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Gallimaufry: News and Events from the British Dam Society

Welcome to issue 4 of *Dams and Reservoirs*. In this issue we complete our write-up of the 2014 conference in Belfast, with an article summarising the pre-conference tour and the technical visits. We are pleased to include a paper by David Porter, of the Rivers Agency, on the Reservoirs Bill in Northern Ireland. We are also pleased to include a paper on the influence of the detailing of the core on slope stability in earth and rockfill dams.

We would like to encourage our readership to submit discussions for our published papers. Please email up to 500 words to Anthea Peters at editor@britishdams.org.

We are currently looking for papers for publication in our 2016 journals. If you have an idea for an article or review, please contact me to register an interest.

Finally, if any of our readers enjoy adrenaline-fuelled sports and a passion for dams, you may be aware of Primoz Ravnik, a mountain biker who cycled down a 60 m-high dam in Slovenia. The footage is widely accessible on the Internet.

1.1 Review of ICOLD Bulletin 143: 'Historical Review on Ancient Dams'

The bulletin on a 'Historical Review on Ancient Dams' was one of the outputs of the Ad Hoc Committee on Small Dams (International Commission on Large Dams (ICOLD), 2013a). The bulletin points out that about 90% of dams in the world are 'small' dams (i.e. they do not meet the ICOLD criteria of a 'large' dam (i.e. > 15 m)) and therefore there is a great interest and involvement of most dam engineers in this large group of structures.

They cite that there is evidence of construction of small dams from about 5000 years ago in Jordan, and 4600 years ago in Egypt and Baluchistan, and from 3250 to 3500 years ago in Turkey, Yemen and Greece. The Romans had a significant impact constructing several dams about 2000 years ago in most countries around the Mediterranean Sea. Most were small dams in the range 3 to 10 m high. In Ceylon in 504 BC there was a dam some 17 km long and 21 m high, consisting of about 13 000 000 m^3 of fill – quite a feat for that time.

As one might expect, the first dams in the world were built by beavers in the northern hemisphere – some as old as 125 000 years – with the first built by man around 5000 years ago.

Sadd-el-Kafara is cited as the first dam; built around 2600 BC to a height of some 14 m and a length of 113 m. It is a rockfill embankment used as flood alleviation.

Examples from Australia include tidal dams, similar to ones built in the UK, using timber and logs but later utilising masonry. Most dams were built for water supply or irrigation. Earthfill later took over to be the most common form of construction. In Australia, dams were originally constructed to enable logs to be floated down the rivers, but later were built as flood retention dams. The first hydro dams seemed to appear in the 8th century.

Other countries included in the bulletin include Brazil, Cambodia, China, Cyprus, the Czech Republic, France, Germany, Holland (where dam building seemed to start in 3150 BC), Iran, Italy, Japan, South Korea, Libya, Mexico, Portugal, Slovenia, Spain, Turkey and the UK.

1.1.1. A wide range of type and uses

This document describes many ancient dams and in so doing gives us a better understanding of how the construction of dams has developed and improved with time.

It contains many case histories and photographs and sketches of old dams and is a fascinating read – highly recommended.

A K Hughes

2.1 Review of ICOLD Bulletin 155: 'Guidelines for Use of Numerical Models in Dam Engineering'

This bulletin (ICOLD, 2013b) is made up of six main chapters and covers modelling physical processes related to dam structural behaviour. It should be noted that the guide does not cover computational fluid dynamics or any other hydraulic modelling techniques. No performance criteria or specific modelling approaches are detailed in this bulletin; these have been omitted since they are covered in detail by different standards and codes adopted in most countries. The topics covered by the bulletin are listed as follows

- numerical modelling for structural analysis of new dams
- issues related to numerical modelling for existing dams
- lessons learnt from 148 case studies covering 30 specific research topics
- integrating numerical modelling into a general engineering approach.

Chapter 2 provides a number of high-level considerations for setting-up, prototyping, running and interpreting a numerical model, specifically with regards to dam design. Also given in this chapter is some limited technical guidance on hydration, self-weight, hydraulic, thermal, blast and earthquake loadings (although the latter of these is covered in greater detail in ICOLD Bulletin 72 (ICOLD, 1989)). Following this, some considerations are also given to design optimisation processes.

Chapter 3 covers issues that an engineer might encounter when using numerical models to analyse existing dams. Considerations include uncertainties in measurements, forecasting methods, use of monitoring systems, structural failure mode identification and unexplained numerical behaviours. While no specific technical guidance is given, as mentioned above, this chapter is intended to inform the philosophy and approach when using and interpreting numerical models.

Chapter 4 commences with a list of 30 topics for research that were proposed across ten ICOLD benchmark workshops. The topics cover a broad range of issues affecting different types of dam and have been answered using 148 individual case studies. Rather than summarising each of the large number of case studies (listed in Table 10), a series of 'Main lessons' for modelling arch, gravity, rockfill, concrete-faced rockfill, and embankment dams have been given. This format is particularly useful for engineers setting-up and running models as it may help inform which techniques can be effectively employed and aid in identification of model instability or spurious results.

Chapter 5 covers the application of models to real world engineering. This chapter addresses a number of fundamental concerns when applying models, including verification and reliability (making reference to a number of specific examples, including internal and surface erosion modelling for embankments, first impounding behaviours and settlement of rockfill dams, and cracking of roller-compacted concrete dams under post-construction thermal shrinkage). Use of modelling for risk analysis, especially with regards to ageing infrastructure, is also discussed in some depth.

The final chapter starts by summarising 'what numerical models can do' (section 6.1.1) and 'what numerical models cannot do' (section 6.1.2). This is followed by a section discussing a number of important precautions and suggested modelling philosophies. The bulletin is concluded by a series of developments which would aid dam engineers in the future.

This document is a valuable source of guidance for engineers who prescribe or undertake numerical modelling since it serves as a useful reminder of where and which models may or may not be appropriate for the design of new dams, or for interpretation and prediction of behaviour at existing dams.

Rhys Coombs

3.1 Review of ICOLD Bulletin 158: 'Dam Surveillance Guide'

The purpose of this recently published bulletin (ICOLD, 2015a) is to provide an update to the ICOLD Bulletins 60 and 68 (ICOLD, 1988a, 1988b). The focus on this bulletin was on surveillance of dams, covering routine visual inspections, testing of equipment, automation, ageing monitoring systems, and more recent developments in the management and safety monitoring of dams. The bulletin covers re-instrumentation of existing dams, and the prioritisation of maintenance, remedial and upgrading works.

Technical committees of ICOLD have already produced several bulletins on instrumentation of which the following are relevant: Bulletin 87 (*Improvement of Existing Dam Monitoring – Recommendations and Case Histories*) (ICOLD, 1992), Bulletin 118 (*Automated Dam Monitoring Systems – Guidelines and Case Histories*) (ICOLD, 2000) and Bulletin 138 (*General Approach to Dam Surveillance*) (ICOLD, 2008).

The bulletin provides an overview of monitoring techniques, ranging from traditional piezometers to recent developments in remote satellite monitoring using the Global Navigation Satellite System monitoring methods.

Modern monitoring systems can now generate vast amounts of data, and this data will need to be processed, analysed and interpreted. The system installed needs to be able to filter any anomalies, particularly those concerning the dam behaviour that would impact on the monitored physical qualities; as such, the bulletin clearly describes various types of models that can be used to highlight these anomalies.

Overall, the bulletin is a useful tool to provide guidance on available methodologies for monitoring and the analysis of the data collected. It provides a good overview of the systems available to both reservoir owners and reservoir engineers alike.

Alexandra Topple

4.1 Review of ICOLD Bulletin: 'Cutoffs for Dams'

The ICOLD bulletin (ICOLD, 2015b) on cutoffs for dams has been produced by the Committee on materials for fill dams.

The bulletin is limited to foundation treatment methods using cutoff-type barriers. The foundations considered include alluvial deposits, previous residual soils, pervious laterites and saprolites, highly fractured and weathered rock, and karst formations.

It is recognised that construction techniques have progressed significantly during the last two decades, through the development of more powerful machinery for drilling and excavation but also through the introduction of 'new' concepts and techniques such as jet grouting and deep soil mixing. The concept of diaphragm wall techniques using a cutter to provide continuous excavation started in Japan in 1980 with rapid developments in Europe following. Cutoff depths exceeding 100 m with vertical deviation of less than one per cent have been accomplished.

The cutoff types presented in the bulletin include diaphragm walls, vib walls (vibrated membranes), pile walls, superimposed concrete galleries, jet grouting and deep mixing.

Case histories are extensively used to illustrate the practical application of the methods and with how difficulties are dealt. The most widely used type of cutoff is the diaphragm wall.

The factors affecting the selection of cutoff are specified as

- depth of strata to be treated
- shape of the valley
- characteristics of the in situ material to be treated including the presence of boulders
- hydraulic gradient
- available equipment for constructing the cutoff
- project (new or existing dam)
- and, in some cases, personal preferences which might influence the choice of cutoff.

It recognises that a cutoff cannot completely eliminate the flow of water through the foundation. That the cutoff itself also has permeability and flow can take place around the cutoff or through incompletely treated strata below the cutoff. The cutoff wall, if not carefully constructed, may also have defects that can develop into preferred paths of seepage.

Seepage is defined as the slow, uniform flow of water through a porous medium, whereas leakage is the concentrated, uncontrolled flow of water through a crack or any other defect. Seepages beneath a dam founded on alluvium are considered unacceptable if they exceed $1{\cdot}6 \times 10^{-4}$ m^3/s per linear metre of dam.

The bulletin reminds readers that an experienced subcontract is necessary and strict quality control is essential. Performance of a cutoff is usually monitored by piezometers installed in the foundation both upstream and downstream of the cutoff.

4.1.1. Need for cutoffs

Usually seepage control is needed

- to ensure the stability of the downstream portion of the dam to prevent uplift pressures and possible piping failures
- to prevent excessive loss of water.

When the impervious strata is shallow (i.e. less than about 5–8 m), a core trench is usually excavated with the pervious material replaced by a low permeability fill that is connected with the impervious element in the embankment. A core trench allows visual examination of the excavation and assessment of the excavated material.

Other methods to control foundation seepage when thicker alluvium or other foundation material is excavated include

- measures to control hydraulic gradient
  - upstream blanket
  - partial cutoff
  - downstream drainage trench
  - downstream filter blanket
  - downstream
  - relief wells
  - downstream filter
  - or a combination

- measures to control the quantity of seepage
  - positive cutoffs
    - diaphragm walls
    - slurry walls
    - sheet pile walls
    - pile walls
    - vib walls
    - superimposed concreted galleries
  - semi-positive cutoffs
    - walls produced by jet grouting
    - walls produced by deep soil mixing.

In a positive cutoff, the wall consists of engineered material placed into a previously excavated trench or driven hole. In a semi-positive cutoff, the barrier is constructed by mixing existing ground with a binder, usually cement. The type of cutoff and depth will depend on the geology and a significant site investigation will be needed to ensure the cutoff meets an impervious strata. Grout curtains are not considered to be positive cutoffs and are not discussed in the bulletin.

The bulletin goes on to discuss the methods to reduce seepage and also to control hydraulic gradient.

Whole chapters are devoted to some types of cutoffs, including diaphragm walls where the single and twin phase methods are described. The machines, the method of construction and the quality control methods are described, and the mixes and mix proportions are shown.

The section on the factors that influence the long-term performance of diaphragm walls is particularly interesting, as is information on post-construction leaks.

A chapter is provided on vib walls, pile walls (e.g. secant, etc.) detailing principle of construction, construction materials, design criteria, methods of quality control, design details and methods of analysis. Jet grouting, superimposed galleries and deep mixing are the subject of subsequent chapters.

More than 30 case histories on all the techniques are given from dams from all over the world.

Again a very useful reference document but also an interesting read in itself.

Dr Andy Hughes

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