The Importance of Geotechnical Engineering Design of Excavated Ponds and Embankments

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GOALS OF PRESENTATION

1. Define and Illustrate

General Geotechnical Issues Affecting Earthen Surface Tailings Impoundments/Embankments
GOALS OF PRESENTATION

2. Illustrate

General Types and Methods of Tailings Impoundment Structure Construction and Remedial Measures to Address Instability and Seepage
### Why are Tailings Impoundments Of Concern?

MSHA Investigations From 1990 through 2010 Failure Of 5 Tailings Structures Cited as a Primary Reason to Develop New Regulations

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Type of Mine</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Puerto Rico</td>
<td>Limestone Mine</td>
<td>100’ High</td>
</tr>
<tr>
<td>1992</td>
<td>Wisconsin</td>
<td>Andesite Quarry</td>
<td>70’ High</td>
</tr>
<tr>
<td>1997</td>
<td>Arizona</td>
<td>Copper Mine</td>
<td>Unspecified Height</td>
</tr>
<tr>
<td>2002</td>
<td>Georgia</td>
<td>Sand &amp; Gravel Mine</td>
<td>30’ High</td>
</tr>
<tr>
<td>2007</td>
<td>California</td>
<td>Sand &amp; Gravel Mine</td>
<td>Unspecified Height</td>
</tr>
</tbody>
</table>
Consequences

- Release 200 M gals. water and tailings
- Moderate to Extensive Damages to Operations, Plant, Equipment, Property, Environment
- Several Injuries
- **No Loss Of Life** most occurred off – hours
Primary Factors Affecting Five Mining Failures

1. Lack of Design By a Knowledgeable Engineer, and/or

2. Lack of Understanding of Geotechnical and Dam Engineering Principles
Failure Of Coal Ash Dredge Spoil Cell
December, 2008 Harriman, Tennessee
Harriman, Tennessee - Release of 200,000 Cubic Yards of Stored Coal Ash
1 Billion Gallons of Flow, Much into Emory River
Alton, New Hampshire
1996
Privately Owned
Impoundment Failure
General Types of Impoundments
INCISED SURFACE IMPOUNDMENT
PARTIALLY INCISED SURFACE IMPOUNDMENT
Dam Size Classification Corps of Engineers
Often Varies by State:
But size does not matter per MSHA and Corps

<table>
<thead>
<tr>
<th>Category</th>
<th>Storage (acre-feet)</th>
<th>Height (feet)</th>
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<tbody>
<tr>
<td>Small</td>
<td>≥ 15 and &lt; 50</td>
<td>≥ 6 and &lt; 15</td>
</tr>
<tr>
<td>Intermediate</td>
<td>≥ 50 and &lt; 1,000</td>
<td>≥ 15 and &lt; 40</td>
</tr>
<tr>
<td>Large</td>
<td>≥ 1,000</td>
<td>≥ 40</td>
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</tbody>
</table>
## Typical Dam Hazard Classification (Varies By State)

<table>
<thead>
<tr>
<th>Hazard Classification</th>
<th>Hazard Potential</th>
</tr>
</thead>
</table>
| High                  | Probable loss of life  
                         | Major economic losses         |
| Significant           | Possible loss of life  
                         | Major economic losses         |
| Low                   | Loss of life not expected  
                         | Minimal property damage      |
General Methods Of Construction
Tailings Impoundments

Depending on the mining operation tailings can consist of a wide range of particle sizes ranging from
Sand - 0.075 mm to 4.75 mm
Silt – 0.002 mm to 0.075 mm
Clay - <0.002 mm

Source AASHHTO
Use of Tailings is practical but it creates stability and seepage concerns
Geotechnical Issues

- Low Shear Strength Tailings – Soft, Loose
- No Internal Drainage – High Water Pressures
- Poor Compaction of Fill Materials
- Steep Side Slopes
- Weak Foundation
- Liquefiable Soils Under Seismic Loads
CENTERLINE CONSTRUCTION METHOD
DOWNSTREAM CONSTRUCTION METHOD

POND

PHREATIC SURFACE

HEAVILY COMPACTED SAND (FREE DRAINING) OR IMPERVIOUS WASTE ROCK

TAILINGS

IMPERVIOUS FOUNDATION

STARTER DAM WITH FILTERS

UNDERDRAINS (TYP)
Classical Rotational Dam Failure

DeKalb County, Georgia
Multi-Jurisdictional Hazard Mitigation Plan, February 2011
Classical Rotational Failure With Liquefaction

Merriespruit Tailings Dam Failure 1994, Virginia, South Africa
IMPROVEMENT OF SLOPE INSTABILITY
IMPROVEMENT OF SEEPAGE CONTROL

MODIFY TAILINGS DEPOSITION TO:
1) MINIMIZE SEEPAGE IN CRITICAL AREAS
2) PROVIDE WIDER AND CLEANER SAND BEACH

VEGETATED COVER PROTECTION AGAINST EROSION

TAILINGS

SEEPAGE

DRAIN WITH FILTERS

SEEPAGE COLLECTION SYSTEM
DECANT PIPE FAILURE MECHANISMS (TYPICAL)
Main Points

• Most Failures of Earth Impoundment Structures Due to Misunderstanding of Geotechnical Issues

• Involve a Knowledgeable Geotechnical Engineer in Design, Construction, Operation and Maintenance of Impoundment Structures

• Address MSHA Regulations

• Increased focus by MSHA due to two recent deaths that MSHA attributed to embankment failure
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