructures are discussed, with an open eye on: monitoring and identification problems; uncertainty quantification and reduction; classification models; visualisation tools and machine learning; cost risk assessment. These topics are proposed in the frame of an Open Theme session that allows to identify possible topics to be proposed in the future Benchmark Workshops.

All together, these contributions constitute a valuable reference for the whole engineering community concerned with safety, planning, design, construction, operation and maintenance of dams.

The 15th International Benchmark Workshop was organized in the main Italian financial city that hosts the headquarters of several global Companies and the seat of many International Institutions. Milano represents the cultural site and an attraction place for many professionals, including designers, fashion-operators, artists, photographers. The rich environment created by its historical heritage, together with several new quarters designed by outstanding architecture studios make Milano the Italian city of glamour with a vivid cultural and social life.

The editors acknowledge the contribution given by several Colleagues for the successful realization of the event and wish to express their deep gratitude to them. The Editors do also gratefully thank:

- the Team of Formulators for the tremendous work done to define the theme content and for providing the synthesis of the results obtained by the several participants, and Giorgia Faggiani for her assistance in the editing process;
- ITCOLD, Politecnico di Milano with the Department of Civil and Environmental Engineering, the research institute Ricerca sul Sistema Energetico-RSE, the Consiglio Nazionale degli Ingegneri for the organizational support;
- the sponsors who provided financial support and facilities for the workshop and the technical visits;
- Regione Lombardia and Comune di Milano for the patronage offered at the event.

Promoted by the ICOLD Technical Committee Computational Aspects of Analysis and Design of Dams, and organized by Politecnico di Milano, ITCOLD, Consiglio Nazionale degli Ingegneri, Ricerca sul Sistema Energetico-RSE.

ICOLD Technical Committee A
Computational Aspects of Analysis and Design of Dams

Under the patronage of Comune di Milano and Regione Lombardia.

With the sponsorship of ENEL, Mapei, Gruppo CVA, Romagna Acque, EDISON, A2A, Gelmi, and the hospitality of ENEL and Consorzio di Bonifica di Piacenza for the technical visits to Isola Serafini weir and Molato Dam.

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