MATTERS RELATED TO ADVERSE INCIDENTS ASSOCIATED WITH DAMS AND THE ROLE OF REVIEW PANELS : THE GEOFFREY BINNIE LECTURE 2004

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1. INTRODUCTION

It is pleasing to have been invited to present the Geoffrey Binnie Lecture for 2004, and particularly at this meeting of the European Club of ICOLD. In addition to recognising Geoffrey's eminent career in dam engineering, and enjoying his books on early practitioners in this field, I have, in the past, had occasion to benefit personally from his generous opinions on specific Project and Institutional matters.

My career, based mainly on hydro power engineering, commenced following the Second World War, and has involved various responsibilities on a relatively large number of worldwide projects. Among these has been that of working with Insurance Companies concerned with construction risk, including investigation of adverse incidents. More recently, and for some years since retiring from line management, I have mostly been involved in the work of Review Panels.

The choice of a topic for this lecture has not been without some hesitation, and originally leaned toward the constitution and responsibilities of such Panels. However, on reflection of more than half a century of work on engineering projects, it is apparent that many changes have occurred during this time in all aspects of our work, including the role we, as Engineers, have in society as a whole, and particularly in relation to accountability for safety of the work in which we are involved.

I propose, therefore, to share with you some thoughts on some of these matters, to discuss some of the changes which have taken place, including the occurrence and potential mitigation of adverse incidents, and, finally the role of Review Panels in development and construction of major dam projects.

2. SOCIETARY CHANGES

2.1 The Engineer

A century ago, engineering achievements were widely recognised and respected by the establishment and society as a whole; and successes of individuals were acknowledged. Even in the fifties, there were still publicly well known dam engineers who had substantial influence in the corridors of power, and I may mention but one of those, Sir Murdoch MacDonald, who had great influence with others on the development of hydro power in Scotland, and whose firm I had the privilege of joining in my early career.

Regrettably, today's professionals are somewhat anonymous other than in a close community. It has been postulated that advancing technology and growth of specialist societies have contributed toward this situation, so that the public image of the engineer is not as strong as, say, the medical or legal professions. It also seems to me that the development of larger companies has contributed to the anonymity of individual achievement.

The Rt. Hon. Tony Benn PC speaking at a Royal Academy of Engineering meeting (6) earlier this year, urged engineers to take a more active role in political decision-making, and instanced the influence of the momentary state of technology on the development of society, from the stone age through to the present, where computers, internet and even space travel are prominent.

Perhaps we can be encouraged by recent media programmes on the achievements of Brunel and his public rating in the hierarchy of famous British persons.

2.2 The Media

The role of the media in present day society is open to question; what happens, and what is perceived to happen in society can be two different things, the reality of which is often lost in the translation (7). The priority appears to be the first to report an adverse situation and to attempt apportioning responsibility, usually with broad imagination and often relying on information from "sources close to the project". The approach is invariably justified to be in the public interest. Attempts at rebuttal are not generally successful. A classic case relates to the aftermath of the Teton Dam failure, referring to the alleged concern over the then safety of Federal dams in the USA, and the subsequent published comments of an engineer member of the Independent Panel to Review Cause of that Event (14). The article is copyrighted by the Society of American Military Engineers.

Media interviews, particularly live on television, tend to require yes or no answers to convoluted or loaded questions, and a change in subject when the thread is going against them. Interviewers admit seeing their role as putting an alternative point of view, seemingly regardless of the validity of a reply.

It is not unknown for journals associated with professional bodies to act in this way. On the other hand, one cannot help but be amused by some of the cartoons which have appeared in those journals, and I have cause to remember one related to Carsington which, as you will see, bears some relation to actual events.

2.3 Environmental and Social Issues

Evaluation of environmental and social issues is presently recognised as an essential consideration in planning of any major works and is applied to development of dams, and has been so for some considerable time.

Such studies have now been more formalised and assessed against acceptable world standards. Global issues such as greenhouse gasses and biodiversity, as well as project factors such as water quality, aquatic habitats, endangered species etc., all have to be addressed. Temporary impacts during the construction also have to be considered, including their potential mitigation.

Agreement on some of these matters can sometimes be difficult, and take time, particularly if there is considered to be the possibility of extinguishing a species by changing its habitat. If we recognise, and accept, that flood control, power irrigation, water supply and even recreation are necessities, the decision to proceed may need to be founded on intelligent preference rather than politics, or emotion.

The provision of facilities for the public at reservoir sites, including such as sailing and fishing and open footpaths, has been well received by the public.

The range of amenities provided by Severn Trent at Carsington, at substantial cost, attract many visitors each year and are extremely popular with local residents. Walkway routes, including across the dam crest at Ladybower and developed during the raising of that structure are also well utilised.

2.4 Compensation Culture

The burgeoning development of compensation culture is also not without influence on our work. Such claims against public sector services are reported to be having crippling effect on health and education sectors of society.

One result is that field trips for schools are declining; some children are to be given "virtual" geography journeys to save them from actually going to the countryside, because of fears that real outdoor activities could be too dangerous. But surely looking at a mountain on a computer screen cannot replicate standing at the base of the Alps, and thinking "wow", and, more importantly, pointing the student towards our profession.

Class actions appear to be often pursued and mainly benefit lawyers and accident firms. Such could well be the case if inhabitants downstream of a dam were affected by release of water in a particular adverse event.

2.5 Impact

The changes briefly outlined above inevitably impact on the profession's approach toward the release and distribution of particular technical information, which otherwise would be of interest and potential use to colleagues.

3. CHANGES IN PRACTICE

3.1 Technology

Advances in technology during recent decades have been impressive. Approaches to computations, analyses, testing and construction have all seen significant changes. It is only half a century ago we were producing by hand three sets of contract drawings printed on linen, coloured and bound. Now we are likely to produce much of the information on soft copy.

But, it has to be recognised that our current capability of precise mathematical analysis, modelling of stresses, deformation and seepage, investigation and testing of site conditions, can exceed our capability to make judgements of comparable accuracy relating to the potential for adverse impact of potential methods of construction, or variability of parameters which have been assumed.

There are obviously a number of fundamental similarities between dam sites in that a barrier must be built to retain the reservoir and the river must be diverted during the construction. Beyond this the arrangement for layout of the structures depends on the particular conditions relating to the site, which may lead to some innovation.

As for the dam itself, there have been some changes in preference in the last few decades, during which some were constructed with upstream or central membranes of asphalt or concrete. Experience with the former has, in cases, led to need for sometimes extensive repairs. Concrete Faced Rockfill (CFR) solutions have been successful, and heights in excess of 200m are presently envisaged.

The development of Roller Compacted Concrete (RCC) solutions has been widely favoured in a number of cases where the foundation is acceptable. The highest of these completed at present is La Miel in Columbia, but programmes are in hand for Longtan in China at 216m and, I understand, in Pakistan, Basha Diaman Dam is planned for an ultimate height of 290m.

The Capanda Dam, in Angola, and 100m high, is referred to in Section 5 of this report. It was started in 1988 and only now nearing completion due to adverse public circumstances in the country. It is of interest because milled fine sand found locally is used instead of importing a pozzolan, an approach developed by Russian Engineers.

Earth and rockfill dams continue to be prominent. The previous leaning towards flattening of slopes for use of weak soils has been ameliorated to some degree by using the cofferdam, well instrumented, as a test fill. Quality of instrumentation and real time monitoring has been a significant factor.

3.2 Auxiliary Structures

A number of changes have been developed with regard to auxiliary structures, both permanent and temporary. The most significant is possibly that of aeration of spillway chutes or tunnels.

The design of intake structures, particularly for water supply projects, is now being reconsidered, particularly for seismic areas. Historically, in U.K. at least, water intakes have been contained at several levels within a vertical tower. Access to the tower is by bridge. At several reservoirs, including Sulby, Westwater, and Windscar, inclined galleries down the abutment upstream have been adopted (16). Operation and maintenance of these are said to be practical. There are some other such galleries in the U.S.A. and in North Africa, and the approach is now being pursued on several dams under construction in Greece.

On one, Gadouras, on the island of Rhodes, the system has been further developed in that vertical inlets are taken from the surface direct into the diversion tunnel. The vertical shafts are cored down to intersect niches in the tunnel walls, and short intake structures are constructed at the surface level of each. A sloping track down the slope will afford access for maintenance, or they can be reached by boat. The system is economic and could, in fact, justify a modified alignment of a diversion tunnel, though this was not necessary in the case of Gadouras.

Gadouras Intake Structures

3.3 Diversion Works

For major projects, the diversion works are obviously critical. The capacity of these works is usually based on a flood probability determined from annual river flow records, by rainfall records for the specific catchment, or from regional data. Historically, probabilities as low as 1 in 10 have been adopted, but that figure is now more likely to be 1 in 50 or even 1 in 100 if insurance cover is required.

Apart from providing the capacity for diversion, the closure of the conduit, be it culvert or tunnel, and by gate or stoplogs, has to be planned at the time of design of the works, and testing in a hydraulic model is essential.

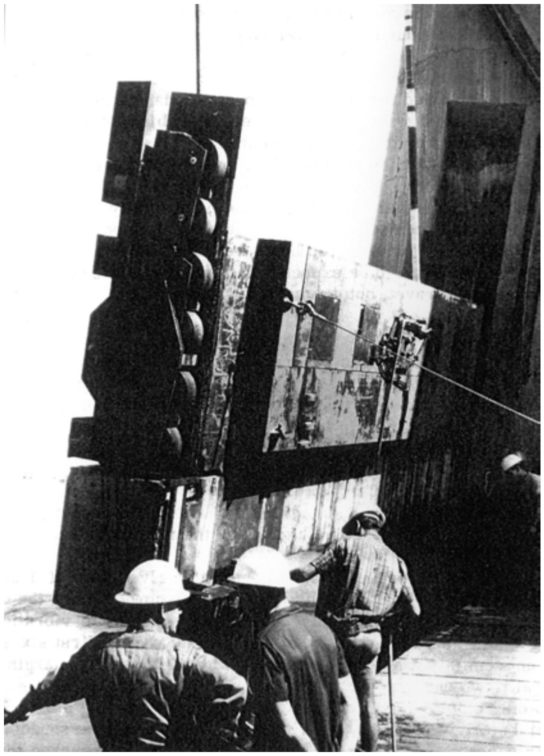
Typical examples are set out in the following paragraphs.

3.3.1 Peace River, Canada
Portage Mountain Dam

This diversion, in Western Canada, took place in the early sixties. The openings left in the structure were 15m wide and were closed by steel arch stoplogs lowered by a special crane and handling frame. The system was based on previous successful model and prototype operation of similar stoplogs in Sweden (17). The flow in the last opening at time of closure was 1140 cumecs.

The investigation demonstrated that the problem of vibrations when an arch beam is buried in streaming water is very complicated and practically impossible to calculate. Good comparisons were, however, obtained between model and prototype.

3.3.2 Kainji, Nigeria



Kainji Stoplog

Kainji was also constructed in the sixties. The selected site was split by an existing island and advantage taken of that in the provisions made for diversion. The river flow was successively passed down one of the channels, then through partially completed sections of the spillway and power house, and finally through the power house while the spillway was raised to full height (18).

Temporary flow through a power station had previously been carried out at the New Aswan Dam in Egypt, but in that case, through temporary conduits installed, and a similar arrangement has been made for the final period of Capanda Dam in Angola, though in this case to temporarily pass flow to feed a power station downstream.

3.3.3. Cabora Bassa,Mozambique

At some sites, with large wet season flows, and construction of a concrete dam, the solution has been to limit the size of a diversion tunnel and, in the wet season, to pass some of the river flow over the partially completed structure. This solution was used at Kariba, and was also followed for the construction of the Cabora Bassa arch dam in Mozambique. In this case, the diversion tunnel was designed for 4000 cumecs and the partially completed dam to overtop with some 10000 cumecs.

The downstream cofferdam was of compacted rock fill with a concrete covered crest and downstream slope. Insurers were prepared to provide cover for the approach following comprehensive model tests carried out in Paris.

In the event, close to the estimated maximum flow took place successfully, although some minor damage occurred to the cofferdam.

3.3.4 Nam Theun 2, Laos

The Nam Theun 2 project in Laos is presently in its final stages of design and contract negotiation. It will also allow for overtopping of the works during the wet seasons. The Project Environment and Management Plan are to be published on the web shortly.

4. ADVERSE EVENTS

4.1 General

In my presentation (4) on risk assessment and management in 1993 reference was made to adverse incidents on several dams and photographs shown on some of these. Some of the examples remain relevant to these discussions, and so there is no hesitation in reminding you of them, albeit in some instances for different reasons.

It is often the case, in fact more often than not, that major losses arise from a combination of causes, one at least of which is human error. Decisions made in emergency cannot rapidly refer to design reports or risk schedules, and often have to be made by site engineers/contractors who may not have been party to the conceptual or detailed design of the works. This is discussed further in Section 5.

4.2 Tarbela Project – Pakistan

One of the most significant accidents, which subsequently influenced many aspects of dam construction, was that at Tarbela Dam in Pakistan in 1974. The dam, with a height of 148m, was constructed during the early seventies, and is shown here during construction. During the first stage of diversion, the River Indus flowed down a 200m wide channel at the right side of the river. In early stages of the work openwork layers in the foundation were identified and an upstream clay blanket was placed upstream some 1000m in length.

Four tunnels were constructed through the right abutment, two each of which were ultimately to be used for irrigation and power supply. The tunnels were provided with upstream gated intakes, and these gates were designed to be lowered into place on the one occasion only, following which concrete plugs were to be constructed close to the intake, and permanent inlets were to be through screened intakes in vertical towers above the tunnels. The gate rails were attached to vertical steel plate sections by bolts. The river flow was diverted through these tunnels during the second stage of construction, while the main dam was extended over the first stage channel.

During this stage of operation, the river passing over the upstream blanket was found to be causing erosion and the gates of the diversion tunnels were used to throttle the flow and so raise the upstream water level to reduce velocities of flow across the blanket. The gates were subsequently used to throttle the flow during the first filling of the reservoir, presumably following familiarity during the earlier phase, but now the reservoir level and consequently water velocities were much higher. Differential water pressure between the gate opening and the back of the rail (9) caused the holding bolts to fail in tension. The gates jammed in a partially open position and cavitation of the tunnels took place with disastrous results. The tunnel section was breached and the abutment, formed of sugar limestone, was scoured into the tunnel.

The cost of repairs arising approached $100m which, at the time, was a large sum. The total insurance premiums for the project were a fraction of this value, but the claim was not agreed to be covered by the policy in place and the works had to be refinanced.

Several innovations arose from the disaster:

- Tests on a large model carried out at Wallingford, mainly using air as the working fluid, were able to lead to determination of possible cause.
- As discussed in Section 6 of this report, the approach to insurance of major projects was significantly changed.
- The reconstruction of the eroded abutment was carried out using RCC (one of the first major applications). The cement and aggregate was mixed using a dropping tower.
- The use of Review Panels on such work became more widely adopted, and particularly on World Bank projects.

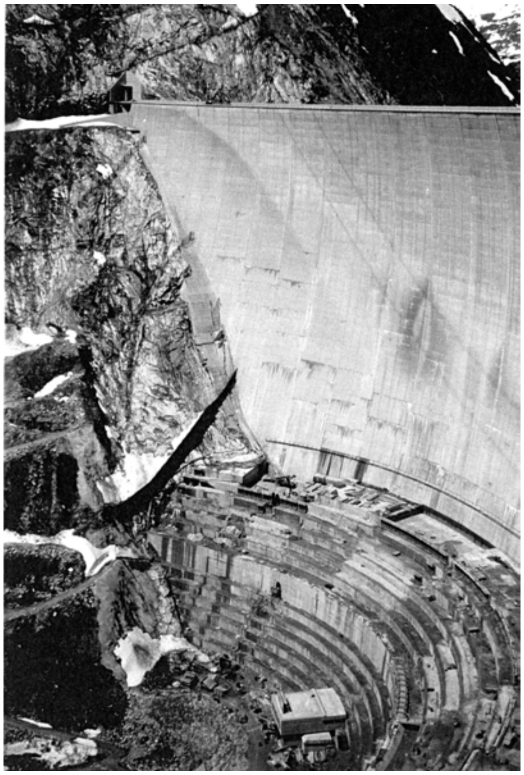
4.3 Kölnbrein Dam, Austria

The Kölnbrein Dam in Austria is a concrete arch structure some 200m high, and located at the headwaters of the Malta River in the Tauern Mountain range. The dam suffered shear cracking in 1978 following commissioning, and it was determined that the reservoir should not then be filled to design level, the shortfall being some 50 metres. This was a unique situation, no other similar case having been recorded, and a great deal of painstaking detailed investigation and remedial work was involved.

The project has been the subject of reports to ICOLD meetings in 1985 and 1991 (11), and the remedial project is covered in a comprehensive publication by the Owners (10). A presentation was also made to BDS by the Owners at the time.

The cracking was shown by investigation to arise from the geometry of a thin section near the base at the centre of the valley, and the inability of the section to carry the shear forces applied. Early attempts to deal with the problem addressed the leakage rather than the basic structural cause, which followed later. The remedy was to build a supporting arch downstream some 70m high, and containing some 460,000m^3 of concrete at a cost of some \$80 million. The partial load transfer to this support is through a series of props bearing through Neoprene pads 1.2m square, which were individually wedged into position at pre-computed time intervals related to reservoir water level. There are nearly 600 of those.

This topic is mentioned because the insurance market was asked to provide cover for the effectiveness of the remedial works which was to be assessed by the degree to which the previously restricted water level could be raised toward the 50m necessary to fill the reservoir to its original design level.



Kölnbrein Buttress

The ensuing discussions involved comprehensive design and risk assessment, and very detailed consideration of factors which would be considered relevant to determination of the degree of success of the new works, and how these would be applied. One factor was that it would probably require an independent Panel to rule on this.

A policy was offered, but the premium was not acceptable to the Owner, partly due to confidence in the technical risk review carried out, and the procedures set in place to ensure the necessary probability of success. The remedial works took three years to complete.

4.4 Slope Failures

The potential for slope failures, during and/or after construction is a recognised risk which has to be addressed throughout the development of a dam project. Reference was recently made to this in the paper to BDS in October last year (12) by Hinks et al. Sometimes the consequences of such failures or potential for them are compounded by the combination of circumstances which obtain, and several such cases will be considered.

4.4.1 Guavio Project, Colombia

The Guavio project in Colombia has an embankment dam 245m high with an underground power station downstream with an ultimate capacity of 1600MW. The effective operating head is 1160m, one of the largest in place. The construction of the dam was started in 1981 and completed in 1989.

The site, in the Cordillera, was initially without access roads and the dam located in a narrow canyon 600m deep. Various landslides occurred on natural slopes of the Guavio River Canyon, and tributary streams near the dam site during the rainy season of 1983 with general characteristics of small volumes and thicknesses conformed by colluvial soils, irregularly deposited on the slopes and covering stable rock surfaces.

The most critical unstable zones, resulting from construction of the project, were in the area of the intake. During construction of an access road on the right bank of the river, a soft topographic depression, covered by quaternary deposits, was identified in which signs of instability appeared. The area consisted of paleozoic and cretaceous fragments within a silty clayey matrix deposited over shaley rock.

During 1982 small landslides occurred in the area, and in September of that year a colluvial slide, less than $1000m^3$, took place; several workers near to the event were killed. Later the same day a slide of nearly $3000m^3$ occurred upstream of the previous one. Work was stopped, and various measures taken to improve stability and provide safety in the zone. They included removal of material, construction of a false pedestrian tunnel, control and surveillance of the failing zone.

Particular measures taken in the interests of safety included lighting of the area, watchman and sirens, topographic control, restriction of vehicle traffic, emergency planning, and automatic alarm systems to be actioned by small ground movements.

In June 1983, a significant increase of displacement caused by severe rains was recorded, but stabilised. A month later the largest rainfall recorded in 21 years of record occurred, and at the end of that month a sudden massive slide spread over the road area, blocked the river, and resulted in a major loss of life. A subsequent smaller slide during rescue operations resulted in a further loss of life. The total mass of material involved was about $50,000m^3$. [It can be noted that the river breached the dyke created by the landslide within a few hours of the event.]

The actions taken following this tragic event were, as may be expected, many and wide ranging, but the purpose of reference in this paper is to illustrate matters related to risk. The slide event took place at 6.30 p.m. during a shift change, the buses for which were near to the slide area; men monitoring the slide were among the casualties. It was dark at the time.

4.4.2 Tachien Project, Taiwan

The second case refers to the Tachien Project in Taiwan which is an arch dam constructed in the early seventies. The terrain is not dissimilar to that of Guavio, but tree covered.

Working space in the valley was limited, and the camp for those involved in the construction was formed by several buildings, each of three storeys, constructed on a plateau cut into the side of a relatively steep slope adjacent to the river.

Concern was expressed about the vegetation overhanging these properties, but tree preservation appears to have been a prime requisite by the Local Authorities.

Again, following fairly heavy rain, there was a slide bringing down a number of the trees which impacted the dwellings with some loss of life.

4.4.3 Sykia Project, Greece

On 14th January 2003 a somewhat large landslide occurred in the form of a mudslide downstream of the proposed Sykia Dam in Northern Greece. The slide debris dammed the Acheloos River for several hours. The material was from flysch, probably saturated by heavy precedent rains.

The slide was at the edge of a so called “Pigae Mass” which forms an old landslide that had however been inactive for some considerable time.

This mass was recognised as a particular feature of the area when the Sykia Project was first considered in 1965, and the brecciated and weak nature of the rock mass, being at the front of the geologic thrust of Pindos, over Gavrovo flysch, had been seen as a potential source of instability, though not previously proven.

The design of the scheme had made allowances for the presence of this mass, but refinements of the final project are in hand to further protect the interests of downstream residents.

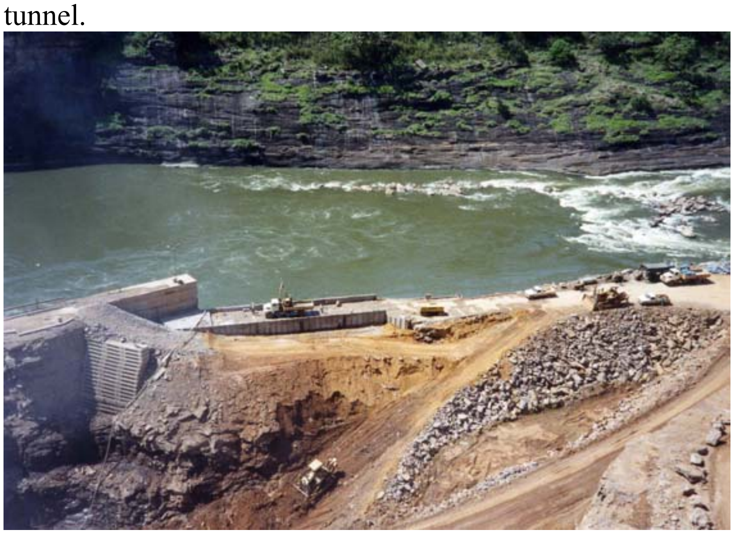
4.5 Capanda Project, Angola

The Capanda hydro power project on the River Cuanza in Angola is now nearing completion after a number of interruptions due to unfortunate disturbances in that country.

The main element of the project is a gravity dam with a maximum height of 100m and mostly of RCC construction. The dam includes a gated spillway in the centre of the river, and an intake structure on the right bank with tunnels leading to an outdoor power station downstream with a capacity of 520MW.

The geology is basically sandstone with a high feldspar content, more or less horizontally bedded with some interbeds of clayey shale. The rock mass has a number of clearly defined joint systems. As stated earlier, part of the fine aggregate was specially milled to use in the RCC mix instead of an imported pozzolan.

During construction the power station area was protected by a cofferdam, partly formed by a concrete wall and partly by an embankment, the toe of which was protected by a thick layer of large rock armouring mostly of the order of 1m in diameter. This section of the cofferdam was breached at the end of March 1990 triggered by erosion/collapse of the armouring following scouring of the bed of the main river channel by discharge of the diversion tunnel.



Capanda Powerhouse Cofferdam

The hole formed by the scouring was estimated to have an in situ volume of some 25000m^3, the deepest section being 7m below river bed level. The side slopes were at some 30° but showed stepping due to the layering of sandstone. One impact of the event was that the scoured material formed a berm downstream which changed the pattern of flow in the river.

Substantial remedial works were obviously required.

4.6 Kainji

The control of flows at Kainji dam during diversion has been referred to earlier. The operation proceeded very much according to design and model tests but with two significant experiences.

The flow of water through the shell of part of the power station inevitably caused some random vibration of the downstream wall which was possibly greater than had been imagined. However, at one discharge condition, and briefly, there appeared to be a tendency to resonance, though calculations had showed that resonant vibrations were unlikely.

Perhaps more significantly, during closure of the last opening in the spillway, the cables were noticeably subject to fairly heavy vibration, and when one of the stoplogs was almost at its sealing position there was a sudden downpull, in excess of the 120 ton dynamometer capacity, and well above the rated crane capacity of 80 tons. That appeared to be a freak condition and was the only instance of its kind, but the requirement to anchor the gantry to the deck during lowering was more than justified.

5. RISK ASSESSMENT AND MANAGEMENT

In a broad sense, risk assessment has long been a function of construction work, associated with matters of safety, but it is in more recent decades that it has become formalised. It was in 1970 that a committee was first set up by ICOLD to examine factors relating to risks to third parties from large dams, and it was not until 1982 that a committee was established on Dam Safety.

Engineers have become accustomed to dealing with uncertainties in the properties and behaviour of materials, and have developed methods and procedures to allow for them. These involve logic, judgement and sometimes complex numerical procedures (19). Today, risk is not readily tolerated by society, and mistakes lead to recriminations. Error implies blame and, in case of damage, society tends to be obliged to find a guilty party. Human causes have been stated as being frequently responsible for civil engineering failures or malfunction. Ignorance or rejection of contemporary technology by the engineers involved has been cited as a cause and could apply, particularly to embankment dam engineering. Some uncertainties in this category are set out by Milligan (13).

Terzaghi (20) in 1958 made some comments on inherent organisational risk which can sometimes be valid today. Basically, he suggests that activities are often carried out by separate units such that practical communication between them is limited:

- Survey – borehole data set out in report.

- Design – based on interpreted subsoil conditions.
- Construction, supervision – in accordance with drawings and specifications but having no obligation to question design.
- Construction by Contractor – sole aim to perform work covered by contract at minimum expense. (Occasional departures from the specifications can reduce the cost quite considerably.)

To some degree this used to be mitigated by transferring engineers from the design office to assist in supervision of the work but, for various reasons, this is often not feasible in today's practice.

An addition can be made in that it could be considered essential to have the hydraulic engineer who is responsible for model tests to be present when the prototype is first tested.

Risk analyses can be qualitative or quantitative, the latter assessing the frequency of an unwanted event and its measurable consequences in terms of cost of damage and number of fatalities. Some consider that, in its present state, risk analysis provides powerful insights into the relative importance of various factors affecting the safety of dams, especially with respect to hydrology and floods, reservoir operation and, to a lesser degree, seismic events. Its contribution in assessment of stability, including the risk of internal erosion and piping, especially if it reduces design for defence in depth, is still open to question.

The analyses need to cover both construction and operation phases, and both carried out initially during design when many can be mitigated. The construction phase must be re-addressed subsequently in collaboration with the Contractor.

Methodology is well established and presentation of results tends to follow relatively standard patterns. It has to be recognised that overly conservative estimates can lead to substantial costs which cannot be justified.

Risk registers which allocate responsibilities are maintained throughout and subject to periodic review to test their current validity. Regular reporting to management is required.

But, it is manifest that risk management is more than check lists, particularly during the construction phase.

Various studies are reported on extreme events. Some refer to seismic risk but others deal with global warming and the potential for superstorms. Should these events occur, they could inevitably have some effect on existing dams, but they would also, among other impacts, cause immense damage to existing and currently planned infrastructure in river basins.

It is not unreasonable to assume that no country in the world can afford to upgrade all its dams or other infrastructure to cope with such extreme events. It is also the case that a number of dams presently under construction, or out to tender, are based on recorded hydrologic conditions for the particular site.

6. INSURANCE OF DAMS

In a previous presentation to the British Dam Society, an outline was given of factors related to insurance of dams, both during construction and operation (4). There have been some significant changes in approach to Construction Insurance of dams over recent decades.

Traditionally, "all risks" contract works and Third Party Liability Insurance was purchased by Contractors in the form envisaged in the ICE Conditions. As the scale and complexity of projects has grown, together with the internationalisation of the Designers, Contractors and equipment suppliers, the purchase of insurance has transferred from Contractors to Employers. This has led to the development of single project insurance protecting Employer and all Contractors and sub-Contractors.

The move towards privatisation of utilities and projects being awarded on BOT, PFI and similar structures, has led to Lenders taking a close interest in insurance cover. The provision of "Delay in Start-Up" (DSU) is at the head of the Lenders' agenda as this covers, as a minimum, debt servicing during any delay period caused by damage to the works.

Over the last 50 years there has been a need for much higher Third Party Limits of Indemnity. This, again, reflects the increasing scale of projects and the potential for the release of larger volumes of water with potential damage to downstream industries and loss of life. In the 1960s a limit of US$5m would have been considered substantial, but in 2004 an insured limit could be in the range of US$100m to US$200m.

The event at Tarbela, already referred to, represented a watershed, not only for dam construction insurance, but for all major projects. The abiding perception of Tarbela is that the insurance purchased did not effectively respond, particularly to the needs of the Employer who had to seek substantial funding from the World Bank in order to complete the project. These events not only further justified the move towards Employer controlled insurance, but also made a strong case for Employers to take specialist consultancy advice on construction risk management and insurance throughout the project planning, development and execution.

An additional more recent factor is the very substantial loss experience by Insurers on tunnel projects, mostly in soft ground using tunnelling machines. While the loss ratio for general engineering/construction has been as high as 100 per cent, that for such tunnel projects has been 500 per cent plus. U.K. projects which have contributed to this were the Heathrow Express tunnel, and the Hull sewer tunnel. A group of Insurers representing the London market in collaboration with the British Tunnelling Society has drawn up a joint Code of Practice (5) which places emphasis on risk management and ensuring that the Employer is involved in the project throughout. Compliance with the Code is required to secure insurance cover, and this is also recently a factor with respect to the rock tunnels of a major hydro scheme about to commence construction.

By its nature, the insurance market is cyclical. It takes around seven years from peak to trough, to peak again. During these cycles the levels of premium rates, policy excesses, cover and capacity available can vary by a considerable factor. However, it is significant to insurance purchasers for dam projects that, as each cycle has been completed over the past 30/40 years, fewer insurers have remained in the market for construction projects.

The major project construction market in Europe now has a low number of participating insurers and probably only four recognized specialist Leaders; to complete a placement, a Broker would probably need to harness the capacity of at least three of these companies.

It follows that Employers of dam projects must give insurance a much higher ranking in the project planning process. If a project is to be "bankable", then the corollary is that it must be "insurable". Risk assessment, mitigation and management is paramount.

The position is somewhat better for insurance cover of operating works where there are probably more participating insurers, though still a limited number of recognised specialist Leaders. Matters relating to potential for fire and seismic or flood events are carefully reviewed.

7. REVIEW PANELS (BOARDS)

7.1 General

Independent assessment of major works has taken place in the U.K. for more than a century, though originally such a role was undertaken by expert witnesses in the case of an adverse event rather than association with a project throughout its conception, development and construction phases. There was not always consensus between the experts, and it appears they were not averse to promoting their own opinions (1), albeit in a gentlemanly manner.

More recently, and following the publication of the 1975 Reservoirs Act, some had maintained that a key omission in that Act was the lack of a pre-construction independent review for future reservoirs and, in fact, Review Panels (sometimes designated as Boards) were subsequently in place for Queens Valley in Jersey and Roadford Dam in Devon.

The report on Carsington recommended that, on such projects, there was merit that Panels should be retained (3) and, although this has generally been accepted, it is not at present mandatory. Panels have since been involved in the reconstruction of Carsington, and the modifications to Audenshaw and Ladybower Dams and, as most will be aware, there is a retained Panel by Severn Trent Water to advise on specific issues which arise on their reservoirs, sometimes related to Inspection Reports, and often to matters of safety.

No attempt has been made in presenting this paper to research the historical use of Review Panels internationally. Following the adverse event at Tarbela in 1974, already mentioned, the World Bank and subsequently the EU have looked for independent review of projects in which they are involved. It is clear that Panels were appointed on some projects prior to this date, sometimes on specific matters. For instance, reference is made in the published history of Mangla (2) to the Review Board for that project and its organisation which was set up in 1959.

Significantly, Panels have been retained for dams but more recently also on other large scale projects which have included major tunnelling projects worldwide. Some personal views on matters relating to the use of such Panels are set out in the following paragraphs.

7.2 Composition of Panels

Early Panels were largely connected with civil engineering and safety matters. This has expanded with time in that there are often now also separate Panels covering such as environmental and social issues, contractual disputes between Owners and Contractors, and downstream sub-Contractors. In a BOOT project, the funding agencies will also invariably appoint their own Technical Review Panel.

The scope of a Dam Safety Review Panel can include any or all aspects of dam safety, and include flood hydrology, seismology, engineering geology, rock mechanics, geotechnical engineering, structure design and construction, concrete technology, etc. Matters relating to risk assessment and avoidance are also now included. An additional member to cover E&M details is sometimes added, or co-opted at appropriate stages of the work.

It is generally considered to be best served by not more than four members who preferably are independent and internationally experienced and, between them, recognised authorities in the disciplines involved in the project. All must be acceptable to the World Bank if that organisation is involved in the project, and compliance with the Bank's safety policy is anticipated.

It is important that individuals do not dominate and all must be prepared to compromise on judgemental issues. Co-ordination may be agreed to rest with one member, possibly a generalist civil engineer with good project experience.

The proposed composition of a Panel should be acceptable in advance to all the members to be involved. Work of the Panel should be carried out in a common language.

7.3 Terms of Reference

The Owner should set out and agree the terms of reference for the Safety Review Panel to ensure that its function and responsibilities are clearly understood by all parties involved in the project. Generally, the Panel will be involved in the project as a whole, though in some cases may be confined to specific elements. Typical items to be included in the terms of reference may be as follows:

- The provision of objective and impartial technical views on the overall design, construction methodology, and progress of the project.
- Recognition that the Panel is not a substitute for regular consulting engineering services.
- Consideration of specific questions put to it, and to make recommendations as required.•

  To have opportunity to question design or procedures in place or in preparation in relation to the overall safety of the work.

- Although not directly involved in cost factors, to responsibly consider economic solutions to the matters under review.
- To be informed on Contractors' concerns and opinions and comment on them as appropriate.
- In the case of the World Bank's involvement, to state whether, in their opinion, the design, construction, commissioning etc. comply with the World Bank's Dam Safety Policy and, if not, to recommend remedial action in the case of considered non-compliance.
- To raise any matters which appear to be in error.
- To contribute to ensure that the works are in the best interest of those who may be affected by them.
- To communicate between meetings on particular issues.

Ideally, the Panel should be provided with a set of briefing notes prior to each meeting which should include reference to progress and matters arising, relevant changes in project details or methodology, instrumentation results and interpretation. Often safety records are also tabled.

Meetings of the Panel need to be arranged to suit progress of the works, though are unlikely to be less than twice per year for much of the programme, or as otherwise necessary. Communication is generally maintained between visits between the Owner and Panel members.

The procedures for reporting are important. As a minimum a summary of the main findings should be tabled and discussed before departure with a copy of the draft report or final report if completed. Otherwise, the latter should be submitted soon after completion of the visit. However, time may be allowed for longer term consideration of specific issues.

7.4 Responsibilities and Liabilities

Generally, provision is made that individual members cannot be sued by the Owner in respect of comments or recommendations made by them even, in cases, if made negligently.

The Owner can have limited right to appeal on recommendations of the Panel but, conversely, the Panel has no power to enforce itself.

It is not normally intended that the Panel should be involved in settlement of disputes, though can be expected to contribute to ensure that disputes are, wherever possible, avoided.

8. IN SUMMARY

This paper has attempted to indicate that some adverse events can arise from various circumstances or combinations of conditions which may not readily be identified in advance by risk analyses, and constant awareness is required.

In my experience of the working of Panels, I am of the opinion that they can make a significant contribution to design and construction matters but their role has to be one of advice; ultimate responsibility rests with those designated by contractual arrangements in place.

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