Enhancing dam safety through contractual strategies

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Dam safety is crucial to ensure the long-term sustainability and the multiple benefits of dam projects, and is the primary condition for acceptance of dams by civil society. Dam failures worldwide continue to be too numerous, and the International Commission on Large Dams (ICOLD) has recently issued a 'World declaration on Dam Safety' [ICOLD, 2019[1]] and declared dam safety the highest priority of the organization. This paper looks into dam safety aspects at different phases of the project lifecycle, and from different stakeholder perspectives, and analyses dam failure records to understand where gaps can be found, in relation to both new dams and the rehabilitation of existing dams.

Statistics on dam failures clearly indicate where corrective measures need to be taken, and have encouraged the authors to formulate a set of recommendations, based on their long experience and complementary expertise, with the aim of helping dam owners, developers and lenders to address dam safety in their projects more effectively. The authors analyse the link between dam safety issues and contractual strategy, and propose an enhanced contractual and organisational set-up in dam development.

1. Past and present dam safety review

ICOLD recently issued a Technical Bulletin (No. 188) on statistical analysis of dam failures [ICOLD, 2021[2]]. When a problem occurs in a dam project, the first task is generally to determine whether its cause is related to a faulty design, poor quality in construction or inefficient operation and maintenance. The available data clearly show that the main causes of dam failure can be attributed to faulty and inadequate design; this relates in most cases to geotechnical issues, as shown in Fig. 1.

Another interesting lesson that emerges from the statistical analysis concerns the time of failure occurrence. More than 50 per cent of the failures of dams built in the 20th century have occurred during the first five years after construction, and since 2000, all failures have occurred during the first five years of operation. Clearly, therefore, the first five years of a dam's life are critical.

1.1 Lessons from some well known case studies

An analysis of a selection of targeted historical and recent accidents that occurred during construction, first filling or at the beginning of operation provides lessons from a technical and contractual/organizational point of view. Historical failures that occurred in Malpasset dam (France) and Teton dam (USA) have been strongly debated and represent key 'break-even' points (milestones?) in dam safety practice. Recent incidents or failures, such as Ituango in Colombia, and Xe-Pian Xe-Namnoy in Laos, both in 2018, demonstrate that a lot still needs to be done.

1.1.1 Malpasset, France

The failure of Malpasset dam, causing more than 400 casualties, occurred in 1959, five years after the closure of the temporary diversion and when the normal reservoir level was exceeded for the first time. The geological causes of the Malpasset failure are well known today, and have contributed to the development of rock mechanics and its application to dam foundations [CFBR, 2022[3]]. The dam owner (Var County supported by Génie Rural administration) had limited technical competence in dam construction and operation. The last monitoring campaign in June 1959, showing abnormal displacements at the toe of the gravity dam, were transmitted to the dam designer with a four-month delay. This was some weeks before the failure, long after the construction company had been fully demobilized, leaving insufficient time to analyse and understand the critical behaviour of the dam. The lesson to be learned is that stakeholders having the expertise and being in charge of supervising the filling (owner, contractor, designer, safety controller, and so on) must remain mobilized and empowered at least until the dam is impounded and preferably for several additional years. It also highlights that organisation causes are also of utmost importance [Duffaut and Larouzée, 2019[4]].

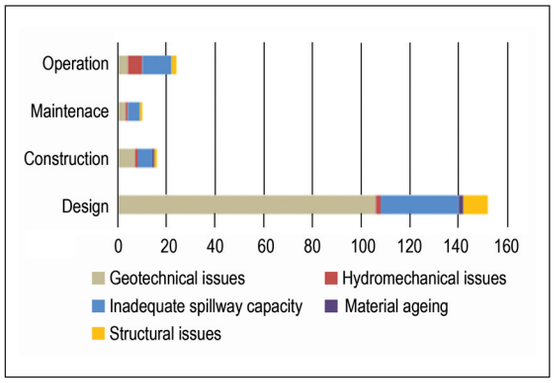

Fig. 1. Organizational versus technical causes of dam failure. Source: ICOLD Bulletin 188 [ICOLD, 2021[2]].

1.1.2 Teton, USA

The dam break at the Bureau of Reclamation's Teton dam project in Idaho on 5 June 1976 has been extensively documented and investigated [Burec and Idaho State, 1976[5]]. Teton failed during initial filling of the reservoir, after a large leak near the right abutment of the dam washed away the embankment and caused the dam breach. Deaths of 11 people were reported, with property damage of about $400 million. Teton dam

From top left to bottom right: Malpasset dam (researchgate.net); Teton dam (damfailure.org); Ituango dam (elciudadano.com); and, Xe-Pian Xe-Namnoy saddle dam (Ahmed Chraibi).

was a zoned earthfill structure with a low-permeability central core. It rose 123 m above its foundation level and 93 m above the riverbed level, and had a crest length of about 915 m (3000 ft). According to the independent panel which reviewed the incident, the fundamental cause of failure may be regarded as a combination of geological factors (numerous open joints in the rock foundation and highly erodible fill material in the area), and design decisions (such as seepage control through deep key trenches filled with windblow soils which also encouraged undesirable arching effects, non-systematic concrete infilling of open joints in the rock foundation, and inadequate provision for drainage downstream the core). The contractor was aware of the risk associated with open rock joints in the trenches, but concrete filling of the joints was not in his contract and he ceased to carry out this treatment after the initial remedial works were not paid by the employer. The lack of a technical review from dam safety experts to inform the employer about the risk, and a solid contractual mechanism to address variation orders, are among the main causes of the failure that could have been avoided if organizational aspects had been properly set up.

1.1.3 Ituango, Colombia

The case of the Ituango project relates to a very large dam impounding a huge reservoir that came very close to failure during its construction in May 2018. The Ituango hydroelectric project in Colombia is located on the Cauca river, and comprises a 235 m-high earth core rockfill dam with a 2.7×10^9 m^3 reservoir and a 2480 MW underground powerhouse. The two diversion tunnels were completed in 2013, and diversion through them began in early 2014. The two diversion tunnels were designed according to the international accepted state of the art.

After the first two years of construction, the project was 20 months behind schedule. An acceleration plan was adopted to avoid time-consuming installation of the control gates in the two diversion tunnels, but instead the two diversion tunnels were plugged and a third diversion tunnel was built, referred to as the auxiliary diversion tunnel (ADT), to allow for an earlier start of the dam construction. Heavy rainfall during April 2018 caused the reservoir level to rise rapidly (100 m within a few days) and submerge the ADT intake, causing pressure flow and high velocity conditions in the tunnel which collapsed in the upstream section, clogging the ADT entrance.

The overtopping of the partially completed dam became an imminent and likely risk, and exceptional emergency measures, such as routing the inflows through the uncompleted underground powerhouse and waterways fortunately made it possible to prevent a catastrophic failure, and major damage to the power station and its equipment. This incident came very close to a major accident. More than 100 000 people were at risk and it would have been one of the largest disasters associated to a dam failure. The impact on the hydro industry would have been of the same magnitude to that of the Chernobyl accident for the nuclear industry. For some experts involved [Brox, 2020[6]], one of the root causes of the accident might have been the late decision, probably technically challengeable, to replace the initial well designed diversion system with an undersized single tunnel. This decision was taken during the construction phase; it was proposed by the designers, primarily reviewed by the engineer and finally accepted by the owner and contractor. It was taken under the pressure of the accumulated delays and to accelerate the commissioning of the project against the recommendations of the panel of experts, mandated by the owner, of not implementing the ADT solution. Unfortunately, the dam safety panel recommendations were not binding, and were not followed by the owner, as budget consideration took priority over safety arrangements.

1.1.4 Xe Pian-Xe Namnoy, Laos

The Xe Pian-Xe Namnoy saddle dam D in Laos failed in July 2018 during the first impounding of the reservoir, after heavy precipitation that had rapidly filled the reservoir. The saddle dam D was a homogeneous embankment, 17 m high and 770 m long. It is founded on a tropical residual soil (TRS), which had been stripped of the topsoil to a depth of almost 1 m. The TRS was around 20 m thick, and no treatment to control seepage had been implemented. The failure occurred while the upstream water level was more than 4.5 m below the crest of the dam. It resulted in the catastrophic release of around 700 × $10^6 m^3$ of water (the total reservoir volume is 1 × $10^9 m^3$). The saddle deepened by almost 20 m down to the sound bedrock, creating a secondary valley which caused 140 casualties and the displacement of more than 12 000 persons. The saddle dam failure event had not been considered in the overall emergency preparedness plan (EPP) for the project.

An Independent Panel of Experts (IPoE) was engaged by the Government of Laos after the disaster, to identify the root cause of the failure. According to the Report of the IPoE [Schleiss, Chraibi and Tournier, 2019[7]], the presence of high permeability and erodibility foundation horizons, combined with the existence of a network of interconnected canaliculus and cavities, had led to internal erosion and softening of the soil-like foundation thoughout its full thickness. It is likely that a positive cut-off keyed in the bedrock would have prevented the failure. In that case, the cause of failure was the poor design of the foundation watertightness treatment. Furthermore, an EPP should be required for any saddle dam or secondary structure, in addition to the main structures, especially if its failure may cause unacceptable or undesirable consequences. No dam safety panel of experts (DSPoE) had been involved during the design and construction of the Xe Pian-Xe Namnoy hydro project. A DSPoE might have challenged the design of saddle dam D and required the saddle dam failure be considered in the EPP.

1.2 National dam safety regulation, norms, state of the art, and international best practice

An extensive review of the dam safety regulatory frameworks in 51 countries, estimated to account for more than 95 per cent of the ICOLD's register of world dams, was carried out by the World Bank [2018[8]]. The majority of the developed countries who are members of ICOLD have established comprehensive dam safety regulations over the past decades. This is far from the case for the developing countries, even those where large or mega projects are currently being designed and constructed. In these countries, the dam safety framework is often imposed by the international lenders, compliance to their dam safety requirements being a compulsory milestone in the financing agreement.

In any project, the contractor has to comply with the national regulations. In the case of a project, including the construction of a new dam or the rehabilitation of an existing one, national dam safety regulations generally provide minimum design criteria to be adopted to ensure dam safety.

As an example, in France, the 'Arrêté Technique Barrage' (ATB), literally the 'Dam Technical Decree', issued in 2018, defines the basic design criteria, including safety factors, to achieve in various load conditions, return periods for design floods, seismic loadings to be considered, and so on [Ministry of Ecological Transition, 2018[9]]. The ATB's requirements are binding, although some specific criteria may differ from the CFBR (French National Committee of ICOLD) Guidelines, which are not legally binding. In addition to the ATB's requirements, the French dam safety regulation imposes that the basic design and the detailed design stages are reviewed by a permanent safety board (CTPBOH) composed of seasoned experts appointed by the Government. This applies to all projects in France, including new dams or large rehabilitation projects. The CTPBOH, exclusively in charge of dam safety issues, was created as a response to the Malpasset dam catastrophic failure in 1959. No major incidents have occurred in France since its creation in 1966, which testifies to its effectiveness.

Construction contracts usually explicitly mention the need for the designer and the contractor to adopt 'state-of-the-art' requirements, which can be fully determined by any expert. In addition, employers might request the contractor to follow standards from international organizations and institutions, such as the ICOLD Bulletins or DIN norms, British standards, USBR Guidelines, Chinese codes, and so on. As those norms are not part of the state law, but have been issued by private independent organizations issuing norms, their application has to be agreed upon in the construction contract, so it can be binding for the contractor, in case those norms are more stringent than state law.

It should also be noted that ICOLD Bulletins, which are essential sources of international state-of-the-art information in the dam industry, are in general not prescriptive documents, and reflect the variety of practices all over the world. Their purpose is to establish, on the various topics, an international state of the art based, as much as possible, on worldwide knowledge and lessons learned from the dam industry.

However, a particular challenge with dam design is that it is not possible to rely only on regulations, laws or codes. Norms and the state of the art can guide the designer, but in the end a significant part of the design must be based on technical experience and engineering judgement.

1.3 World Bank policy and the Dam Safety Panel of Experts

The World Bank (WB) has led the way among development banks in raising dam safety standards, by introducing in 1977 the policy Operational Manual Statement 3.80 'Safety of Dams', replaced in 2001 by the policy O.P. 4.37 [World Bank, 2010[10]], and superseded in October 2018 by the ESS4, Annex 1 [World Bank, 2018[11]], compliance with which is included as a condition in the implementation and financing agreements for all dams classified as 'large'. The policy is part of the wide range of safeguard instruments and calls for an independent panel of international experts in dam safety with the responsibility of reviewing the investigation, design, and construction of the dam, including review of the four detailed dam safety plans to be prepared by the borrower as per the policy requirement, namely:

- the construction supervision and quality assurance plan;
- the instrumentation plan;

- the operation and maintenance plan; and,
- the emergency preparedness plan.

The panel reviews and advises the borrower on matters related to dam safety and other critical aspects of the dam project. The Dam Safety Panel of Experts (DSPoE) usually consists of three or more experts, appointed by the borrower and acceptable to the WB, with expertise in the various technical fields relevant to the safety aspects of the dam. Usually, a DSPoE is composed of a dam specialist, a geological/geotechnical expert and a hydrologist; hydropower dams may require an electromechanical specialist as well. Additional expertise can be added as necessary, as the borrower sees fit. The DSPoE requires mobilization of international experts and is an essential technical resource for the project; it must be fully considered as a fundamental component of the project cost. The panel's costs should be treated as development costs before construction, and as a construction management fee afterwards. Usually, the panel is disbanded after commissioning and final acceptance, leaving some gaps if long-term dam safety inspections are not planned for.

After a few decades of application on more than 400 dam-related projects funded by the World Bank, the DSPoE has proven to be a valuable technical resource for borrowers and their projects. To date no major failures or accidents have been recorded in WB-funded projects, either for the construction of new dams or the rehabilitation of existing ones, during their project life cycle.

1.4 The role and tasks of an independent expert

The dam failure cases investigated by the authors demonstrate the importance of the involvement of a body of independent experts within projects. These bodies, such as the DSPoE, can be nominated (and, as the case may be, upon request) by the project owner, a developer, the lender, a state authority in charge of supervising a dam or a private concessionaire.

Ensuring independence in the panel's opinions is a key aspect. Independence means that the expert is in a position to give his advice without being influenced by an interested party to the project, such as the owner and operator of the dam, the engineer or the contractor. It does not necessarily imply the non-existence of a contractual relationship between the expert and the nominating and/or another interested party, as long as the expert does not generate a considerable part of his income from the contract with one of the interested parties. But the future expert should run a conflict-of-interest check, as standard, according to various Bar Association's Guidelines.

The monitoring and supervision of the behaviour of small or large dams, starting from the planning and design, and through the construction phase, will be (as provided for in most legislations) primarily the responsibility of the owner/operator of the dam. Some legislations known to the authors not only prescribe how to monitor a dam, but call for the participation of an independent expert during the lifecycle of a dam. The owner should give evidence of the results of the monitoring and the surveillance by submitting at certain intervals (for example, every five years or less), a detailed report to be established by an external engineer or engineering company, that means, the independent expert, showing that the dam and its operation are safe. Even in countries where such a framework does not exist, the owner/operator responsible for the dam and its safety must be aware of the need for careful evaluation of whether he has the necessary in-house expertise to assess the safe behaviour of the dam, or rather should rely on the advice of a nominated external expert.

The tasks and obligations of the dam safety expert will usually be defined by the contract, through which the nominating party entrusts and mandates the expert to give his/her advice. This means that the rights and obligations of the expert result directly from that contract, and are described in its terms of reference, complemented by the laws and codes that govern the contract itself. In some cases, the expert will be officially appointed and sworn in by a public entity, and then mandated by a court, a private party or another entity.

No matter how the expert is instated, his/her independency is an essential condition in addition to his expertise. A DSPoE is nothing other than a body of several individually nominated experts. As he is liable for the performance of his services, the expert should pay attention on how the decision-making process within the panel will take place (majority or unanimity decisions) and how his/her own recommendations will be imposed.

A panel or an expert act like any other consultant or service provider, and in a similar way to a technical advisor or an 'Owner's Engineer'. He must render his/her services within the defined scope of works and according to the terms of reference of the nomination contract, with due care and diligence, and will be fully liable if he neglects his/her duties. Considering that full liability means the obligation for compensating all damages resulting from advice given in case of at least a negligent breach of his obligations, the authors strongly advise the expert to limit his liability amount contractually (for example to x-times the fees) and to try to exclude liability for normal negligence and (if possible, under the applicable law which governs the nomination contract) for gross negligence of the mandate. It should be noted that the liability for damages to life and physical property of third parties, as well as for intentional breach of contract, can never be excluded. It is in the expert's interest to subscribe to the appropriate insurance covering his professional liability. This liability aspects are not always dealt with in dam safety panel contracts.

As observed in the case studies, one of the dam safety risks might result from the fact that the nominated expert often has no direct contractual relationship with the party (for example, the contractor) who should follow the expert's advice, and thus cannot (unless additionally agreed upon in the construction contract) impose his/her recommendations on that party. This means, as mentioned above, that during dam construction an owner being advised by an expert, has to either reserve the right to give instructions to contractors himself and, as the case may be, initiate 'Variation orders' following the expert's recommendation, or directly impose the DSPoE's advice on the contractor as if it was an instruction given by himself. It is important that the construction contract properly allocates the financial risk if compliance with recommendations by a DSPoE leads to additional construction costs and an extension for the time for completion. In particular, the employer and contractor should provide for solutions in case that the recommendation of the DSPoE

governs issues that are not covered by the original Employer's Requirements of the construction contract. Obviously, the early involvement of a DSPoE in the review of the tender design and the Employer's Requirements may certainly reduce such risk. The DSPoE recommendations should be recorded accordingly.

1.5 The independent expert in public versus privately developed projects

Dam safety should be addressed the same way, irrespective of the source of funding or the nature of the developer. However, private sector involvement in hydropower and dam projects is usually done through build own operate and transfer (BOOT) business models where the independent power producer/developer's focus on dam safety spans the duration of the concession or the power purchase agreement (PPA), which very seldom goes beyond 25 years of dam operation. Once the concession expires the assets and the dam safety responsibility are transferred to the public authority or the entity that will take over. The concession agreement (or the PPA) shall include all provisions (including the applicable institutional and organizational arrangements) for assuring that the private owner maintains the required level of safety and for implementing a dam safety review a few years before transferring the asset to the state. The project financing shall allow for generating sufficient revenue over time to implement monitoring and safety management procedures, refurbishment and rehabilitation works to keep the required level of safety.

Dam safety standards and guidelines may differ for public and private projects. In developed countries, dam safety standards are usually well established, and correspond to national regulations or more stringent requirements; any public or private owner must comply with them as far as they are legally binding or contractually agreed upon. In countries where a dam safety framework does not exist, the private sector usually adopts IFC performance standards (PS) or equivalent, whereas public sector infrastructure schemes are by using WB Environmental and Social Standards.

Dam safety in the IFC performance standards package is covered in PS1 'Assessment and Management of Environmental and Social Risks and Impacts', which calls for an independent review by one or more experts not associ

ated with the design or owner's engineering services. The IFC standard does not specify the scope of the review or any additional requirements, such as the dam safety plans of the WB ESS4; therefore, it is less stringent than WB ESS4, and may create some ambiguities to be solved early, on while drafting the project agreements. The WB has recently issued guidance notes [World Bank, 2021[12]] to help borrowers understand the application of the dam safety policy better, including how to address differences between private and public sector projects.

2. Dam safety from different stakeholders' perspectives

2.1 Employer/owner/operator's perspective

As mentioned, the employer/owner (whether a privately owned company or the state or a public-private partnership) of a dam and the operator of a dam (if it is separate from the owner) are ultimately responsible and liable for dam safety aspects during design, construction and operation.

Therefore, it is of utmost importance for a robust national dam safety framework to be in place and applicable. But even in the absence of a detailed and compulsory national dam safety framework, it should not only be at the employer's and operator's own discretion to follow well established international standards strictly. The authors strongly advise the employer/owner/operator to do this. While, unfortunately, national frameworks do not exist in many countries where dams are currently being built or developed, some development banks, including the WB, are financing technical assistance to the implementing agency, to enhance ability and capacity in maintaining existing dams, and at the same time observing international safety standards.

A good example of such efforts is the DRIP I project (Dam Rehabilitation and Improvement Project) in India [Pillai and Giraud, 2014[13]], funded by the WB, where 223 dams were rehabilitated in around 10 years. A strong institutional capacity building programme was conducted from 2012 to support the client, the Central Water Commission, in implementing best practices and international standards in dam safety for Indian dams, including the preparation of an emergency action plan and dam break analysis.

Another aspect that is commonly observed is the potential misalignment or conflict between national standards and recommendations from international associations such as ICOLD. Although national standards as implemented by the national law are always binding, and have to be complied with, as is the case for the state-of-the-art requirement often explicitly mentioned in the applicable national laws, it is a matter of priority that can and shall be solved in the contractual agreements. In the case of non-binding diverging standards being more stringent, they become binding if referred to as the contractor's obligation in the construction contract. This matter should already be addressed during the procurement process when developing the project and establishing the employers' requirements; a DSPoE will be certainly able to guide/advise the employer/owner in making the right technical choices. An early involvement of a DSPoE or a dam safety expert (if necessary, together with a legal expert) from the beginning of the project development, to advise on the design and the contractual strategy or on the dam safety standards to be included in the employers' requirements for the construction contract, is certainly desirable.

2.2 Designer's perspective

When the dam designer is employed by the contractor in case of a design-build contract, for example when the FIDIC Yellow book or Silver book with lump sum (EPC) is used and the contractor is responsible for the design, the dam designer is sometimes in an awkward position: the project's bankability and the objective of achieving the best competitive bid leads to a search for savings. On the one hand the dam designer must respect the dam safety requirements, and on the other hand there is the risk that the contractor is requesting him to find ways of saving money. This is a common problem for all designers working as sub-contractors for the contractor. From a legal point of view, the designer must carry out his work diligently, otherwise he might be held liable in the case of a dam failure

and/or damage to the contractor and potentially other third parties. However, the subcontracting condition of the contractor's designer may put him into a difficult position, being confronted by requests from the contractor to save money, even though it is clear that the employer may not optimize his budget by sacrificing safety issues. He must resist those requests if they would lead to a design which does not respect adequate safety considerations. In the event that a deep disagreement cannot be solved on a major safety issue, the designer might even consider termination of the contract.

When dam designers are hired by an employer in the case of more traditional design-bid-build procurement strategy with a traditional construction contract (such as the FIDIC Red book with Bill of Quantities), the situation might be different, as the designer has more latitude to address safety and quality directly in his design vis-à-vis the employer, and to adopt more relevant solutions with regard to safety aspects. His direct contractual relationship with the employer may push him to cap his liability with respect to the consequence of a potential faulty design.

It is important that the employer understands better the dam safety requirements and the potential consequential damage (including casualties which would be caused by a failure) for which he would ultimately be fully responsible (regardless of who designed the scheme).

As the tendency is to adopt a design-build scheme through EPC contracts, it can be observed that the involvement of the consulting engineers/designers in the dam industry for the employer has decreased over the years. Dam designers, little by little, have lost their predominant role as designer for the employer. The result could be a deteriorating quality of the design (especially when it comes to the level of detail) if the contractor puts pressure onto the designer for the reasons mentioned above. This clearly could have a negative impact on dam safety aspects.

The following shortcomings have been observed by the authors at some projects.

- The contractor's technical office on site may be composed of engineers with no skill on dam engineering (they might have worked on bridges, ports, buildings, roads, for example, and not have the knowledge of special provisions used in dam construction, or the instinct to deal with special geotechnical and hydraulic problems we are confronted to).
- The designer might be based far from the site and not have a clear vision of what is happening (only a few residents, one or two, insufficient to have a comprehensive view of all the construction activities, and some infrequent site visits of engineers from the headquarters).
- To save money, or to avoid having external experts with an eye on what they are doing, or just because of a lack of knowledge of the consequences, the contractor may not make enough use of technical assistance from the designer, or give him only a partial mission (for instance no review of method statements, no assistance during the full-scale trials…).
- There may be a missing link between the design and the construction, with no-one checking the consistency of these two activities and the standard of the construction procedures. Then, like a firefighter, the designer will have to try to fix things in a hurry, if they go wrong, and are discovered too late. Worse still, bad things may go undetected, and could compromise the safety of the dam. This kind of organization can also be very demotivating for designer's staff.

2.3 Contractor's perspective

Respecting dam safety aspects should be as important for the contractor as it is for the employer, and for other stakeholders such as investors.

Because of budget restrictions and the tender competition, there may be a risk that contractors could be tempted to shift focus onto short-term objectives such as budget limitation and completion time; the contractor may try to save some money sacrificing quality or material quantity, rather than respecting stringent dam safety requirements. If, within his scope of work, the contractor is responsible for the design, he will bear the full responsibility even if he has subcontracted the works to a designer. In any case, he should resist any temptation to sacrifice safety considerations for cost savings.

As far as dam safety requirements are concerned, it may be interesting to involve the contractor at the outset of the project. In that case (Early Contractor Involvement), the consistency of the project and the adherence to dam safety requirements may be improved, and the competition among the contractors can be maintained.

2.4 Financier's/banker's/insurer's perspectives

Development banks, international financial institutions (IFI), both public and private, fully understand the importance of adopting adequate dam safety standards in the projects they finance. The potential hazard to the downstream communities with the risk of loss of lives and property, the high reputational risk and the financial consequences of a dam failure, and the awareness of risks arising from faulty design, construction and erection or inadequate operation, are enough reasons for them to prescribe enhanced dam safety requirements in their financing and loan agreements.

However, some IFIs are also reluctant to impose any cost increase after the financial closure, which can be non-compliant with the use of Emerald book, that brings fear of uncontrolled cost increases, above contingencies. They have to accept that in the hydro sector, costs can rise in the event of unforeseen circumstances, and ultimately accept a tariff increase to ensure the long-term safety of the dams. On the positive side, the use of Emerald Book may allow for cost reductions if more favourable geological conditions are encountered and the tariff gain that may derive from it would be lost if a traditional lump sum contract were adopted.

The insurance sector is one of the largest industries in the world. Insurance mechanisms can play a beneficial role in resilience policy, and contribute to a regulatory form of supervision of dam safety management when insurance premiums are linked to the level of dam safety being provided for dams. If dams are not managed to an acceptable standard by owners and operators, insurance premiums will be significantly higher, or in the worst case, insurance coverage will not be available. The compliance with safety standards within the design and construction phase, including quality assurance during dam construction, and the long-term safety during operation of the asset, are aspects that are checked as part of the due diligence by insurance companies.

2.5 DSPoE's perspective

The adoption of an independent dam safety review is common practice today in dam and hydropower projects developed under project finance and non-recourse funding. Lenders require from borrowers the formation of the DSPoE from an early stage of development, so that all requirements are captured from the design phase through to operation.

As mentioned above, it has to be assured that the recommendations of the DSPoE will be implemented, for example, by imposing them directly on the contractor or the employer/owner, who will issue the corresponding instructions to the contractor. Even though the panel required by the lenders is hired and contracted by the borrower, which means the implementing agency, and it has no contractual relations with the owner's engineer or the dam contractor, the leverage of the panel remains high, as any non-compliance identified by the DSPoE if not corrected may lead to the suspension of funding.

It has to be ensured that the DSPoE experts, paid and mandated by a client such as the borrower (as the case may be upon request of the lending institution) or the owner/employer, are independent and impartial, which means, not submitted to any financial interest to either party or to hidden instructions by their clients.

2.6 Civil society's perspective

Civil society and communities at risk are also major stakeholders in dam safety issues. They are basically protected by the state's regulations. Those regulations or 'good practice' in the country concerned sometimes provide for active participation of the potentially affected people. Moreover, in some cases, because of the social and environmental impacts associated with the dam, they become a direct counterpart in decisions that affect the dam design and operation.

In the case of a failure, they are major actors during emergency action plans and recovery after a disaster. It is paramount to involve civil society in the preparation of the emergency preparedness plan, and to include the local community in the public consultation meetings and emergency response training.

This also helps to spread consensus and acceptance of a dam project and its impacts, and to developing a positive feeling around the needs and objectives.

3. Dam safety across the project lifecycle

3.1 Dam safety issues during preparation

Dam safety requirements, including standards and design criteria, have to be captured throughout the whole process, starting from site investigations, through the early stage of studies (preliminary design) and the structuring of the financing. An independent dam safety review is required to validate the feasibility design and move into tender preparation for many countries and institutions. Some IFIs, such as the WB, have established dam safety policies including a set of dam safety requirements considering the types of intervention, potential risk to dams, complexity of projects, and so on, which require the early mobilization of the DSPoE, and support the preparation of the dam safety plans, as well as setting adequate design criteria for ensuring the safety of dams and downstream communities. Some studies, such as dam break analysis and downstream wave propagation, will inform the emergency preparedness plan or emergency action plan, and request for a panel review.

Projects where the DSPoE has been mobilized after validation of the studies have suffered delays in financial close, because of the need to discuss again fundamental technical decisions which have not been prescrutinized by the panel.

3.2 Dam safety issues during procurement

The first question to be raised, just before entering the construction procurement phase, is definition of the contractual strategy and set-up. Will the dam be constructed under:

- a 'Design-Bid-Build' scheme (Red Book with BoQ)?' or,
- a 'Bid-Design-Build' scheme (Yellow or Silver book with lump sum)?

Similarly, will that be:

- a single turnkey contract? or,
- a multi-contracting strategy with various lots for different contractors?

These two questions are fundamental, and have huge implications on dam safety requirements. In the case of a 'Design-Bid-Build' scheme, all the dam safety requirements should be reflected by the designer hired by the employer before tendering for the construction contract or other dam safety associated works. The dam design criteria should be established prior to the tender for the construction contract. Such design criteria must comply with the dam safety requirements required by the employer, and should take into account state-of-the-art requirements as well as well proven international guidelines, such as the ICOLD bulletins.

In the case of a 'Bid-Design-Build', it is important that all the dam safety requirements be mentioned in the Employer's Requirements (including norms and ICOLD Bulletins to be referred to), as part of the construction contract, which the contractor must adhere to. In both cases, mobilization of the DSPoE in good time, at least before tendering, would allow the panel to review the dam safety requirements including norms, standards and guidelines that will form part of the construction contract.

Another common issue that materializes during procurement is the lack of coordination and communication between the legal and technical teams which the employer is using to prepare the tender. The legal team will be focusing mainly on the part of the request for proposal (RfP) addressing the administrative conditions, Particular Conditions of Contract (PCC) or the General Conditions of Contract (GCC), as well as financial schedules, insurance, and other commercial provisions. The technical team will be focusing on the technical performance, design requirements, specifications and other technical annexes. This gap must be filled by more collaborative work, as there is an interdependence between the different parts of the construction contract, which often cannot be understood in isolation, for example, the technical prerequisites and legal consequences of the performance guarantees.

There may be some gaps, or even contradictions, between the different parts forming the entire contract, and a cross-check is often forgotten or carried out superficially before the tender phase is launched. Also, a final choice has to be made as to the priority of the

contractual documents in case of contradictions, to be sure that the contract documentation is consistent, and the dam safety requirements cascade down without legal ambiguity.

A final legal review will also be required, to check the legal compliance with the law applicable to the construction contract (which is not necessarily the law of the country in which the project is being constructed, but can be chosen by the contractual parties). Sometimes, there are mandatory legal provisions to be respected (such as the decennial liability requirements for civil works, for instance in France and some other countries) and to be checked before tendering. To avoid of any misunderstandings, it should be noted that in case the contracting parties choose a contract law other than the law in the country where the project is located, the state regulations regarding safety as any other part of the administrative law in this country must mandatorily be observed while constructing or operating the dam.

3.3 Dam safety issues during construction

In a FIDIC Red Book case (design done by the employer), the execution drawings are provided to the contractor who will construct the dam. In that case, any differing site conditions, such as adverse geological conditions, have to be dealt by the employer at his risk and costs. This is in line with the fact that the employer takes the overall responsibility of the dam safety requirements upfront, along with a dam safety compliance which ideally has been previously approved by the DSPoE.

In a FIDIC Yellow Book case (design done by the contractor, based on the employer's requirements and design criteria), the design for execution shall be reviewed by the Owner's Engineer (and cross-checked by the DSPoE) who issues binding instructions to modify the design if any dam safety criteria are not met. In case of differing site conditions, the responsibility of the contractor is reduced to some extent (see Sub-Clause 4.12 YB Ed. 1999/2017).

In a FIDIC Silver Book case (design done by the contractor, based on the employer's requirements and design criteria), nearly all the risks are supposed to be borne by the contractor, even in the case of differing site conditions. This may lead to a bias if the contractor challenges the dam safety requirements for timeline or budgetary reasons. An example would be if a major geological fault were discovered beneath the foundations, and the cost of filling the fault with concrete would be in excess of the provision for risks (contained in the contractor's budget), there would likely be a situation where the contractor would file claims, or even oppose the remedy, and eventually might either leave the site or suspend the works, creating a long dispute.

It should be noted that the contractual parties are free to allocate the financial risk and the consequences on the time for completion. They might even modify a model contract they use, such as the FIDIC model agreements, and adapt it to a more project-specific situation. This requires careful identification of potential risk and evaluation on the consequences for both contractual parties. In recent years, so-called partnering or collaborative contracting agreements have been more frequently used, according to which the contractual parties share the risks (pain/gain sharing mechanisms) in case of different site conditions and other unforeseeable events. FIDIC is currently working towards publishing a standard form of collaborative contracting.

Regardless of the method of delivery and contractual strategy the owner chooses (Bid-Design-Build or Design-Bid-Build) quality assurance during the whole construction and erection phase is crucial. Even if the employer's requirements stipulate that the contractor must set up a quality assurance programme (QA) to be strictly respected, the owner is well advised to reserve his right to approve the content and procedures of the QA and then subsequently to ensure that the contractor respects it, and also to supervise in general way the supplies and erection works are handled by the contractor. The owner should reserve himself ample inspection rights (for example, at the contractor's production site) and approval rights and also, if necessary, the instruction rights.

3.4 Dam safety issues during operation

During testing and the initial operation and maintenance (O&M) period, the interface between the civil works contractor and the electromechanical or hydromechanical contractor must be properly managed (if separate contracts apply). For instance, at the time of take-over, when the reservoir is about to be filled to allow for wet tests and early operation, the consequence of an incident of non-compliance relating to dam safety may be difficult to resolve if it affects both lots and the liability aspects are not cross-referenced and linked between the two contracts. This should be carefully scrutinized and clearly detailed at the time of the tender, to avoid an ambiguous situation where none of the contractors has been clearly designated to handle the dam safety aspects at the initial impounding.

As observed from case studies and as discussed in Section 1, the initial filling and the first five years of operation have been found to be critical when it comes to dam safety. The Defect Notification Period of contractors and suppliers usually extends from 12 to 24 months after completion of the works, and sometimes their liability ceases even before the reservoir is completely full and wet tests have successfully been concluded. The handover of the dam, with all its safety requirements and procedures, demands more time and requires a proper programme of knowledge transfer to the final dam operator. Experience shows that usually these aspects are left behind, and in many cases the dam operator starts his mandate unprepared.

4. Potential contractual solutions to close dam safety gaps

4.1 The FIDIC contract environment

Contractual solutions must be found within the existing contractual framework that is most often adopted by the industry. It is well known that since 1957, FIDIC (Fédération Internationale des Ingénieurs-Conseils) has published several standard construction contracts which have been broadly used for the last 60 years in more than 150 countries (see www.fidic.org). These standard forms of contracts are known to reflect best international construction administration practices, and to provide for a fair and balanced allocation of risks between the parties. The various parties therefore have sufficient scope to address all dam safety issues through FIDIC contracts.

FIDIC and many IFIs like the WB, the African

Development Bank, and the European Investment Bank have signed licence agreements giving the IFIs the right to use the entire spectrum of FIDIC contracts (called the 'Rainbow Suite of Contracts', including the most famous Red, Yellow and Silver Books Edition 2017) for all the projects they may finance. These will be part of their standard procurement bidding documentation.

In addition, it is interesting to note that the WB has just included the FIDIC Emerald Book Ed. 2019 [FIDIC, 2019[14]] for any project with substantial underground works, such as tunnelling or complex foundation treatments, which is also particularly relevant for hydropower and dam projects.

It should be noted that FIDIC is not the only available standard form of contracting. Other types of contracting arrangements can be adopted in the construction sector, such as 'Model Contracts' or individually drafted (bespoke)contracts.

However, the authors note that different principles may be used across the various standard forms of contracts (that is, NEC, JCT, ENAA, ICC, and so on). Therefore, particular attention needs to be paid to the rsk allocation in the standard form of contract, to reflect the contractual strategy decided in the preliminary studies by the employer.

4.2 Definition of a robust geological and the hydrological baseline

The main construction risks identified as dam safety risks in section 1 are:

- geological risks (such as unforeseen ground conditions); and,
- hydrological risks (such as flooding during and after construction) [ICOLD, 2021[2]].

To allocate these two risks to one party or the other, or to both under a risk sharing system, it is recommended to establish, in the project preparation phase, a clear baseline through a report containing assumptions on the main parameters and their interpretation for design. This is the so-called Geotechnical and/or Hydrological Baseline Report (GHBR). The GHBR will provide threshold values and minimum and maximum ranges for the key design inputs, so that the baseline and the allocation of the risk for differing site conditions from the baseline or the occurrence of unforeseen events are well known to the contractor when he bids, and when he is selected for implementing the contract.

This GHBR will become not only a design document but also a contractual tool as regards the allocation of responsibilities between the parties. Any events occurring on site will be compared with the limits and thresholds contained in the GBHR, and the consequences will be allocated to one or the other party, as well defined from the beginning of the project.

The geotechnical baseline report (GBR) [ASCE, 2007[15]] is now widely used in the FIDIC Emerald Book form of contracts (1st edition published in 2019), as the key contractual feature to allocate the geological risks during the construction of the project. Defining an accurate geotechnical baseline could be very expensive in terms of the amount of site investigations required, and this is critical when the funding for project preparation is not sufficient. This could be an issue when the preliminary studies to undertake the basic design have not been sufficient to cover all design aspects affecting the safety of the dam. This needs to be correctly budgeted from the outset of the project (or requested to the lenders during the preparation phase) to avoid a situation where unforeseen conditions would actually have been foreseeable, had investigations been conducted at an earlier stage.

Ultimately, as the geology may be unpredictable at a site, an appropriate contingency budget should be allocated in case a risk materializes, even if this contingency may increase the project cost and ultimately the project tariff. The employer should have taken this risk into account during project preparation, and not hide from it or transfer it to the contractor.

The risk of flooding during construction can also be shared, by defining in the hydrological baseline report (within the GHBR) the design flood and the threshold beyond which the responsibility to fix any damage caused by hydrological conditions on site move from the contractor to the employer. The GHBR should also define a robust flood measurement system, to avoid a situation where nobody is able to qualify the flood because measurement of the river level is not possible because of damage, or lack of maintenance, or because it has been destroyed by the flood itself. The risk of flooding during construction can be insured, and hence transferred to third parties (insurers). The hydrological risk during the long-term operation of a dam cannot be shared, however, and remains with the employer, as transferring the risk of overtopping to an insurer can only be done to a very limited extent for economic reasons.

While the geotechnical baseline can be reviewed by the contractor after he has carried out additional investigations under the scope of his Design & Build (D&B) or EPC contract, adjusting the hydrologic baseline during the period of construction would be impractical, as it would only add a few years of observation to the long-term records. It is therefore the full responsibility of the employer/owner to adopt the highest international standard in the design criteria, for prior review by the DSPoE. Essential to factor in are all the hydrologic analysis, the impact of climate change and the effect of long-term hydrologic variability, to ensure that the permanent flood discharge works to be built by the contractor will be climate resilient.

4.3 The new FIDIC Emerald Book: an improved approach for dam and hydropower projects

The Emerald Book Ed. 2019 is a combination of a Yellow Book Ed. 2017 (D&B form of contract, where the contractors deliver the works on a lump sum price basis, and gives a fitness for purpose warranty) with the addition of a special feature which is a specific re-measurement process when the actual site conditions are outside the limits of the GBR [ASCE, 2007[15]]. Under the Emerald Book, the geological baseline can be reviewed during construction, accepting variation for new quantities resulting from the new site conditions and to be paid on pre-agreed unit prices submitted at the tender stage in the so-called 'Schedule of Rates and Prices' and 'Schedule of Baseline' for the production rates. This very useful contractual tool avoids lengthy discussions/claims/disputes from occurring during the course of the project. Ultimately, the contractor is to be compensated in the event of differing site conditions based on actual ground conditions, once the updated design is approved by the Engineer.

The Emerald Book brings additional advantages, as it helps avoid disputes and bid price exaggeration that is usually observed in lump sum contract tendering, especially when the design and the geological assumptions are based on insufficient or unreliable data. In the authors' opinions, this may represent a major improvement in managing geological risk associated to dam foundation treatments (or any other underground works) and ultimately the safety of dams.

Although it is probably too early to provide feedback and evaluate performance and results of the application of this new form of contract, it clearly tends to be the recommended contract for dam and hydropower projects, whenever applicable.

4.4 Extending the liability period

As mentioned, the period just after commissioning is often a very critical one for many reasons. The Employer's Engineer (often called the 'Owner's Engineer') and the contractor are no longer in charge of the supervision of the dam. In many cases, the first complete impounding will not even have been completed before the takeover by the owner, for hydrological reasons. In addition, the owner/operator might not be fully prepared and trained to take over full responsibility of monitoring and surveillance or, in many countries, the organization that operates the dam may not be the same as the one that followed the construction, and this potential gap would occur precisely at the most critical time of the dam's life.

The authors believe that the situation could be significantly improved by:

- increasing the period of responsibility of the engineer and/or contractor for monitoring the dam behaviour after completion; and,
- extending the initial Defects Notifications Period (DNP) or the warranty period for the dam contractor, by increasing it from the usual two years (while FIDIC recommends one year by default) to five years, as the majority of the failures observed occurred in the five first years. The dam contractor's liability would be extended to five years and lifted (partially in some cases, as some legal liability may still apply) after all the dam components have finally been approved and accepted. Ultimately, it can be necessary to adapt the overall insurance scheme. The contract of the engineer could include assistance for monitoring and surveillance for the same period of five years. This period could be used to increase the capacity of the owner/operator team with a progressive transfer of responsibility for the dam monitoring and surveillance. The lenders could also include this extended period of liability in their dam safety policies, which usually terminate after the last and final disbursement. In other words, the O&M would be split into two phases:
- O&M 1, ideally five years long, where the contractor (and his designer in some cases) would still be liable for dam safety aspects as far as they are caused by construction or by design defects (if it is a D&B or EPC scheme), or if he is in charge of operations, the panel would continue its audit and the owner's engineer would extend assistance services to ensure capacity building and prepare the owner for dam monitoring and surveillance during the long-term operations; and,
- O&M 2, after five years, when the contractor's liability would be lifted and the owner would take over full dam safety responsibility.

Another way of ensuring proper O&M, is to bind the contractor from the beginning of the project under a DBO (Design and Build and Operate) form of contract (for five years, for instance) by keeping the contractor responsible for the design, construction and operation for five years after commissioning. There is a virtuous circle in this arrangement, as the contractor is ultimately interested in designing and constructing the best plant to be operated by himself. FIDIC is providing the FIDIC DBO Gold Book Edition 2008 for this DBO contractual strategy.

4.5 From review plus determination: the evolving role of the DSPoE

Fortunately for the safety of dams, the appointment of a DSPoE is now good practice in dam projects from the beginning of a project (preliminary studies). In recent years, it had been observed that the implementation of a DSPoE enhances the safety and quality of IFI-funded projects. It involves safety in coordination with the employers, engineers, and ultimately contractors in a professional manner.

For instance, the WB's Environmental and Social Framework (ESF) has adopted a risk management/informed approach, which defines the dam safety requirements in a proportionate manner to potential risk to dams, complexity of projects, and so on. The capacity of the employer and the operator of the dam, as well as the adequacy of the national dam safety framework/regulation are also important factors for assessing the required O&M mechanism, including the need for external technical support after commissioning. As mentioned, the WB Good Practice Note (GPN) under the ESF provides further details on these subjects [World Bank, 2021[12]]; this is a recommended approach as to dam safety assurance mechanism, including the DSPoE.

Therefore, the DSPoE provides an independent review and recommendations on the safety of dams to the employers/project implementing entities, while not releasing the role/responsibility of the engineers. The DSPoE typically conducts a review every six months during construction. The WB ESF GPN on Dam Safety also elaborates on the role and responsibilities of the independent DSPoE. The GPN provides practical guidance on how to set up the DSPoE with due consideration to team collaboration needs and so on, based on its operational experience. Ultimately, during O&M, the local employers'/owners' capacity should be considered when recommending the appropriate scope/duration of DSPoE services. In a project where there is a stronger in-house and oversight capacity of the dam owner/operator, or in countries with a robust dam safety regulatory framework, the frequency and scope of DSPoE inspections may be reduced accordingly.

It is found that the agreement signed between the employers and the DSPoE usually contains clear and well described terms of reference for project preparation, but leaves gaps regarding the construction phase. This is mainly because: the DSPoE agreement is drafted at a time when construction and dam safety risks are not yet fully understood; and, the contractor does not review or accept/sign on the ToR of the DSPoE, usually not attached (appended) to the construction contract. These gaps, especially where there are material cost/time implications, may lead to situations where the contractor challenges a decision by the

DSPoE, or the employer decides not to follow a DSPoE dam safety recommendation.

With regard to the contract, the DSPoE signs an agreement with the employer, but has no contractual link with the contractor. Therefore, the scope of services of the DSPoE and the modus operandi are sometimes unknown to the contractor. This information should be included in the tender documents to explain the role of the DSPoE.

As far as dam safety issues are concerned, the cost and time implications of a DSPoE's recommendations can be substantial. Therefore, there is a need to improve the contractual mechanism to address and implement in a more simple and direct way the independent opinions of the Panel. The role, scope and terms of reference for the Panel should be incorporated in the contractual framework in which the other stakeholders operate.

To fill this 'contractual gap', the authors suggest adaptations to the usual scheme by:

(1) Adding a new role for the DSPoE, in addition to its usual 'review and advise role' during the project life. Essentially, the authors propose an evolving role of the DSPoE during the various phases of a project lifecycle (see Fig. 3), where the DSPoE has capacity to issue binding instructions during construction to the employer on very technical and specific issues concerning dam safety (for example, recommending not to reduce a freeboard against flooding, to treat a geological fault with special concrete filling, not to undersize the diversion scheme/system, or not to excavate during heavy rain season). These would then to be passed on to the engineer for implementation[(a)] , leaving the opportunity for the employer to seek advice (or recommendations) from the sponsors/financiers if the binding decision is challenged by the employer. In addition, this mechanism would be detailed in the financial agreements between the employer (or the state) and the development banks.

Therefore, for this new DSPoE role, the following bodies should be appointed:

- During the preparation phase, a DSPoE 1 for the independent design review at the various milestones, such as feasibility, basic design (including design criteria) for D&B, detailed design (for Red Book scenario) and tender.
- During the construction phase, a DSPoE 2 (with the same members from DSPoE 1 or new members) for technical design review, works supervision (at least every six months), commissioning, and the provisional acceptance procedure including the impounding.
- During the O&M operation phase a DSPoE 3 (with same members from DSPoE 2 or new members) for reviewing and auditing the dam behaviour and the dam safety procedures (with inspections at least every six months during the most critical first five years).

(2) Adding the new DSPoE role, its rights and obligations in the construction contract and the provision that the DSPoE may issue binding instructions to the employer as to dam safety requirements in circumstances to be detailed by the project. This is to keep the contractor continuously informed.

(a) For example, in the FIDIC contracts, the binding recommendations of the DSPoE could be sent to the engineer in charge of the supervision of the project. The engineer may then subsequently issue an Instruction (SC 3.3 1999, SC 3.5 2017) or a Variation (Cl.13), as the case may be, such as the contract form may allow.

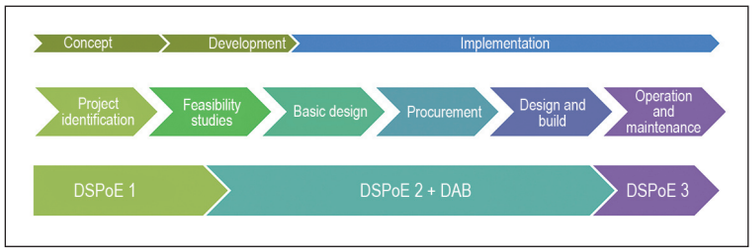

Fig. 3. The DSPoE role, from identification to operation and maintenance[(b)].

(3) Ensuring that the binding recommendations of the DSPoE are well recorded, and that the Dispute Adjudication Board (DAB) or the Dispute Avoidance and Adjudication Board (DAAB) are well informed. The DAB/DAAB may then decide on potential disputes arising from the cost/time effect of a dam safety decision. Then, any party who is still dissatisfied with the DAB/DAAB decision may escalate the matter to the next steps in the construction dispute resolution clause (under ICC Arbitration rules in FIDIC contract, or in courts, depending on the contract). Alternatively:

(4) An 'Expert Determination' provision may be inserted in the construction contract as an alternative dispute resolution procedure. For instance, ICC is proposing ad-hoc procedures for this. The DSPoE may then act with an 'Expert Determination' role, particularly suited for technical matters, with final and binding effect, if the parties wish so.

(5) Or it may also be possible to insert a provision in the construction contract to ensure that the contractor is directly bound to comply with any instruction of the DSPoE with respect to dam safety issues.

The last two options, (4) and (5), will require the acceptance by the contractor of the existing DSPoE's appointment by the employer, or a joint nomination by both the employer and the contractor may be requested (as is the case for the DAB or the DAAB).

Ultimately, it is important to check that the role and responsibility of the DSPoE is clearly mentioned in the various contractual documentation (agreements, covenants, agreements between the developer, the financing institutions, the employer, the engineer and ultimately the contractor(s)) of the project.

It may then be interesting to inform the engineer that there may be a prevailing and binding instruction by the DSPoE about any particular dam safety issue. This DSPoE's instruction procedure must be clearly and coherently included in all the project/contract documentation.

If the DSPoE is allowed to give binding instructions only on dam safety issues, this restriction must be clearly mentioned in the DSPoE agreement, to avoid misunderstandings.

In case of cost/time impact, any challenge of an Engineer's Determination by the contractor may then be brought before a DAB/DAAB, as defined in the

(b) In this proposition, it should be clarified that ICOLD would not be held responsible for any of the DSPoE acts, but would only be responsible of maintaining the list of potential DSPoE members. Employers may be helped in their choice by selecting CVs from this list which may be an alternative way to select experts, especially to find suitable people in their local context. The experts could be selected following specific prerequisites (CV with criteria) and competences evaluated once, and checked each year, for a three-year period, according to the requirements of the norm ISO17024 which contains principles and requirements for a body certifying persons against specific requirements, and includes the development and maintenance of a certification scheme for persons, for example.

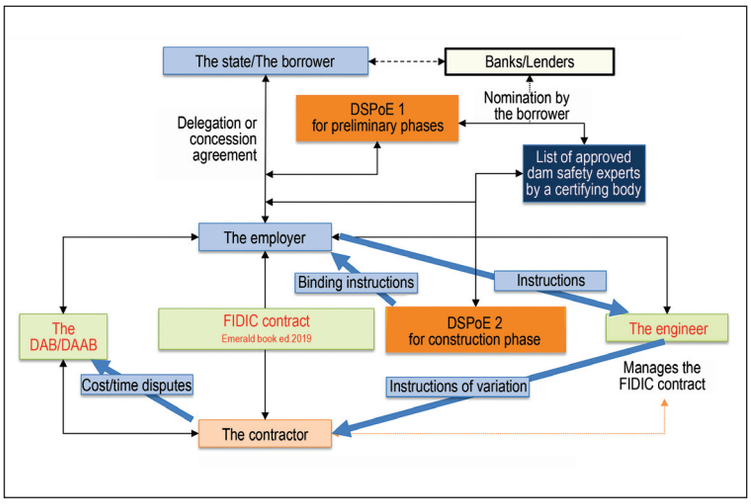

Fig. 4. The contractual architecture of the DSPoE.

FIDIC contract, as the DAB/DAAB remains the only dispute resolution board in case of conflicts.

4.6 Appointment of the DSPoE: Promoting an ICOLD register of dam experts

The ToRs for the DSPoE should cover the required qualifications of the experts to be retained, considering the particular context of the project and potential risks/technical challenges of the dam. The employer should prepare the ToRs of the DSPoE, including the required qualifications for panel members, based on which suitably qualified experts will be proposed by the employer. The draft ToRs and subsequently CVs of recommended experts would be subject to review for lenders (IFIs or private banks) and approval. Initially, the DSPoE appointment mechanism would be governed/controlled by the development banks (IFI), lenders or the developer during project preparation. The DSPoE would speak with one voice; one panellist should take the role of chairman, and harmonize the formulation of the recommendation in case of conflicting opinions within the panel.

During construction, to guarantee neutrality, the contractor would be able to exercise his rights to object to any member of the existing panel, or contribute to recruiting a new one under a new process before the construction contract signature. It is clear that a pre-agreed list of experts would be better able to achieve the quality and independency requirements of the panel and avoid reputational risks to the project.

To fulfil the establishment of an independent DSPoE, ICOLD, as a leading institution in dam safety matters, could organize the certification and maintain a list of potential dam experts, to be appointed by parties and mobilized on projects.

The 'ICOLD list of Dam Safety Experts' would serve to evaluate and certify the competences of each expert, classify international dam safety experts based on several criteria, including nationality (country of residence?), areas of expertise, and years of professional experience. ICOLD may review the list on regular basis and ensure its quality and independency.

It may also be recommended to stipulate a minimum of three members on the DSPoE with different professional experience, comprising for example:

- a dam expert;
- a geology expert, including undergrounds works;
- a hydrological expert; and, in some cases,
- an electromechanical expert if a hydro plant is involved in the project; and,
- recourse to a contract expert, if required, to review the contractual strategy before the tender and to help address dam safety disputes and claims during construction.

More experts could be mobilized depending on the specific features of the project. The cost of the panel should be properly budgeted across the project lifecycle, so that appropriate funding can be mobilized. Although this cost may not be negligible, it would usually represent some percentage of the total project cost and the benefits it would bring would certainly outweigh the cost.

ICOLD's List of Dam Experts should be made up of high-level international experts, and it should be regularly evaluated and certified with a scheme which follows international standards for certification. ICOLD would not be liable for the DSPoE or take part in the recruitment of the experts, but only maintain and disclose the list.

The preparation and maintenance of such a list by ICOLD, which would be available for DSPoE taking into account the specific scope of works and level of expertise required for each position, is likely to be appreciated by employers.

The experts may be dam specialists, geologists, hydrologists, seismologists, electro-mechanical experts, and others who are active in other entities such as IAHS, ISRM, IAEG. The International Hydropower Association could also attract relevant experts for dams where hydropower is involved. The wider collaboration would help to increase networks of experts for the respective fields. Moreover, DSPoE members would be able to work collectively in a group setting, and would serve together with other potential members, which should be checked by the employer who establishes the DSPoE (as with the WB GPN on Dam Safety). These experts would serve within a panel in a professional manner, meaning also that soft skills competencies would be required, such as referred to by Hoek and Imrie [1995[16]]. The employer would still have to check the prerequisites and CVs in selecting DSPoE members, and the chairperson in particular[(c)].

5. Conclusions

Statistics on dam failures show that the vast majority of accidents are associated with design errors, which manifest themselves within the first five years of operation and are mainly caused by geotechnical issues, including failure of the dam foundation, or insufficient spilling capacity leading to overtopping. These figures clearly demonstrate that:

- dam safety aspects need to be properly addressed from an early stage of planning and design;
- dam safety acceptance should not finish when a dam is commissioned, but rather it should extend into the initial O&M period; and,

(c) A single DSPoE should, if possible, cover all the project lifecycle or, because of the long implementation period of a dam project, a different DSPoE could be formed. As far as possible, DSPoE 1 and DSPoE 2 should be the same panel, to provide continuity from design to construction. Since it is quite unlikely that the same panellists will stay throughout operations, new panellists may replace those leaving and form the DSPoE 3

• the geological and hydrological risks should be better managed.

In the present context, where developers tend to transfer design risk and responsibility to the contractor under Design and Build or EPC/Turnkey contracts, the definition of the geological and the hydrological baselines of the dam project, and management of these two key risks during execution, becomes critical. The geotechnical and hydrological baseline reports become important contractual tools for allocating the two major technical risks affecting the safety of the dam between the parties. It is key that dam safety requirements are properly defined by the employer before tendering, and correctly drafted in the employer's requirements. The new FIDIC 'Emerald Book' in 2019 will contribute to enhancing dam safety, especially in dam projects with complex foundation and substantial underground works.

The first five-year period is critical to monitor and ensure the safe performance of the dam. The contractual set-up with the contractor's and the key technical experts' responsibility for safety issues must remain in force until after the initial dam commissioning, to monitor the structural and hydraulic behaviour of the dam and gradually hand over the infrastructure to the final dam owner or operator. For at least five years, the contractor must be liable for non-compliance related to dam safety aspects. Provisional acceptance can be given after completion of construction, but the final acceptance would be given after the five-year 'defect notification period', when the contractor's liability is lifted and the owner takes over full responsibility for dam safety.

The DSPoE that most lenders and IFIs already create for the dam projects they finance can play a key role in raising dam safety standards, and they are certainly a powerful resource to the dam project, provided that:

• the DSPoE is engaged from the early feasibility design stage; and,
• a direct contractual link between the panel, the employer and the dam contractor exists so that all key dam safety recommendations are binding and have immediate execution.

The DSPoE should act as:

• a design review authority during project preparation;
• a prevailing and binding decision-making board on high level dam safety issues during construction; and,
• an auditing body during initial operations.

ICOLD, as the main international organization in terms of dam safety, could facilitate the mobilization of dam safety panels by promoting, validating, retaining and regularly updating a list of accredited or certified experts that are eligible for a DSPoE, without taking any responsibility in their procurement or role, or the liability of each individual expert.

The recommendations given in this paper are aimed at improving best practice in dam safety. They are intended for dam owners, developers, planners, designers, contractors and operators who comprehend the challenges of securing sustainable and safe construction and operation of their dams, and require lenders and international institutions to review their own practices/procedures and take necessary actions to enhance their implementation. The whole industry has to adopt corrective measures to address safety and long-term sustainability issues better in dam projects, in a future where water and energy security will be key to combatting climate change and ensuring resilience in water and energy systems. ◊

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