Article, Published Version

**Yun, Li; Guoxiang, Xuan; Xiaogang, Wang**

# Research progress of the dam break test and simulation technology

Hydrolink



# RESEARCH PROGRESS OF THE DAM BREAK TEST AND SIMULATION TECHNOLOGY

BY LI YUN, XUAN GUOXIANG, WANG XIAOGANG

## 1 The status and significance of dam break study

Dams have brought enormous social and economic benefits to human beings. However, for various reasons, quite a lot of dams have potential safety defects. Once a dam fails it can potentially cause tremendous losses in lives and properties downstream. For example, the 1993 failure of the Gouhou Dam in Qinghai Province in China resulted in the loss of over 1,000 lives, together with serious social disruption and economic losses. The Opuha Dam in the South Island of New Zealand failed during construction (at about 60% of design height) in February 1997. Although no lives were lost from the overtopping failure of the 35-m-high dam, the resulting flood event caused huge economic and environmental damages. Accurate assessment of the consequences of dam failure events has been a worldwide problem, which has promoted dam failure studies and analyses in recent years.

Dam breach usually occurs in embankment dams[1, 2], and is a gradual process. Forecast accuracy of the flow process in dam breach directly determines the accuracy of flood routing calculation. Therefore, it is of great significance to master the practical process of dam breach development. The process of dam breach involves sediment transport in unsteady rapidly varied flow, and is a strongly nonlinear process. The mechanism involves hydraulics, soil mechanics, sediment transport mechanics and so on. Therefore, the research on dam breach has no breakthrough as yet[3]. Dam break model test technology is still at the starting stage.

The magnitude and extent of damage caused by a dam break depends largely on the dam-breaking rate and degree, which determines the breach outflow and its spreading speed downstream. Due to the capability for simulating dam break and predicting flood hydrograph, a dam break model is of tremendous importance to the disaster control and reduction.

## 2 Ongoing research

*2.1 Numerical simulation technology for dam break*

The CADAM project launched by the European Commission in 1998 compared the results obtained by calculation with experiment achievements (the observed data included). The research report indicates that the existing mathematical models have limited accuracy. The errors may reach ±50% between the predicted peak flow and the observed data. And the consequences are even worse in other aspects.

The numerical models developed at present can be divided into two categories. The first one is based on parameters, such as the DAMBRK model and SMPDBK model developed by the National Weather Service of U.S. This type of model is relatively simple. It has less input requirements and are more convenient to use the data, but the accuracy is inadequate as they do not reproduce the dam break mechanism. The second one is based on the physical process of dam break. The models always integrate hydraulics, sediment transport mechanics, soil mechanics, hydrology and other disciplines to build a time-dependent process in order to simulate the actual process of dam failure and outburst flood. This type of model is more complex in structure and more accurate and detailed to simulate the dam break process. However, the models are also restricted by current mechanisms. There are some famous models, such as the BEED model, BREACH model, BRES model, and Zhu (2006) model.

The study of dam break in China began in the 1950s. The research is mostly based on the analysis of dam break data in history. Empirical relationships are established between various parameters by making some assumptions (instant outburst for example). Many achievements have been obtained up to now. Based on the study of the mechanism of dam break, Nanjing Hydraulic Research Institute under China's Ministry of Water Resources has been conducting an in-depth research on three subjects: "whether it will collapse", "when the collapse happens" and "how to rescue" in recent years. Some discriminating models have been achieved. By use of various formula [4, 5], we can calculate the discriminating score to distinguish the stability of the dam quickly and

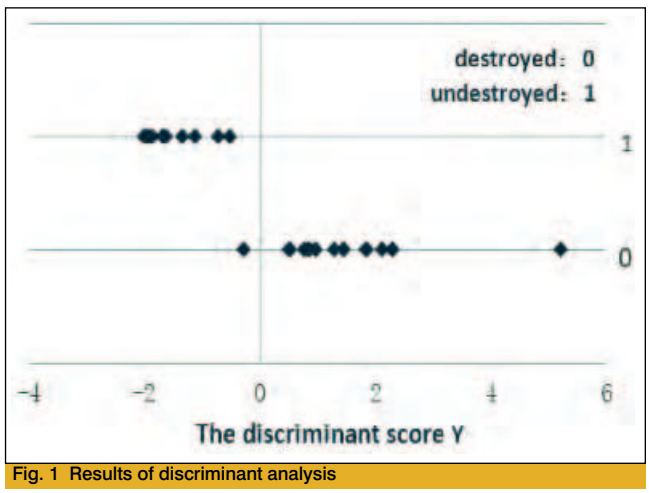

Fig. 1 Results of discriminant analysis


Fig. 2 Large-scale field test

effectively. The calculation results with a set of data are shown in figure 1.

*2.2 Physical experiment study on dam break*

Countries all over the world attach great importance to the dam safety since the consequences of dam break are so serious. Since the 19th century, quite a good number of scholars have carried out detailed studies of the dam break problem through theoretical analysis, physical model tests, numerical simulation, historical data statistical analysis and so on. In recent years, dam break risk assessment, dam monitoring, the development of early warning systems and dam failure mechanisms have become new research targets. Physical model tests are still necessary to discover unknown factors in breach formation. The experiment results can not only compensate for the limitations of historical data in quantity and reliability, but also provide validation data for the numerical simulation.

At present, physical simulation research at home and abroad can be divided into three main regions: the European Union, the United States and China.

*2.2.1 Physical experiment study abroad*

The European Commission launched the IMPACT (Investigation of Extreme Flood Processes and Uncertainty) project immediately after the end of the CADAM (Concerted Action on Dam Break Modeling) project in 2001, focusing on the key technical issues presented by the research report of the CADAM project. The study mainly includes five aspects: the process of dam break, flood routing, sediment movement, error analysis and geophysical exploration.

*The NDSP (National Dam Safety Program) in U.S.*

Dam break analysis is the ninth subject of NDSP, which started in 1999. A workshop named "Workshop on Issues, Resolutions, and Research Needs Related to Dam Failure Analyses" was held in June 2001, and its purpose was to determine the recent and long-term research goals based on the dam break research and technical level of America.

*The others*

Besides, human stability and mobility in flood as well as the roughness of forests and buildings were considered in the research of the RESCDAM project in Finland. The NATO project in Portugal made a discussion of dam break flood routing and sediment movement in an

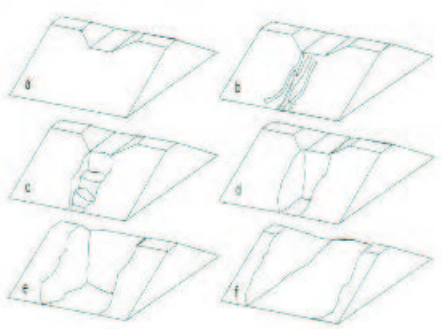

Fig.3 Headcut advance mechanism

irregular valley. A project named IJKDIJK was started in the Netherlands in 2007 and is still continuing. It's a Dutch research program with the two-fold aim to test any kind of sensors for the monitoring of levees under field conditions and to increase the knowledge on levee failure mechanisms. The all-in-one Sensor Validation Test of the IJKDIJK was carried out in August and September 2012, while the liquefaction test will be carried out in 2013. Experts and scholars from all over the world have made various studies on dam break issues and related experimental studies have been carried out. The flood routing, overtopping, dam break process of non-cohesive homogeneous dams, seepage failure, characteristics of thixotropic flow caused by the dam failure, the aeration of water flow, vortices generated by the flood wave and so on have all been investigated.

### 2.2.2 Physical experiment study in China

The experimental study of dam break in China began in the 1950s, and the models were generally distorted models whose test results were directly offered to engineering design. An insightful discussion was held after the dam break of Banqiao reservoir in 1975. Some experimental studies on fuse plug spillways have been carried out since the 1970s. Scholars in Henan Province have made some 30 tests on the fuse plug spillway for Yahekou reservoir. The Hydraulic Research Institute of Zhejiang Province carried out some experiments on the

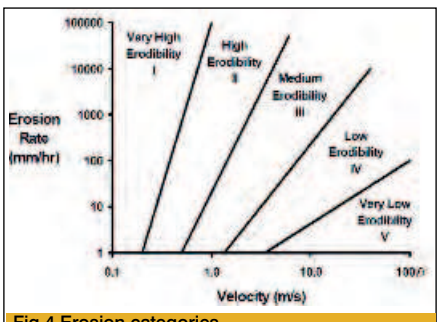


Fig.4 Erosion categories

***Prof. Li Yun,* vice president of Nanjing Hydraulic Research Institute, is now director of the Key Laboratory of Water Science and Engineering under China's Ministry of Water Resources, director of the Chinese Society for Hydropower Engineering, and deputy director of IAHR China Chapter, etc. So far, he has chaired and completed a number of national and international research projects with a lot of innovative achievements.**

***Professor Xuan Gouxiang,* chief engineer of Hydraulic Engineering Department of Nanjing Hydraulic Research Institute and vice secretary-general of Navigation Committee of China Society for Hydropower Engineering, has published about 30 papers and written more than 30 research reports, 1 academic monograph, and 2 standards of related specialties.**

***Senior Engineer Wang Xiaogang,* member of the Chinese Association of Young Scientists and Technologists, long engaged in dam-break hydraulics research, works in Hydraulic Engineering Department of Nanjing Hydraulic Research Institute, and has published more than 15 papers.**

**NHRI IS AN IAHR INSTITUTE MEMBER**