Dam Safety Monitoring Program for Earthen Dams

Why, When and Where It Should be Used

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Why Do We Use it?

• **For Information**
  – Characterize site conditions prior to design
  – Monitor construction activities
  – Monitor performance of a structure
  – Compare design assumptions to actual loading conditions
  – Identify problems before they lead to failure

• **For Action**
  – During Emergencies
  – During Floods
  – Maintenance
Dam Safety Instrumentation

• Basic
  – Settlement Plates
  – Survey Monuments
  – Lake Level Sensors

• Instrumentation
  – Relief Wells / Monitoring Wells
  – Inclinometers
  – Tiltmeters
  – Piezometers
When and Where to Use

- **Function**
  - Measure settlement under an embankment

- **When to Use**
  - Installed during construction

- **Where to Use**
  - In areas where significant settlement either will or may occur
  - Can differentiate settlement of embankment from consolidation of foundation

**Purpose:** Observation of Rate and Total Amount of Settlement for Embankment Construction
When and Where to Use

• Function
  – Location Marker

• Prior to Construction
  – Locating property/construction boundaries
  – Set temporary benchmarks

• During Construction
  – Reference point for monitoring construction activities

• Post Construction
  – Monitor structure movements

Purpose: Reference Point for Survey Benchmark and Monitoring Movement
When and Where to Use

• **Function:**
  – Observe Water Surface Elevation
  – Measure Depth of Headwater & Tailwater

• **When to Use**
  – During and Post Construction

• **Where to Use**
  – At point of maximum depth along heel/toe of dam

• **Types**
  – Staff Gage, Pressure Transducer, Bubblers

**Purpose:** Headwater/Tailwater Data to Use in Conjunction With Other Instrumentation Data When Analyzing Dam Performance
When and Where to Use

• Function
  – Measure rate (velocity) of seepage or discharge

• When to Use
  – During Construction

• Purpose
  – Monitor rate of seepage for stability and erosion analysis

• Where to Use
  – Along downstream toe of dam

**Purpose:** Monitor rate of Seepage for Stability and Erosion Analysis
When and Where to Use

• Function
  – Measure angles of slope, elevation or depression of an object with respect to gravity

• When to Use
  – Post construction

• Where to Use
  – Casing installed within or attached to structure or slopes
  – Existing cased boreholes (sometimes abandoned piezometers)
  – Concrete to Soil Interface

**Purpose:** Monitor Dam Performance During and After Impoundment – Movement in Slopes and Spillways
Tiltmeters

When and Where to Use

- **Function**
  - To measure relative angular displacement

- **When to Use**
  - During Construction
  - Post Construction (if observations warrant it)

- **Where to Use**
  - Securely attached to structure

**Purpose:** Monitor Dam Performance During and After Impoundment (Rotation of Retaining Walls, Training Walls, Piers, & Piles)
When and Where to Use

• Function
  – Measure pore water pressure (effective stress) in a soil medium

• When to Use
  – Pre-construction
  – During Construction
  – Post Construction

• Where to Use
  – Foundation & Foundation/Structure Interface
  – Within Structure
  – Upstream/Downstream of Structure

**Purpose:** Monitor Dam Performance, Rate of Construction, Slope Stability Assessment, Ground Improvements
# Types of Piezometers (Pros & Cons)

<table>
<thead>
<tr>
<th>Standpipe Piezometers</th>
<th>Vibrating Wire Piezometers</th>
<th>Pneumatic Piezometers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
</tr>
<tr>
<td>- Simple</td>
<td>- Automatic Data Collection</td>
<td>- Remote Readings Possible</td>
</tr>
<tr>
<td>- No Calibration</td>
<td>- Remote Data Collection</td>
<td>- No Power Needed</td>
</tr>
<tr>
<td>- No Power Needed</td>
<td>- Good Response Time</td>
<td>- Can Be Calibrated at Any Time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages:</th>
<th>Disadvantages:</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Requires Manual Readings</td>
<td>- Requires Power</td>
<td>- Difficult to Automate</td>
</tr>
<tr>
<td>- Slow Response time</td>
<td>- Erroneous Readings in Unsaturated Conditions</td>
<td>- Condensation Can Cause</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inaccurate Readings if Not Controlled Properly</td>
</tr>
</tbody>
</table>

*Type of Piezometer and Frequency of Readings are a Team Decision (Engineering Consultant and Owner)*
Typical Instrument Cross Section

Piezometers

**Station 1650**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Median</th>
<th>5-Year High</th>
<th>5-Year Low</th>
<th>High</th>
<th>Low</th>
<th>Tip</th>
<th>Riser</th>
<th>Screen</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F4</td>
<td>107.3</td>
<td>1239</td>
<td>1299</td>
<td>1299</td>
<td>100</td>
<td>100</td>
<td>89.4</td>
<td>179.5</td>
<td>80.4 - 81.4</td>
</tr>
<tr>
<td>E4</td>
<td>107.3</td>
<td>1346</td>
<td>1346</td>
<td>101</td>
<td>80.1</td>
<td>152.5</td>
<td>80.1</td>
<td>82.1</td>
<td>80.1</td>
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<tr>
<td>D1</td>
<td>106.8</td>
<td>117.4</td>
<td>104.4</td>
<td>102</td>
<td>91.6</td>
<td>151.0</td>
<td>15.0</td>
<td>18.0</td>
<td>83.0</td>
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<tr>
<td>P2</td>
<td>114.9</td>
<td>114.9</td>
<td>114.9</td>
<td>114</td>
<td>16.0</td>
<td>141.8</td>
<td>141.8</td>
<td>14.0</td>
<td>14.0</td>
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<tr>
<td>EW 8</td>
<td>105.5</td>
<td>105.5</td>
<td>104.4</td>
<td>114</td>
<td>18.2</td>
<td>15.0</td>
<td>15.0</td>
<td>42.0</td>
<td>104.0</td>
</tr>
<tr>
<td>S22</td>
<td>106.7</td>
<td>106.7</td>
<td>104.5</td>
<td>107</td>
<td>27.3</td>
<td>107.0</td>
<td>27.3</td>
<td>26.3</td>
<td>93.0</td>
</tr>
</tbody>
</table>

**Notes:**
1. All elevations are in NAVD08 feet above mean sea level (FT-MSL).
2. All locations of instruments, boreholes, and internal features of embankment are approximate and provided for illustrative purposes only.
Developing Your Dam Safety Monitoring Plan

- Dam Safety Consultant and Owner Should Coordinate Type of Instrument Necessary Pre & Post Construction
- Discuss Frequency of Measurements
- It is Important that Owner and Dam Safety Consultant Review the Data on a Pre-determined Frequency (& Especially during Unusual Times)
- With the Data – Make Decisions

Know Your Dirt – Or Make Sure Your Dam Consultant Knows Your Dirt

<table>
<thead>
<tr>
<th>Site Information</th>
<th>Usual</th>
<th>Unusual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well defined</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Ordinary</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Normal Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well defined</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Ordinary</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Limited</td>
<td>3.0</td>
<td>2.6</td>
</tr>
</tbody>
</table>
**Examples**

**PIEZOMETER CONSTRUCTION LOG**

- **Project Name:** Dam Safety Instrumentation
- **Location:** Texas
- **Piez./Well No.:** US-1
- **Installed By:**
- **Inspected By:**
- **Method of Installation:** Mayhew 250, Wet Rotary
- **Remarks:**

<table>
<thead>
<tr>
<th>Elevation of top of riser</th>
<th>165.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of riser above ground</td>
<td>3.0</td>
</tr>
<tr>
<td>Ground Elevation</td>
<td>6.2</td>
</tr>
<tr>
<td>Type of surface seal</td>
<td>Concrete-Bentonite Grout</td>
</tr>
<tr>
<td>Depth of surface seal</td>
<td>21.0</td>
</tr>
<tr>
<td>Type of backfill</td>
<td>Cement-Bentonite Grout</td>
</tr>
<tr>
<td>Depth to top of seal</td>
<td>24.0</td>
</tr>
<tr>
<td>Type of seal</td>
<td>3/8 inch Bentonite Pellets</td>
</tr>
<tr>
<td>Depth of top of screen</td>
<td>29.0</td>
</tr>
<tr>
<td>Type of filter pack</td>
<td>20/40 silica</td>
</tr>
<tr>
<td>LD./Type of screen</td>
<td>2&quot; Schedule 40 PVC</td>
</tr>
<tr>
<td>Screen slot size</td>
<td>0.010&quot;</td>
</tr>
<tr>
<td>Depth of bottom of screen</td>
<td>39.0</td>
</tr>
<tr>
<td>Type of backfill below observation well</td>
<td>Cuttings + 1.5&quot; Filter Sand</td>
</tr>
<tr>
<td>Depth of bottom of plugged blank section</td>
<td>39.3</td>
</tr>
<tr>
<td>Diameter of boring</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

**Spillway Piezometers**

- Top of Embankment Elevation at 212 ft

**Well Point Piezometers**

- Top of Embankment Elevation at 212 ft
Questions?