SEEPAGE COLLECTION & CONTROL SYSTEMS: THE DEVIL IS IN THE DETAILS

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WHY IS THIS IMPORTANT?

- Seepage is the second leading cause of dam failures
- Seepage collection and control systems are a common rehabilitation solution
- Seepage collection and control systems are typically included in dam enlargements and new dams
- These systems are key elements in safety of a dam
- Success of systems depends on the details
SPECIFIC DETAILS TO BE DISCUSSED

- Drain pipes embedded in sand
- Verification of pipe installation
- Access to pipes for inspection and maintenance
- Sand filter gradations
- Use of standard gradations
- Chimney drain width
- One-stage versus two-stage filters
DRAIN PIPES EMBEDDED IN SAND

- Have been used on many dams
- Author has used them
- Recent experience has indicated potential problems
EXAMPLE

- 6-inch diameter pipes with 0.02 inch slots, embedded directly in sand chimney
- ASTM C33 fine aggregate sand
- Sand and pipe slots designed according to current filter criteria
- With 10 feet of head in the chimney, flow through the slots was limited (less than 30 gpm)
- Limited flow confirmed with camera survey
- Replaced with pipes in gravel – produced > 500 gpm
- Similar experience reported by others
RECOMMENDED DESIGN
- PIPE IN GRAVEL ENVELOPE
EXAMPLE – PIPE IN GRAVEL ENVELOPE
ADVANTAGES OF RECOMMENDED DESIGN

- Water flows freely
  - Sand to gravel
  - Gravel to pipe
- Pipe capacity is fully realized
- Gravel allows for larger pipe slots – less prone to clogging

Design is more expensive, but much more robust!
PRACTICAL CONSTRUCTION SEQUENCE
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UNCERTAINTIES WITH GEOTEXTILE SLEEVES

- May improve flow into slotted pipes
- Susceptible to installation damage
- May clog or deteriorate
- Not accepted by all regulators
- Not as robust as gravel envelope
VERIFICATION OF DRAIN PIPE INSTALLATION

- Important to verify undamaged installation
- Important to verify at a time when corrective actions are practical
- Damage could include:
  - Open joints
  - Cracked or punctured walls
  - Crushed or distorted pipes
SPECIFICATIONS AND OBSERVATION

- Compaction limitations in the vicinity of the pipe
- Observation of installation
- With limitations and full-time observation, damage is still possible
EXAMPLE

- 12-inch diameter pipe in gravel envelope
- Installed with qualified, full-time observation
- Puncture in the pipe wall occurred
- Likely due to construction equipment impact
RECOMMENDED VERIFICATION

- Camera survey
  - With no more than 3 to 5 feet of fill
  - After completion of construction
- Cameras preferred over torpedoes or balloons
  - Need to verify condition as well as continuity
  - Camera costs are reasonable
ACCESS TO DRAIN PIPE

- Access for future inspection and maintenance is highly desirable
- Need to avoid long sections and inaccessible ends
- Design to accommodate internal camera surveys will provide adequate access
  - Minimum 6-inch diameter
  - Manholes or cleanouts at 500- to 1,000-foot intervals
  - Bends no sharper than 22.5 degrees
  - Sufficient straight sections between bends
SAND FILTER GRADATION

- Key factor in a successful seepage collection and control system
- Must prevent piping of all embankment and foundation soils
- Based on most recent design guidelines: NRCS (1994), USBR (1999), USACE (1993)
  - Base soils divided into four categories
  - Regrading of base soil
## BASE SOIL CATEGORIES

### Criteria for Filters and Base Soil Categories, from USBR (1999)

<table>
<thead>
<tr>
<th>Base Soil Category</th>
<th>Percent Finer than No. 200 sieve</th>
<th>Base Soil Description</th>
<th>Filtered Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;85</td>
<td>Fine silts and clays</td>
<td>$D_{15F} \leq 9 \times D_{85}$, but not , 0.2mm B</td>
</tr>
<tr>
<td>2</td>
<td>40 – 85</td>
<td>Sands, silts, clays, and silty and clayey sands</td>
<td>$D_{15F} \leq 0.7$ mm</td>
</tr>
<tr>
<td>3</td>
<td>15 – 39</td>
<td>Silty and Clayey sands and gravels</td>
<td>$D_{15F} \leq 0.7$ mm + $(40-A)(4xD_{85B}-0.7m)/25$</td>
</tr>
<tr>
<td>4</td>
<td>&lt;15</td>
<td>Sands and gravels</td>
<td>$D_{15F} \leq 4 \times D_{85B}$</td>
</tr>
</tbody>
</table>
BASE SOIL REGRADING No. 1

The diagram illustrates the comparison between base soil and reggraded base soil in terms of particle size distribution. The base soil curve is shown as a solid red line, while the reggraded base soil curve is indicated with blue dashed lines.

The diagram compares the percentage passing through different grain diameters. The key points are:

- **Without Regrading**:
  - $D_{15}$ < 40M
  - $D_{15}$ < 7.5M

- **With Regrading**:
  - $D_{15}$ < 40M
  - $D_{15}$ < 7.5M

The reggraded base soil shows a significant reduction in the percentage passing through smaller grain diameters compared to the original base soil.
BASE SOIL REGRADING No. 2

Diagram showing the percentage passing different grain diameters for baseline soil and regraded soil. The baseline soil shows a higher percentage passing for larger grain diameters compared to the regraded soil, which has a lower percentage passing for the same grain diameters.
USE OF ASTM C33 FINE AGGREGATE

- Suitable for almost all base soils
- Readily available from commercial sources in most locations
- Must add a 200 sieve size requirement to specifications
- Similar gradations can be used, if available at less cost
- May not be suitable for some clays and silts (Category 1 base soils)
ASTM C33 FINE AGGREGATE SAND
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C33 OK for CATEGORY 1

0.2mm limit for CATEGORY 1

CATEGORY 2

% PASSING vs. GRAIN DIAMETER (mm) (LOG SCALE)
ASTM C33 FINE AGGREGATE SAND

The diagram illustrates the particle size distribution for fine aggregate. Categories are defined based on the percentage of material passing through different sieves. C33 is acceptable for Category 1, while Category 2 requires an additional specification.
USE OF STANDARD GRADATIONS

- Advantageous if off-site sources are anticipated
- Specify locally available sand and gravel materials that fall within the latitude in the filter requirements
- Sources for standard gradations include:
  - State DOT specifications
  - AASHTO gradations
  - ASTM gradations
  - Products of local aggregate producers
- Verify local availability
CHIMNEY DRAIN WIDTH

- Recent trend toward smaller widths – inclined filters 2- to 3-feet wide
- False economy, if effectiveness of filter is compromised
- Constructability and construction QC must be considered in design
- Misalignment of layers can cause lack of continuity
RECOMMENDATIONS

- 3-feet minimum, if placed against an excavated slope
- 5-feet minimum, if placed together with upstream and downstream zones
- Specifications must require prevention of contamination
  - Slope adjacent zones away from filter
  - Maintain filter at least 6-inches above adjacent layers
ONE-STAGE VERSUS TWO-STAGE FILTERS

- One-stage filter adequate in most cases for average seepage
- Coarse filter may be needed between sand filter and coarse shell
- Two-stage filter needed, if concentrated seepage is expected
EXAMPLE
Several details of seepage collection and control systems have been discussed.

Opinions offered for appropriate treatments.

Seepage collection and control systems will remain a key element of the dam safety engineer’s toolbox.

With appropriate attention to details these systems make dams safer.
QUESTIONS?
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