DAMS AND MANAGEMENT OF THEIR RISKS

Throughout history the construction, operation and maintenance of dams and their reservoirs have provided significant benefits to mankind. Storage of water behind dams provides effective means to regulate natural streamflow but at the same time creates a new hazard downstream if the dam fails.

No matter how small the likelihood of failure, any dam failure is still a matter of great concern to engineers in the dam engineering community. This concern arises from the potential catastrophic effects of the flood wave on a populated valley downstream of the dam. Through engineering education, research and from the experience of many years of dam operation it is known that on average, in any year, less than 1 dam out of every 10,000 large dams fails. Dam engineers recognize this possibility and have been systematically increasing the knowledge of dam failure mechanisms and how to engineer against them. This leads to the question of how safe should new or existing dams be? Given the potential consequences to third parties of a dam failure, many would say safety should not be based purely on engineering considerations, but should consider the level of risk that is tolerable to the general public.

Reflecting on this important subject, it should be noted that the steadily increasing trend in the industries with a potential to cause harm is to clearly delineate the roles and responsibilities with respect to safety within the political/societal and engineering domains. Thus the modern approach to safety postulates that the political bodies representing the interests of the entire society establish the required safety levels or risk management systems and through appropriate regulations monitor whether the levels are being achieved. The role of the engineering community is to ensure that all necessary arrangements are in place to achieve these safety standards in order to protect people, property and the environment from the harmful effects of dam failure or inappropriate operation. The term 'arrangements' can be understood in a very broad sense as the entire range of operational and management activities with the safety assessment being one of the most important operational activities. The importance of safety assessment activities originates from the fact that the outcome provides the information for judging whether the legal and societal safety requirements are met. Thus, the role of the engineering community is to support the process of safety assessment by continuous development of better assessment means through leveraging off the progress in technical and analytic knowledge.

Traditional methods of dam engineering have always been focused on performance integrity in design and have resulted in a history of dam designs that have an excellent overall record of performance. For various historical and technical reasons, the safety of dams has been controlled by a rules-based approach. This has evolved from the "accepted best practices of the day" over many years, initially for the design of new dams, but over the past few decades increasingly this has been applied to assess the safety of the existing dams. In following this approach dam engineers have always been conscious of the effects of uncertainty at all stages of analysis and assessment and have taken this into account either intuitively or, indirectly, by following the widely accepted methods of traditional analysis, such as the use of safety factors and conservatism in applying loads and considering plausible scenarios.

Societies are evolving and their populations are becoming increasingly aware that safety is not an absolute condition, but is a tolerated situation, with various levels of residual risk always present and there is an implied trade-off between costs and benefits. Societal development has resulted in the need for this trade-off to be examined explicitly in the public domain. This demand by society brings the requirement that risks are identified, assessed, kept under review and properly controlled has resulted in the application of risk assessment over a very wide spectrum of public and private activities which have the potential to affect the welfare and interests of the community. Some are now asking whether the techniques of risk assessment, developed for other industries, could be adapted as an additional means to assist in decision-making for dam safety management. At the same time the increase in the complexity of decision-making for dams, to meet societal demands for transparency and accountability, requires an improved approach for their economical and safe operation, maintenance and overall management. The traditional standards-based approach, by itself, is becoming increasingly inadequate to handle a single dam or a portfolio of dams in allocating limited resources for their operation, repair or improvement, in a climate of growing public scrutiny.

Risk assessment is one technique, which has the capacity to assist with this type of complex problem. It focuses on relating performance levels to consequences thus allowing an engineer to better demonstrate to decision-makers the real human and economic and engineered risks associated with investment decisions. In risk assessment the uncertainties are explicitly taken into account by expressing them in probabilistic terms. This approach is a way of dealing with inherent or natural uncertainty, which can be statistically analysed with some degree of confidence, as well as uncertainty due to lack of information or knowledge, where the basis for estimation of probabilities is sometimes limited to expert opinion. The uncertainties are propagated through the system to get a quantitative estimate of the probability of failure and the likelihood of associated unwanted consequences (be it lack of water or power or a dam-break flood).

The application of probabilistic methods of risk analysis in dam safety assessment also provides an improved understanding of the unique way in which different types of structural and non-structural measures can reduce dam failure risks, thereby giving greater confidence in the effectiveness of a wider choice of risk reduction measures. Non-structural measures which in the traditional approach were felt to enhance safety, but often with concerns for their reliability, can now be demonstrated, by formal analysis of likelihood, consequences and uncertainties, to have a role in reducing risk, which is distinct from that offered by structural measures.

Key elements of risk assessment are now past the research and developmental phase in application to dams. The fundamental principles of risk assessment are logical and sound and should be considered by all ICOLD countries as part of the decision-making for dams and overall management of risk posed by dams. Keeping in mind that applications of technology and extent of transparency of decision-making are strongly conditioned by the cultural background of a particular country and recognizing that cultural differences between countries must be respected, each country needs to consider the relevant framework and modeling techniques for their society. Thus, risk assessment should not be the only decision basis that is used in the management of dam safety risks. Other bases should include consideration of engineering principles, standards and current good practice, owner or wider societal values, and stakeholder expectations and perceptions. The inclusion of risk assessment in this process is sometimes referred to as a risk-enhanced or risk-informed approach, in which risk assessment informs the decision process and provides solid basis for development of effective and efficient management of dam safety risks.

The understanding of dam safety risk through a comprehensive risk assessment is thus a key element in developing dam safety management system – a formal and organized process ensuring that the dam safety risks are properly managed through the entire lifecycle and that all aspects of safety management are properly integrated and aligned with the dam owning organization’s overall management structure.