Session:

Hydropower safety
What is good practice?

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For more information:  www.hydropower.org/congress
Hydropower Safety: What is Good Practice?

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About MWH Global
Since 1844
7500 employees
180 Offices

MWH has been Integral to
Water Resources, Hydropower & Dam Development on Every Continent

- Canada
- Pacific NW, USA
- Iceland
- China
- California, USA
- Peru
- Ethiopia
- Fiji
- Hawaii
What is Hydropower Safety

• Objective: To Prevent the Uncontrolled Release of Reservoir Waters and Consequential Physical/Environmental Damage and Loss of Life

• Elements of Safety:
  – Design and Analysis
    • Spillway Adequacy
    • Stability/Stress Analysis
    • Seismic Design
  – Construction Quality
  – Inspection
  – Performance Monitoring
  – Operation & Maintenance
  – Emergency Preparedness
    • Emergency Action Plan
    • Public Safety Plans
  – Personnel Safety

Tekeze Dam - Ethiopia
Why be Concerned?

Dams Do Fail: Over 50 Dam Failures per Year
Total Loss of Life in Thousands
Most Failures Occur at Dams Under 75 Ft Tall
Estimated Annual Costs of Failures Exceed US $1 Billion Globally

- Dam failures are rare, but high consequence.
- ICOLD data shows failure rate is declining;
- Dams built before 1950 – 2.2 % have failed;
- Dams built after 1950 – less than 0.5 % have failed;
  - Why the improvement and how do we continue to improve?
When and Why Dams Fail

• Over 70% of failures occur in the first ten years, many on ‘first-filling’
• Balance typically occur after 50+ years of service
• More than 94,000 dams in the U.S. - Over the next 20 years, 85% will turn 50 years old

• Main Causes:
  – Overtopping (34%)
  – Foundations (30%)
  – Seepage and Piping (28%)

• Three contributory areas to incidents:
  – Design
  – Construction
  – Operation (and Maintenance)

Uncertainties in materials, construction procedures, nature (PMF, Earthquakes)
Human Factors Contribute in Each Area – Humans are not infallible
How Safe is Safe Enough?

- Failures cannot be eliminated completely.
- Society is willing to tolerate some risk of “failure” for the benefits in return (traffic accidents, plane crashes, etc.);
- Public generally expect to be safe from everything, but mostly do not remember “low consequence” events;
- Engineers abhor failures under any circumstances.
Managing the Risks

• Challenge – especially with the non traditional forms of contracting – to ensure that risks lurking in the design and construction process are suitably identified, and responsibly placed.

• Contracting methods and influence on risk in Design, Construction, O&M. (Design-Bid-Build, EPC, Turnkey, PPP, BOOT, DBOF, etcetera).

• Safety By Design

• Quantitative and Qualitative Risk Assessments
State of Art in Design

- Risk Informed Decision Making - Failure mode analysis;
- Use of BIM software that makes routine design tasks easier, freeing up engineers to concentrate on the analyses and matters that can be catastrophic.
- Efficient use of freely available and proprietary software; however suitable caution must be used. The capabilities of computer analysis is to be regarded with caution: “the results of computations are not guaranteed to be reliable simply because they come out of computer analysis.”;
- Proper and focused site investigation and 3D geological models;
- Clear distinction between geological factual data (GDR) and interpretation (GBR);
- Appropriately experienced engineers, teams and design management that are able to “feed-back” industry and personal experience;
- Proper design QC and QA;
- Experienced Review – no substitute for experience;
- Communication of Risks and Uncertainties
- Learn from prior experience of others – sharing lessons learned
State of Art in Construction

• Qualifications Based Selection vs Lowest Price. Evaluation criteria should include substantial weighting towards technical experience with similar construction of both the contractor and supervisory staff.

• Use the drawings and specifications (don’t rely on foremen’s experience). One integrated BIM model from planning, design, through construction, and operation.

• Investigation and Design is not complete until construction is complete. Materials and conditions change based on new information during construction, and design needs to be adapted accordingly. There is no perfect knowledge prior to start of construction.

• Proper monitoring of construction and involvement of the engineer. ICOLD 129 suggests that “for most of the project time two parallel decision lines exist. Design decisions are made by the design project manager and the dam(design) engineer, whereas execution decisions are made by the construction project manager(or his representative) and the contractors”

• Balancing pressures of schedule, cost, and quality.
Improving Hydropower Safety via Construction--FutureWorld?

- Robotics Revolution? Autonomous Vehicles?
  - Higher quality and greater precision?
  - Autonomous drilling jumbo in 2017
  - Autonomous/robot concrete mixing and delivery – reduce the opportunities for individual concrete truck drivers to decide on the concrete water content!
  - Laser assisted levelling and direction control – look for more such controls.
  - Self-diagnosing instrumentation?
  - Drones?

- Future of Materials
  - Self-healing materials - autonomous healing of concrete – polymeric capsules to help to meet the requirements for self-healing concrete;
  - Carbon fibre used in repair, but not yet in design of new works;
  - Self-monitoring materials – often based on electrical performance of the material;
• “Failure rate of dams has been reduced by a factor of four over the last forty years. This improvement doubtlessly results from the appearance of, and improvements in certain investigation techniques, but it also arises from the wider dissemination of knowledge on risks.” (ICOLD).

• Designing and building a dam is not a «once-and-for-all» exercise. The structure must be continually supervised and inspected throughout its whole life, to ensure that it remains in good health.

• Event reporting (ER) System
  – Event Report (ER) is developed and submitted by the reporting organization
  – ER form is reviewed by central coordinator and revisions made before sharing, i.e. quality control.
  – Central coordinator posts ER document to share site alerting participating organizations
  – Searchable database of past Ers
National Performance of Dams Program

- Formally launched in 1994, the NPDP is an effort to establish within the dam engineering and safety community the ability to learn from the in-service performance of dams, supporting improvements in dam design, operation, engineering, and public policy.

https://npdp.stanford.edu/
Association of State Dam Safety Officials

Dam Failure & Incidents Committee (http://www.damsafety.org)

The mission of the committee is to assist the States (in partnership with other stakeholders) to improve the practice of investigating/learning from dam failures and incidents.

The ASDSO Board of Directors approved an updated committee charter in September 2013 and the committee's updated goals are the following.

• Goal #1: Maintain and update the Dam Failure Investigation Guideline through ongoing committee research into past dam failures and investigation practices of others.

• Goal #2: Collect and share lessons learned from past dam failures/incidents with the ASDSO membership.

• Goal #3: Provide support to ASDSO and states during and following dam failures and incidents with the goal of advocating for successful investigations by qualified and trained personnel.

• Goal #4: Train the state dam safety officials and other ASDSO members in the best possible industry methods and practices for investigating and reporting on dam failures and incidents.
NHA’s Operational Excellence (OpEx) program is a voluntary event reporting system that receives, distributes, archives, and catalogs Operational Excellence Information (OEI) and any resulting best practices and lessons learned.

With aging assets and an aging workforce, OpEx and the event reporting system will provide a trusted and reliable database of historical and current operational issues and serve as an educational and training resource for future personnel.

NHA’s OpEx Event Reporting System module captures important events using a simple form. The event report is drafted and submitted for approval. NHA coordinators will review, categorize, and redact any sensitive information. The event report can be searched based on criteria.
Summary

- Three contributory areas to incidents:
  - Design
  - Construction
  - Operation and Maintenance
  All subject to the Human Element.

- Construction Contracting Mechanisms influence Hydropower Safety

- Failure rate of dams has been reduced by a factor of four or more over the last forty years. This improvement ...........also arises from the wider dissemination of knowledge on risks, (ICOLD).

- Sharing Feedback – Event Reporting Systems

- Improving Hydropower Safety in the Future
  - Expand Sharing of Information – Global Database, IHA/ICOLD/ Safety Working Group
  - Integrated Design/Construction/Operation/Maintenance (BIM)
  - Proper Contracting Mechanisms and Allocation of Risks to those Best able to manage
  - Technologic advances in construction methods and materials (autonomous vehicles, robotics, etc)
building a better world
building world
A BETTER