DAM SAFETY MONITORING & SURVEILLANCE IN MALAYSIA

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DAM BREACH:
SOME CASE HISTORIES
Teton Dam (1975 – 1976)

Immediately following the disaster, Mulholland said he "envied those who were killed" and went on to say, "Don’t blame anyone else, you just fasten it on me. If there was an error in human judgment, I was the human, and I won’t try to fasten it on anyone else."

"The construction and operation of a great dam should never be left to the sole judgment of one man, no matter how eminent."

St Francis Dam, US
1924-1928
(Killed 600 people)

Vajont Dam, Italy
1959-1963
(Killed 2000 people)
Situ Gintung Dam, Indonesia (1933 –2009)

CURRENT INVENTORY OF DAMS

Water Supply Dam – Klang Gates (Taman Melawati)

Water Supply Dam (Sg. Selangor)
CURRENT INVENTORY OF DAMS

Irrigation Dam – Pedu Dam (Alor Setar)
Flood Defense Dam – Beris Dam (Kedah)

Hydropower Dam - Bakun (SESCO)
Recreation Dam (Putra Jaya)
Objective of Dam Safety Monitoring & Maintenance

- Prevent disastrous consequences to:
  - National Security
  - Public Safety
  - Social Economy
  - Environmental
OBJECTIVE OF DAM SAFETY MONITORING & SURVEILLANCE

**Dam Safety Monitoring & Surveillance** should include identifying:

- **Factors** that influence
  - Safe operation of dam / appurtenant structures
  - Dam’s potential to adversely affect human life, human health, property, and the environment surrounding it.
- **Adequacy** of operations, maintenance & emergency plan of the dams

ROLE & RESPONSIBILITY OF STAKEHOLDERS
ROLE & RESPONSIBILITY OF DAM REGULATOR

• **Regulator**
  – Monitor obligatory tasks (monitoring & surveillance) by dam owner
  – **Review & approve competency** of technical staff by the owner for monitoring & surveillance
  – Organize scheduled **independent inspection** for compliance check
  – Review & approve **surveillance report**

ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

• **Owner**
  – **Collect and storage** of up-to-date documentations:
    • **Static data** in Data Book - design, as-built, operating manual
    • **Dynamic data** in Dam Safety & Surveillance Report - maintenance, monitoring, repair & incident reports of dam
  – Implement **Monitoring & Surveillance**
  – Implement **Maintenance Scheme**
ROLE & RESPONSIBILITY OF DAM OWNER & OPERATOR

• Operator
  – Perform regular visual inspection
  – Perform periodical check and maintenance of control systems, discharge structures, etc.
  – Annual reporting

ROLE & RESPONSIBILITY OF DAM ENGINEER

• Engineer
  – Perform comprehensive technical inspections
  – Plan additional monitoring & taking measurements at scheduled interval or changes in operational conditions
  – Interpret, analyze data collected & visually present outcome in graphical form
  – Highlight any slowly developing but rapid deteriorating dangerous trends or signs (anomalous behaviors)
  – Prepare surveillance report
ROLE & RESPONSIBILITY OF DAM CONTRACTORS

- **Contractor**
  - Assist the **Engineer** on their tasks
  - Repair damaged **instruments** or install additional instruments
  - Improve precision & reliability of **instruments** & measurements
  - Take measurements & compile **data** collected
  - Prepare factual monitoring report

DAM SAFETY MANAGEMENT
DAM SAFETY MANAGEMENT

- **Safety Inspection**
  - Routine Safety Inspection
  - Periodic Safety Inspection
  - Special Safety Inspection

- **Dam Safety Management Plan**

- **ERP – Emergency Response Plan**
  - Prepared based on dam break study
  - ERP during construction and operation phases
  - Avoid and minimized injury/loss of life to employees and public during emergency incidents

DAM SAFETY REGULATORY FRAMEWORKS
ANCOLD (1976 & 2003) defines:

- **Monitoring**
  - Acquiring data from measuring devices
  - Recording of data
  - Deducing performance and behavioral trends

- **Surveillance**
  - Continuing examination of conditions
  - Reviewing operation, maintenance and monitoring procedures and results
  - Determining whether hazardous trend is developing or appears likely to develop
Monitoring & Surveillance shall be continued as long as the hazards associated with the existence of the dam present.

- **Level** of Monitoring & Surveillance depends on consequences of failure.

- Survey on:
  - Deformation of dam
  - Reservoir level & rainfall

- Measurements on:
  - Seepage & pore pressure
  - Foundation pressure
  - Stresses in dam & structures

- Spillway performance & condition
- Monitoring on:
  - Cracks
  - Erosion
  - Seismicity (esp. for large reservoir or at seismically active areas)
**MONITORING**

- **Consequence of Failure**
- **Nature of Behavior being monitored**
- **Special Incidents** (Extreme climatic condition, earthquake)
- **Stage of Maturity of Dam**

**Monitoring Frequency depends on**

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**SURVEILLANCE**

- **Safety Inspection**
  - Routine Safety Inspection
  - Periodic Safety Inspection
  - Special Safety Inspection

- **Dam Safety Management Plan**
VISUAL INSPECTION OF DAM

UNCONTROLLED LEAKAGE/SEEPAGE
CRACKS ON DAM STRUCTURES

TENSION CRACKS ON DAM CREST
EROSION ON EMBANKMENT SLOPES

- Erosion at the Downstream Face of Dam
- Erosion due to Dam Overtopped

INSTRUMENTATION MONITORING OF DAM
STATE-OF-ART & FUTURE TREND OF INSTRUMENTATION

Instruments
- Fiber Optic Sensors
- Automated Total Stations
- LIDAR Terrestrial Survey
- GPS Displacement
- Real Time Data Acquisition & Communication Systems

Problems & Solutions
- Electromagnetic Interference (EMI)
- Damage during Electrical Storms
- Data Reliability
- Longevity of Instruments

Analysis & Software
- Early Warning System
- Data Processing, Interpretation & Presentation Software
- Data Acquire & Data Management Systems

TYPICAL INSTRUMENTATION FOR EARTH DAM

Source: http://www.geokon.com/products
TYPICAL INSTRUMENTATION FOR CONCRETE DAM

Source: http://www.geokon.com/products

TYPICAL INSTRUMENTATION FOR TUNNEL

Source: http://www.geokon.com/products
DAM LEAKAGE/SEEPAGE MEASUREMENT

\[ Q = \left( \frac{2}{3} \right) \frac{\sqrt{2} g H}{V_0} = \sqrt{V_0}^2 = 1.267 H^{2.5} \text{ (m in m)} \]

Flow Through a V-Notch Weir

SEISMOMETER

![Seismometer Image]
HYDROLOGICAL INSTRUMENTATION

Flip Bucket Rain Gauge

DISPLACEMENT SURVEY USING 3D GROUND BASED TERRESTRIAL LiDAR

3D Light Detection and Ranging Equipment (LiDAR)
BEHAVIOURAL ANALYSIS

Seepage Analysis (FEM Modelling)

FEM - 0.2 lit/s to 0.4 lit/s
1. Inclinometer Monitoring

3 inclinometer stations were installed at respective chainages to measure horizontal movement in the dam embankment (e.g. A-B direction: Upstream-downstream direction).
2. Magnetic Probe Extensometer

Magnetic Probe Extensometer is used to monitor the internal vertical displacement of embankment and foundation of the dam.

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<th>Settlement (m)</th>
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<tr>
<td>-0.06</td>
<td>6-Oct-03</td>
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<tr>
<td>-0.05</td>
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<tr>
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<td>6-Aug-07</td>
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<tr>
<td>-0.09</td>
<td>14-Nov-07</td>
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Total settlement for all 3 stations EX 3001, EX 3002 and EX 3003 are well below the specified permissible limit of 50mm in the past (2002-2006) and during the IMP.
3. Vibrating Wire Piezometer

There are 24 numbers of vibrating wire piezometer gauges installed/embedded in clay core of the dam at predetermined locations to measure the pore pressure.

4. Standpipe Piezometer

Standpipe piezometers are used to monitor the Groundwater Table in the stability berm at the downstream of the dam. There are five stations installed at the dam toe.
5. Seepage Measurement Chamber

There are 3 seepage measurement chambers (v-notch weir) downstream of the dam at SC 01, SC 02 and SC 03 to measure the amount of the dam seepage water.

Rainfall Data vs Seepage

It is evident that high seepage readings invariably were attributed to high rainfall values recorded at Seri Kembangan station located within the Putrajaya upper catchment boundary.
7. Total Station and Optical Prism Position, Precise Settlement Monitoring

To monitor any settlement or movement along the dam crest and its profile. Survey work was carried out during the IMP to monitor the following instruments:

1. Existing Surface Settlement Marker (21 pts)
2. Additional Optical prism (32 pts), and
3. Additional Settlement Pin (14 pts)
8. Visual Inspection of inclinometer tubing

Micro camera for inclinometer tubing inspection

The recorded video images show that there is no physical damage found in all the 3 inclinometer tubing. The inspection also confirmed that the maximum displacement recorded for the inclinometer was all at the joint locations.

It has cleared the earlier doubt that the useful life of these tubing ended when tubing curvature had forced the inclinometer probe out of the access grooves in the tube and prevented passage of the inclinometer probe.
The ramp at the access groove interface between the tubings and the telescoping coupling has introduced slight discontinuity, caused the new inclinometer probe (Bluetooth inclinometer), which is much lighter compared to the old inclinometer probe, to experience difficulty to advance into the tubing.