Design, Construction and Maintenance of Large Dams

Gerald Zenz
Graz University of Technology

Contributors - Dam Surveillance Practice from Kaprun Seminar:
P.Obernhuber; P.Schöberl; R.Melbinger;

Dam Safety in Austria
Authorization Procedure
Multilevel Principle
Obligation of the Owner
  Dam Safety Engineer
  Dam Attendant
Safety During Operation / Surveillance
Annual Inspection
Five Year Assessment
Austrian Commission on Dams
Aspects of Visual Inspections
Design, Construction and Maintenance

2nd Experts Seminar
Dam Surveillance Practice
30 May to 2 June 2005

Invitation

Contributors to Dam Surveillance Practice from Kaprun Seminar:
P. Obernhuber; P. Schöbert; R. Melbinger;

Design - Construction
- State of the Art
- Regulations
- Design / Concept

Monitoring
- Measurements
- Surveillance
- Testing

Emergency
- Draw Down
- Emergency Plan
Dam Safety

Structural
- Erosion
- Sliding
- Fracturing

Operational
- Failure
- Ageing
- Seepage

Flood Relief
Draw Down
Reservoir Emptying

Dam and Foundation
Reservoir and Downstream
Appurtenant Structures
Equipment

Authorization Procedure

Permission Construct
Construction Permission
Temp. Operation
Unrestricted Operation
Design Documents; Reports; Permission
Certification for permitted operation
DAM SAFETY in AUSTRIA

2 Hazard Categories
   - $H \leq 15m / I \leq 500,000m^3$
   - $H > 15m / I > 500,000m^3 \rightarrow$ special check procedures

Public Safety and Rights of Third Parties protected by the Water Law
High Safety Level required → Load scenarios with very low probability of occurrence considered

Periodical „Safety Assessment“ stipulated by the Law

Awareness and Control of Residual Risk (Risk Management)
Sound Engineering Judgement
EXPERT – and Multilevel PRINCIPLE

Obligation of the Owner

Maintenance, i.e. keep the plant in proper and safe condition, according to the license and to the State of the Art
Stick to the operation rules granted by the authority
Appoint a DAM SAFETY ENGINEER and the necessary deputies
Inform the population periodically regarding provisions made for incidents ($H > 15m, I > 2$ Mio $m^3$)
Establish and steadily update a Dam file containing all relevant information on the dam
SAFETY

Design Construction
Surveillance
Emergency Preparedness
Maintenance
Repair/upgrading
Damage Limitation
...in due time!

Competence to decide and act

Sound Engineering Judgement

In due time!

acc.: Fed. Office for Water and Geology/Biel/CH

Institute for Hydraulic Engineering and Water Resources Management

Ljubljana – November - 2008

Dam Safety during Operation

Design Documents; Permissions; Expert Statements; Instructions to Operate, ...

Surveillance

Continuously ⇒ Safety checks
Annually ⇒ Institutional Assessment
Every five years ⇒ Institutional Assessment

Ljubljana – November - 2008
Continuous Surveillance

**Program**
- Visual Inspection
- Measurement Values

Automatic System: Boundary Values
Dam Attendant (DA): Visual, Measurement, Plausibility Check
Dam Safety Engineer (DSI): Plausibility Checks

Dam File, Reports, Data Base

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Annual Inspection

Measurement Reports, Report of Dam Safety Engineer, Geologist, ...

**Dam Safety Engineer**
- Surveillance
- Evaluation of Measurements
- Safety Assessment

**Annual Report**
Statement for safe dam operation

**Company**
- Management
- Employee

**Authority**
- Federal
- Central Government
Annual Report
written by the Dam Safety Engineer

Report:
- General: Unusual Events, Data retrieved
- Observations: Conclusion of Observations
- Measurements: Interpretation of behaviour
- Conclusion: Safety Assessment

Attachments:
- Inspection Reports, Geology, ..
- Display of measurements

CHANGES
- Load scenarios: static, dynamic, hydraulic
- System Characteristics: design, condition, material properties, fissures, cracks, appurtenant structures, surveillance system
- System Behaviour: deformations, seepage, uplift
- Stake Holder Interests: new arising public safety concerns
- State of the Art: new criteria, new calculation methods

DAM SAFETY = DYNAMIC PROCESS
Five Year Assessment

Annual Reports, Five Year Report
Dam File

Commission of Dams - independent Experts:
- Visual Inspection
- Assessment of Measurements, Comparison, Long Term Behaviour
- State of the Art
- Safety Assessment

Written Assessment
Permission to operate, Additional Requirements
Established in the Fed. Min. of Agriculture, Forestry, Environment and Water Management
Experts of all dam related Sciences
Check of the Project in course of the Water Rights Procedure
  - mandatory if $H>15m$, $I>500,000$ m$^3$
  - mandatory if special/unusual methods of design/construction applied, or if difficult foundation conditions
Matters of general importance, fundamental questions (e.g. guidelines)
"Backbone" dam supervision (steady Subcommittee)

Stability Assessment for Embankment Dams
Stability Assessment for Dams under Seismic Loads
Design of Spillways

Resolutions of the Commission on Dams:
  - Requirements for the Dam Safety Engineer
  - Education of Personnel, Dam Safety Courses
  - Supervision on Minor Dams
The DAM SAFETY ENGINEER

„Central Switchboard“ for all issues of dam safety

- normal operation
- extraordinary events/incidents

Requirements (DSE+Deputies)

- Techn. Top Management
- Dam Expert
- familiar with the plant
- reliable
- appropriate Directive Power to take measures
- appropriate availability

Comprehensive Liabilities regardg. Dam Supervision

Comprehensive Liabilities as to Reporting

- Annual Safety Report (Safety assessment)

Approval by the Water Authority!!!

Dam Surveillance – Structural Safety Assessment

Attendant

Visual Inspection

Dam Safety Engineer

Annual Inspection

Water Authority

Five Year Assessment
Visual inspection - what?

**concrete dams**

upstream face (if visible),
downstream face,
crest
cracks
flaking
damages in concrete
joints
wet areas
sintering

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visual inspection - what?

**concrete dams**

inspection galleries
cracks
flaking
damages in concrete
block joints
concreting joints
rock (if visible)
pipes (grouting, drainage)
wet areas
leakage
percolation water
Photo documentation - Schlegeis dam

block joint 7/9

block 19, annual joint
date: 13th October 1999, reservoir level: 1776.38 m

Items of Visual Inspection

crack

leakage

Schlegeis dam, block 2, radial inspection gallery
date: 29th May 2001, reservoir level 1722.29 m

Schlegeis dam, block 9, inspection gallery 3
date: 28th May 2002, reservoir level 1723.65 m
visual inspection - what?

**embankment dams**

**surface**

- leakages: wet areas, seepage, springs, siltation, vegetation
- deformations: bulging, cracking, sliding, settlements

**inspection galleries**

- see concrete dams

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visual inspection - what?

**reservoir, slopes**

- sliding, settlements
- vegetation
- river branches
- glaciers
- driftwood

**downstream dam area**

- springs
- settlements
- slidings

**tunnels and caverns**

- flaking of rock or shotcrete
- cracks in rock or shotcrete
- leakages

**hydromechanical equipment**

- damages leakages
**down stream dam area**

*Durlaßboden dam*  
*springs*

**date:** 28th August 1985, reservoir level 1404.25 m

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**leakage showed by vegetation**

*Waag reservoir, date: 12th August 2004*
Leakages

Schlegels dam, spring in downstream area
date: 14th August 2002, reservoir level 1772.02 m

Eberlaßte dam, relief well
date: 9th September 2003, res. level 1115.92 m

Bennett Dam, British Columbia
“Sinkhole”
Damages, Deteriorations

Birecik dam, date: 26th May 2003
repaired bulging

Bürg reservoir, date: 31st May 2001
local subsidence of reservoir bank

Bürg reservoir
left quay

local sliding of reservoir slope
date: 18th February 1998
Driftwood and spillways

Bürg dam

Valle di Lei dam / Switzerland

no danger
danger of plugging

Damages, Deteriorations

supporting structure

concrete steps
visual inspection - why?

earliest recognition of
deteriorations
defects
damages
failures
abnormal incidents

and

start of necessary measures

testing

of

hydromechanical equipment

bottom outlets
spillway (if gated)
emergency power supply
voice transmission lines
signal transmission lines
warning and safety devices
measuring equipment
remote monitoring system
testing - when?

<table>
<thead>
<tr>
<th>Component</th>
<th>Action</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro mechanical equipment</td>
<td>Partial opening</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>Full opening</td>
<td>dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 year</td>
</tr>
<tr>
<td>Communication devices</td>
<td></td>
<td>1 month</td>
</tr>
<tr>
<td>Limiting values</td>
<td></td>
<td>1 month</td>
</tr>
<tr>
<td>Emergency power supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standby generator</td>
<td>Start</td>
<td>1 month</td>
</tr>
<tr>
<td>Malfunction signal</td>
<td></td>
<td>1-3 month</td>
</tr>
<tr>
<td>Warning signals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication devices</td>
<td></td>
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</tr>
</tbody>
</table>

Testing scheme for the bottom outlet:

1. Emergency gate (no discharge)
2. Main gate partial opening
3. Main gate full opening (dry)
Documentation of Bottom Outlet Testing

attention in the river bed !!

- date, reservoir level
- circumstances
- opening value, discharge
- time for opening, closing
- hydraulic pressure
- current consumption

even testing of manual drive !!

SIGNIFICANT REDUCTION OF WATER LOAD (DANGER)
COMPLETE DRAW DOWN OF RESERVOIR
CONTROL OF REIMPOUNDING
OTHER PURPOSES:
- Sediment flushing
- Minimum flow in the river
- Flood mitigation (lowering res. level before flood)
- River diversion during construction

BOTTOM OUTLETS

SAFETY OPERATIONAL PURPOSES
Equipment

≥ 2 Gates or Valves
- Main Control/Service Gate
- Standby/Emergency Gate (suitable to cut off discharge)
- Types: sluice/radial gates, plunger/hollow jet/butterfly valves

DESIGN (continued)

INSPECTION and TESTING

<table>
<thead>
<tr>
<th>Event</th>
<th>Test Type</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of construction / major design alterations</td>
<td>COMPREHENSIVE TEST</td>
<td>Extreme conditions (load / discharge) (Hydraulic Model Test)</td>
</tr>
<tr>
<td>Periodical dam inspection (dam attendant)</td>
<td>VISUAL ASSESSMENT OF STRUCTURE</td>
<td>Accessible components</td>
</tr>
<tr>
<td>1 year</td>
<td>DISCHARGE TEST</td>
<td>High reservoir level partial opening</td>
</tr>
<tr>
<td>10 years</td>
<td>ASSESSMENT OF STATE INCLUDING UNDER WATER COMPONENTS</td>
<td>Reservoir empty → scope and schedule of maintenance works</td>
</tr>
<tr>
<td>Depending on before mentioned assessment</td>
<td>COMPREHENSIVE REFURBISHMENT/OVERHAUL/UPGRADING</td>
<td>Extreme conditions (load / discharge) (Hydraulic Model Test)</td>
</tr>
<tr>
<td>Depending on catchment area conditions</td>
<td>SEDIMENT MONITORING SEDIMENT CONTROL</td>
<td>flushing (shredding)</td>
</tr>
</tbody>
</table>

Include check of remote monitoring / control systems!!
SPI LLWAYS

Discharge extreme floods ➔
Keep reservoir level within allowable limits

➤ Flood control, flood mitigation

MAINLY SAFETY PURPOSES

Types (preferred):
• ungated – fixed sill, free flow conditions
• gated – gates opened by water pressure
Availability / Operational Reliability

- Energy Supply ➔ redundant! ➔ see Bottom Outlets
- Reliability/availability of control/monitoring systems ➔ ➔ ➔
  Redundant/self monitoring systems
- Access to Control Chamber all over the year
- Availability under extreme weather conditions
  Ice (heating)
  Snow
- Provisions to prevent clogging
  Trash racks, log booms
  Control of sedimentation level at intake
Fixed rack

Log boom
MAINTENANCE
Weathering, Corrosion
Abrasion
Fissures, cracks
Leakage, seepage
Scour
Wear of moveable components (gearboxes, seals)
Material deficiencies (e.g. in cast metal, welding)
Damage to access paths

Discrepancy with STATE of the ART

UPGRADING