Dam Safety Instrumentation with Case Study

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Dam Instrumentation

• Safety of Dam
  • Construction
  • First Filling
  • Operation
• Refinement of Design
• Back Analysis
Status of Dam Instrumentation in India

- 4800 Dams + 475 under construction
- 200 Instrumented Dam (< 5 %)
- About 50 years ago, instruments were not usually specified in Water Resources Project Proposals and instruments were installed only when problems were encountered during construction and operation of the project.
- Instrumentation is generally specified in each Project Proposal: Tala, Tehri, NJP, SSP, Indira Sagar.
Tala Hydroelectric Project, Bhutan
Layout of Head Race Tunnel

- Dam Complex
- Thiyomachu (101m)
- Padechu (268m)
- Geduchu (963m)
- Mirchingchu (320m)
- Kalikhola (520m)
- Takctchu
- D/s - 2244m
- Thiyomachu
  - D/s - 3027m
  - U/s - 1212m
- Padechu
  - D/s - 2081m
  - U/s - 2916m
- Geduchu
  - D/s - 2525m
  - U/s - 1875m
- Mirchingchu
  - D/s - 2201m
  - U/s - 2214m
- Kalikhola
  - D/s - 1592.6m
  - U/s - 1175m

AGO Reach

- By Pass of HRT

Excavation of HRT from 11 Faces

HRT 6.483 km  HRT 4.997 km  HRT 4.400 km  HRT 7.183 km
PROJECT FEATURES

Dam on River Wangchu

Concrete Dam - 92 m height  130 m length
(Located  3 km d/s of Chukha Power House)

Diversion Tunnel - 6.8 m diameter 356 m length
U/S View of Dam
Intake Structures
Coffer Dam
Diversion Tunnel
Dam D/S with Sluices Glacis (HPC)

During Construction  
During Operation
Dam U/S & D/S during Operation
Instrumentation Programme at THEP

- Planning
- Technical Specifications
- Contractual Arrangement
  - Calibration of Instruments
  - Supply
  - Installation
- Monitoring
Instrumentation Programme at THEP

- Accuracy of Data
- Analysis
- Documentation/Report
- DAS
- Attitude/Interest of Project Management
- Instrumentation Responsibility
- Cost of Instrumentation [3%]
Cost and Power Generation

- **Cost to Completion** – Rs. 43210 million
- Project Fully financed by the Govt. of India
- Indian Technology
- Instrumentation Cost

- **Annual Generation** - 4865 million units
- **Cost per unit**
  - Rs. 1.80 per unit (India)
  - Rs. 0.30 per unit (Bhutan)
Instrumentation at Tala Project
Quality Control and Instrumentation

- Contractual Arrangements
  - EnCardio Rite Electronics Ltd., Lucknow
- Calibration of Instruments
- Supply
- Installation
- Monitoring
- Reporting of Monitoring
- Documentation
<table>
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<tr>
<th>S. No</th>
<th>Name of Instrument</th>
<th>Total No. of Instruments</th>
<th>Remarks</th>
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<td>3</td>
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<td>11</td>
<td>Automatic Water Level Recorder</td>
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Instruments Installed in Dam

- Instruments Installed = 282 Nos.
- Instruments Working = 277 Nos.
- Instruments Not Working = 5 NOs.
U/S View of Dam, Intake Structures
Coffer Dam, Diversion Tunnel

TYPE: CONCRETE GRAVITY
HEIGHT: 92 M
NO. OF BLOCKS: 7
UNDERSLUICES: 5
OVER SPILLWAY: 1
OBSERVATION OF TEMPERATURE METERS

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Temperature (°C)

Date
Figure 6A: Observation of Temperature meters B5T16 to B5T22
Temperature Meters in Block 2

Monitoring Time (Date)

Temperature (degree c)
## Cement Content & Concrete Temperature

<table>
<thead>
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<th>Cement Content kg/m³</th>
<th>Temperature of Mass Concrete</th>
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<tr>
<td>210</td>
<td>25.4 (10-30.9)</td>
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<td>22.5 (10-28.8)</td>
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<td>190</td>
<td>19.0 (10-27.7)</td>
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<td>180</td>
<td>14.9 (10-15.6)</td>
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<td>160</td>
<td>13.6 (10-13.6)</td>
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<td>140</td>
<td>12.4 (10-5.2-12.4)</td>
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Cube Compressive Strength at Different Testing Age

Compressive Strength (MPa)

Testing Age (Days)

Cement Content = 200 kg/m³
Cement Content = 190 kg/m³
Cement Content = 180 kg/m³
Cement Content = 170 kg/m³
Cement Content = 160 kg/m³

Comp. Strength = 15 MPa after 365 days
Comp. Strength = 12.5 MPa after 28 days
Pore Pressure Meters in Block 5

Monitoring Time (Date)

Pore Pressure (kg/cm²)

B5P1
B5P2
B5P3
B5P4
B5P5
B5P6
B5P7
B5P8
B5P9
B5P10
B5P11
B5P12
B5P13
B5P14
B5P15
B5P16
Strain Meters in Dam Block 2

Monitoring Time (Date)

Strain (micro meter)

Report on Instrumentation Monitoring

TALA HYDROELECTRIC PROJECT, BHUTAN (1020 MW)
A Symbol of India-Bhutan Friendship & Cooperation

The largest hydro power project in Bhutan estimated to cost about Rs. 43 billion on completion was taken up for construction in October 1997 and first generating unit has been commissioned on 31st July 2006

Salient features of the Project are:
- Concrete Gravity Dam: 3 km downstream of Chhukha power house; 92 m height and 130 m length.
- Three (3) De-silting Chambers (250m x 13.90m x 18.5m) for removal of > 0.2 mm size sediments.
- Head Race Tunnel (HRT): 6.8 m dia & 23 km long.
- Surge Shaft: 15/12 m dia & 184 m high.
- Two inclined Pressure Shafts: 4 m in dia, 1.1 km long each trifurcating into 2.3 m dia six penstocks.
- Underground Power House Cavern (206m x 44.5m x 20.4m) for 6x170 MW hydro-generators.
- Underground Transformer Cavern (191m x 26.5m x 16m) for 19.13/400 kV/7MVA transformers.
- Tail Race Tunnel (TRT): 7.75 m dia & 3.1 km long.
- Surface Pothead Yard for dispatching power.
- 400 kV/220 kV, 4 x 67 MVA, Sub-station at Malbazar.
- Two double circuit 400 kV Transmission lines upto Bhutan-India border: 140 circuit km length.
- First two units of the Project stand commissioned.

We pledge our dedication and hard work for the full commissioning of the project to benefit both the people of Bhutan & India

*Tashi Delek*

Volume-II: Instrumentation

Editors
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S.M.Dhiman
R.N.Khazanchi

October 2006

Quality Control Department
Tala Hydroelectric Project Authority
Gedu: Bhutan

October 2006
Report on Reprt # 6
Quality Control and Instrumentation for
Concrete Gravity Dam of
1020 MW Tala Hydroelectric Project in Bhutan

Volume II: Instrumentation

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Engineer-In-Charge, Instrumentation
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October 2006
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CONCLUSIONS

- Mass concrete temperature, which was about 10.0°C at the time of placement, has risen up to 30.9°C and finally settled down between 21.6°C to 22.5°C.
- Due to low ambient temperature (4°C) in the month of January, temperature of mass concrete dropped during 3 days from 9.9°C to 5.2°C and increased again up to 12.6°C.
- Cement content in mass concrete should be optimized to achieve required strength. High cement content leads to cracking in mass concrete.
- Temperature readings should be monitored from the time of placement of concrete.
- Instrument should be calibrated with the temperature of mass concrete.
The pore pressure meters installed have shown pore pressures in the range of 3.2 kg/cm$^2$ to 4.0 kg/cm$^2$, in Blocks 2 and 5 respectively.

Three joint meters/crack meters installed in blocks 3 and 5 at the cracks, show the increase in crack width in the order of 0.01mm to 0.11 mm.

The joint meters installed between two blocks joint have shown insignificant displacement in the range of 0.01mm to 5.40mm.
CONCLUSIONS … contd.

- The concrete pressure cells installed in Blocks 2 and 5 have shown pressures in the mass concrete varying from 5.5 kg/cm$^2$ to 4.4 kg/cm$^2$ which is 3.8 to 4.76 time lower than theoretically expected stresses of 20.16 kg/cm$^2$ and 20.95 kg/cm$^2$ based on mass concrete density of 2400 kg/cm$^2$ and height of blocks 84 m and 87.30 m above the pressure cells, respectively. However, the pressure cells have shown increasing trend during observations.

- 9.2 kg/cm$^2$ & 12.6 kg/cm$^2$ from FEM

- The safe design parameters must be made available and may be attached with data acquisition system as alarm for further monitoring the safety of dam.
CONCLUSIONS ...contd.

In general, behaviour of all instruments installed in Tala dam was in order with respect to increasing/decreasing trends in observations.

A record number of 277 instruments were in working order out of 282.

This was possible due to awarding a contract for supply, installation, maintenance and monitoring of instruments before commencement of dam construction.
Instruments Installed

- Temperature Meter
- Pore Pressure Meter
- Joint Meter/Crack Meter
- Concrete Pressure Cell
- Strain Meter
- Spider For Strain Rosettes
MULTI POSITION BOREHOLE EXTENSOMETER (MPBX)
Instruments Installed

READ-OUT UNIT/
DATALOGGER
NORMAL & INVERTED PLUMBINES
INSTRUMENTS INSTALLED

• Uplift pressure Meters

• Water Level Indicators

• Surveying Points or Targets
INSTRUMENTS INSTALLED

SEISMOGRAPH

STRONG MOTION ACCELEROMETER

GPS

SAM
SETTLEMENT MAGNETIC SYSTEM

- MAGNETIC PROBE
- DISC/PLATE MAGNET
- SPIDER MAGNET
Thank You

For your

Kind

Attention Please