SPECIALTY DRILLING, TESTING, AND GROUTING TECHNIQUES FOR REMEDIATION OF EMBANKMENT DAMS

Presented By: Douglas M. Heenan, P.Eng
Advanced Construction Techniques, Ltd.
Typical Cross Section of Embankment Dams

- Imperious Fill (Central Core)
- Earth Fill
- Pool Water EL.
- Tail Water EL.
- Native Soil
- Limestone
- Karst
- Grout Curtain
Key Elements of Dam Remediation

- Central Core
Typical Cross Section of Embankment Dams

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- EARTH FILL
- POOL WATER EL.
- NATIVE SOIL
- LIMESTONE KARST
- LIMESTONE KARST
- GROUT CURTAIN
Key Elements of Dam Remediation

- Central Core
- Interface
Typical Cross Section of Embankment Dams

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- POOL WATER EL.
- GROUT CURTAIN
- INTERFACE
- NATIVE SOIL
- LIMESTONE KARST
- LIMESTONE KARST
Key Elements of Dam Remediation

- Central Core
- Interface
- Foundation
Reason
Why Drilling & Grouting Is Used For Remediation of Embankment Dams

• Repair Defects
Typical Defects of Embankment Dams

- Sinkholes
Typical Defects of Embankment Dams

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- SINKHOLE
- EARTH FILL POOL WATER EL.
- NATIVE SOIL
- LIMESTONE
- GROUT CURTAIN
Typical Defects of Embankment Dams

- SINKHOLES
- PIPING / SEEPAGE
- DAMAGED CLAY CORE
Typical Defects of Embankment Dams

- Damaged Clay Core
- Impermeable Fill (Central Core)
- Earth Fill
- Piping/Seepage
- Earth Fill
- Pool Water EL.
- Tail Water EL.
- Native Soil
- Limestone
- Grout Curtain
Typical Defects of Embankment Dams

- SINKHOLES
- PIPING / SEEPAGE
- DAMAGED CLAY CORE
- SEISMIC SENSITIVE SOILS
Typical Defects of Embankment Dams

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- POOL WATER EL.
- EARTH FILL
- NATIVE SOIL
- LIMESTONE
- GROUT CURTAIN
- SEISMIC SENSITIVE SOILS
Typical Defects of Embankment Dams

- SINKHOLES
- PIPING / SEEPAGE
- DAMAGED CLAY CORE
- SEISMIC SENSITIVE SOILS
- DAMAGED INTERFACE
Typical Defects of Embankment Dams

- **ImperVIOUS Fill (Central Core)**
- **Earth Fill**
- **Tail Water El.**
- **Earth Fill Pool Water El.**
- **Native Soil**
- **Limestone**
- **GROUT Curtain**
- **Damaged Interface**
Typical Defects of Embankment Dams

- SINKHOLES
- PIPING / SEEPAGE
- DAMAGED CLAY CORE
- SEISMIC SENSITIVE SOILS
- DAMAGED INTERFACE
- KARST SOLUTION FEATURES
Typical Defects of Embankment Dams

- Impervious Fill (Central Core)
- Earth Fill
- Tail Water El.
- Earth Fill Pool Water El.
- Native Soil
- Limestone
- Grout Curtain
- Karst Solution Features
Typical Defects of Embankment Dams

- SINKHOLES
- PIPING / SEEPAGE
- DAMAGED CLAY CORE
- SEISMIC SENSITIVE SOILS
- DAMAGED INTERFACE
- KARST SOLUTION FEATURES
- DEEP SOLUTION FEATURES
Typical Defects of Embankment Dams

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- EARTH FILL
- POOL WATER EL.
- NATIVE SOIL
- LIMESTONE
- LIMESTONE
- GROUT CURTAIN
- DEEP SOLUTION FEATURES
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<th>Topic</th>
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<tr>
<td>Procedures for Drilling in Earth Embankments</td>
<td>ER 110-1-1807</td>
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<td>Grouting Technology</td>
<td>EM 1110-2-3506</td>
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<tr>
<td>Geotechnical Investigation</td>
<td>EM 1110-1-1804</td>
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<td>Soil Sampling</td>
<td>EM 1110-1-1906</td>
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Types of Embankment Drilling

- Sonic Drilling
- Rotary Drilling with Drilling Fluid
- Cased Auger
INTEROCK AN160
SONIC DRILL
Sonic Drilling

SOIL SAMPLE

OUTER CASING

INNER STRING/SAMPLER TUBE

OVERBURDEN

INTERFACE

LIMESTONE
Sonic Drilling

- OVERBURDEN
- LIMESTONE
- INTERFACE
- OUTER CASING
- INNER STRING/SAMPLER TUBE
- SOIL SAMPLE

Diagram showing the Sonic Drilling process with a soil sample, outer casing, inner string/sampler tube, and the interface between overburden and limestone.
Cased Auger Drilling

- Overburden
- Limestone Interface
- Outer Casing
- Auger
- Split-Spoon Sampler
- Soil Sample
- Interface
- Limestone
Cased Auger Drilling

OVERBURDEN

LIMESTONE

OUTER CASING

PLASTIC SLEEVE PIPE

INTERFACE
Specific Tests of Embankment Dams

- Core Integrity Test (C.I.T.)
- Interface Integrity Test (I.I.T.)
- Foundation Integrity Test (F.I.T.)
Core Integrity Test (C.I.T.)
<table>
<thead>
<tr>
<th>WATER ELEVATION</th>
<th>CORE CONDITION</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>NO WATER RISE</td>
<td>EXCELLENT</td>
<td>GOOD LONG TREM PERFORMANCE</td>
</tr>
<tr>
<td>RISE TO TAIL WATER ELEV.</td>
<td>POOR</td>
<td>CONNECTED TO DOWNSTREAM</td>
</tr>
<tr>
<td>RISE TO POOL WATER ELEV.</td>
<td>POOR</td>
<td>CONNECTED TO UPSTREAM</td>
</tr>
<tr>
<td>RISE BETWEEN HW &amp; TW</td>
<td>POOR</td>
<td>GENERAL CONNECTION</td>
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Interface Integrity Test (I.I.T.)

Casing Installation

- Drill Casing
- Borehole
- Drill Rod
- Drill Bit
- Sleeve Ports
- Sleeve Bag
- Plastic Sleeve Pipe
- Central Core
- Interface
- Bedrock
Interface Integrity Test (I.I.T.)
Interface Insulation

- BOREHOLE
- SLEEVE PORT
- INFLATE PACKERS
- GROUT SLEEVE BAG
- PLASTIC SLEEVE PIPE
- IMPERVIOUS FILL
- BEDROCK
Interface Integrity Test (I.I.T.)
Overburden Casing Grouting

- BOREHOLE
- DOUBLE PACKERS
- SLEEVE PORT
- SLEEVE BAG
- PLASTIC SLEEVE PIPE
- IMPERVIOUS FILL
- BEDROCK
Interface Integrity Test (I.I.T.)

- Interface Integrity Test
- BOREHOLE
- SINGLE PACKER
- SLEEVE BAG
- PLASTIC SLEEVE PIPE
- IMPERVIOUS FILL
- BEDROCK
# Interface Condition Chart

<table>
<thead>
<tr>
<th>LUGEON VALUE</th>
<th>CONDITION OF INTERFACE</th>
<th>COMMENT</th>
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<tr>
<td>0 - 1</td>
<td>EXCELLENT</td>
<td>INTACT / NO ACTION REQUIRED</td>
</tr>
<tr>
<td>1 - 5</td>
<td>GOOD</td>
<td>INTACT / LONG TERM MONITORING REQUIRED</td>
</tr>
<tr>
<td>5 - 10</td>
<td>POOR</td>
<td>SUSPECTION CONDITION / MONITORING REQUIRED</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>UNSATISFACTORY</td>
<td>POSSIBLE PIPING / REMEDIATION REQUIRED</td>
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</tbody>
</table>
Interface Grouting

BOREHOLE

SINGLE PACKER

SLEEVE BAG

PLASTIC SLEEVE PIPE

IMPERVIOUS FILL

BEDROCK
Overburden Casing Installation
Exploratory Drilling

100 – 200 FT

P1  T1A  S1  T1B  P2  T2A  S2  T2B  P3  T3A  S3  T3B  P4
Sequences of Drilling, Water Testing & Grouting

EMBANKMENT

INTERFACE

FOUNDATION BEDROCK

BOTTOM OF GROUT CURTAIN
Upstage Grouting

GOOD QUALITY ROCK

EMBANKMENT

INTERFACE

GOOD QUALITY ROCK

FOUNDATION BEDROCK

BOTTOM OF GROUT CURTAIN
Single Packer Water Testing
Double Packer Upstage Water Testing
Single Packer Upstage Grouting
Single Packer Upstage Grouting
Downstage Drilling

STAGE I

POOR QUALITY ROCK

EMBANKMENT INTERFACE

STAGE I

FOUNDATION BEDROCK

BOTTOM OF GROUT CURTAIN
Downstage Water Testing
Downstage Grouting
Downstage Drilling
Downstage Water Testing

- Stage I
- Stage II
- Stage III
- Stage IV

- Embankment Interface
- Foundation Bedrock

Bottom of Grout Curtain
Downstage Grouting
Probable Solutions for Karst Solution Features

- IMPERVIOUS FILL (CENTRAL CORE)
- EARTH FILL
- TAIL WATER EL.
- POOL WATER EL.
- LIMESTONE
- NATIVE SOIL
- DEEP SOLUTION FEATURES
- KARST SOLUTION FEATURE
- LIMESTONE
- CEMENT GROUTING
- EARTH FILL
- GROUT CURTAIN
Solution Feature Remediation
(Upstage Casing Extraction (LMG or HMG))

Primary Holes

Karst Solution Feature
Solution Feature Remediation
(Upstage Casing Extraction (LMG or HMG)
Solution Feature Remediation
(Upstage Casing Extraction (LMG or HMG)

VERIFICATION HOLES

DRILLING

WATER TESTING

GROUTING

KARST SOLUTION FEATURE
Solution Feature Remediation
(Downstage Grouting (LMG or HMG))

P1  P2  P3

PRIMARY HOLES

KARST SOLUTION FEATURE
Solution Feature Remediation
(Downstage Grouting (LMG or HMG))

SECONDARY HOLES

KARST SOLUTION FEATURE
Solution Feature Remediation
(Downstage Grouting (LMG or HMG))
Solution Feature Remediation
(Upstage Sleeve Pipe Grouting (HMG))

PRIMARY HOLES

P1  P2  P3

KARST SOLUTION FEATURE
Solution Feature Remediation
(Upstage Sleeve Pipe Grouting (HMG))

SECONDARY HOLES

KARST SOLUTION FEATURE
Solution Feature Remediation
(Upstage Sleeve Pipe Grouting (HMG))

KARST SOLUTION FEATURE

VERIFICATION HOLES

DRILLING

WATER TESTING

GROUTING

V1  V2  V3

KARST SOLUTION FEATURE
Key Elements for Drilling and Grouting Embankment Dams

- Exploration
  - Site Characterization
- Execution
  - Grouting Method
- Verification
THANK YOU

Presented By: Douglas M. Heenan, P.Eng
dheenan@agtgroup.com
Advanced Construction Techniques, Ltd.
Tel. (877) 373-7248