TOP 10 FOR CHIMNEY FILTER / DRAIN SYSTEMS

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Presented at National Dam Safety Program's Technical Seminar No. 19 - Filters, Drains, and Geotextiles in Dams and Levees

February 23, 2012
#1 – Be cautious in considering natural soils for filters

- Rare to find natural soils suitable for filters
  - Not “clean” enough
  - Can be gap graded
  - Variable gradations

- Readily available ASTM C33 fine aggregate is an excellent filter in almost all cases
Effectiveness of ASTM C33 Fine Aggregate as a Filter

- C33 Fine Aggregate OK for CATEGORY 1 Coarser Than This Point
- 0.7mm Maximum $D_{15F}$ for CATEGORY 2 Soils
- 0.2mm Maximum $D_{15F}$ for all CATEGORY 1 Soils

Diagram showing grain diameter and percentage passing, with logarithmic scale.
Always mathematically regrade base soil

- Required in all current filter design guidance: NRCS, USACE, USBR
- Provides retention for critical finer portion of the base soil
- Failure to mathematically regrade can result in substantially inadequate filter
Point 1 is to satisfy filter requirements – prevent internal erosion
Point 2 is to satisfy permeability requirements
All other points are to prevent gap grading and prevent segregation
Importance of Regrading the Base Soil – Example 1

The graph illustrates the comparison between the grain size distribution of the Base Soil and the Regraded Base Soil. Without regrading, the grain size distribution is indicated by the red line, showing a significant proportion of finer grains (D_{15F} < 180mm). With regrading, the blue line demonstrates a more optimal distribution, particularly with a lower proportion of finer grains (D_{15F} < 9.7mm) and a peak at Maximum D_{15F} Sizes.
Importance of Regrading the Base Soil – Example 2

- **Base Soil**
- **Without Regrading**
- **With Regrading**
- **Maximum D_{15F} Sizes**
- **Regarded Base Soil**

Graph showing the percentage of passing grains at different grain diameters (mm) on a log scale.
#3 – Limit fines content in filters and drains

- Suggest ≤3% in stockpile and ≤5% in place
- Some breakdown should be expected
- Permeability decreases dramatically with fines contents greater than 5%
Effect of Fines Content

After Barber and Sawyer, 1952
#4 – Do not overestimate permeability of concrete sand

- Even with low fines content, permeability of ASTM C33 fine aggregate will be on the order of $10^{-2}$ to $10^{-3}$ cm/sec

- Cannot convey large seepage quantities from concentrated flows

- Cannot be first material placed with flowing water
Effect of Concentrated Seepage

Concentrated Seepage Greater than Filter Capacity; Seepage Bleeds into Shell
#5 – Consider constructability in selection of filter / drain zone dimensions

- In many cases calculated seepage quantities do not require large filter thicknesses
- Constructability will most often control filter dimensions
A Set of Suggested Chimney Filter Dimensions

Simultaneous Construction

Simultaneous Construction

Downstream Modification
“Christmas Tree” Effect from Placement
Trenching Method

3 ft min.
#6 – Consider method specifications for filter / drain materials

- Overcompaction of filter and drain materials is not desirable
  - Increases breakdown
  - Reduces permeability

- Typical filter and drain materials are easy to compact

- Field compaction testing can be difficult for these materials
Typical method specifications for filter / drain materials

- 2 to 4 coverages with vibratory compaction equipment
- 8-inch loose lifts; less for hand-operated equipment
- Freely add water during compaction of clean filter
Typical Compaction Curves for Clean Sands

![Diagram showing compaction curves for clean sands.](image-url)
#8 – Include full-height chimney filters in embankment repairs or enlargements

- Provides protection against internal erosion through defects
- Lowers phreatic surface
  - Preventing breakout of seepage on downstream face
  - Increasing stability of downstream slope
- In risk analysis, a chimney typically lowers probability of an unfiltered exit to 0.001 to 0.0001.
Prevention of Internal Erosion Through Defects

Without Chimney Filter

With Chimney Filter
Lowering of Phreatic Surface

Without Chimney Filter

With Chimney Filter
Internal Erosion Event Tree

- Reservoir Rises
- Erosion Initiates
  - Erosion Continuation (lack of filtering)
    - Progression Step 1 (roof forms to support a pipe)
    - Progression Step 2 (upstream zone fails to fill crack/pipe)
    - Progression Step 3 (constriction or upstream zone fails to limit flows)
  - Unsuccessful Intervention
    - Catastrophic Breach
Top Elevation for Chimney Filter

- Historic practice – top of estimated phreatic surface
- Current practice
  - Top of maximum normal pool as a minimum
  - Often top of maximum flood pool
On the other hand, the writer has not found a single case of piping or internal erosion of core fines where the core was protected with a filter zone of clean cohesionless sand-rich material for which care was taken to prevent segregation during placement, and where necessary, the filter zone itself was adequately protected by appropriate downstream zones.
• P. 5. I believe there is already sufficient evidence from dam behavior, supported by theory, to require the designer to assume that small concentrated leaks can develop through the impervious section of most embankment dams, even those without exceptional differential settlement.

Recently, to avoid construction defects such as loose lifts, poor bond between lifts, inadvertent pervious layers, desiccation, and dispersive soils, inclined filter drains in combination with a horizontal drainage blanket have become almost standard. Because drainage modifications to a homogeneous section provide a greatly improved design, the fully homogeneous section should seldom be used.
Every dam should have a first line of defense against piping, in the form of a chimney drain and a blanket drain under the downstream shell, unless the designer can determine that there is no unacceptable risk in eliminating one or both.

The primary line of defense against a concentrated leak through the dam core is the downstream filter (filter design is covered in Appendix B). Since prevention of cracks cannot be ensured, an adequate downstream filter must be provided (Sherard 1984).

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1 General Design and Construction Considerations for Earth and Rock-Fill Dams
#8 – Use two-stage filter / drain if concentrated flows are possible

- Provides capacity to handle large flow
- Also negates effects of filter contamination
Two-Stage Chimney Filter / Drain System
Prevent Concentrated Flows from Overwhelming Filter

Concentrated Seepage Greater than Filter Capacity; Seepage Bleeds into Shell

Concentrated Seepage Accommodated by Drain
Washakie Dam – Original Modification
Washakie Dam – Temporary Berm and Piezometers Readings
Negate Effects of Filter Contamination
Carefully select plastic pipes for toe drains and provide for camera inspection.

- Performance of different pipe types has varied.
- Camera inspection provides verification – short term and long term.
# Plastic Pipe Materials

<table>
<thead>
<tr>
<th>Product</th>
<th>Type</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Recommended?</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>Solid</td>
<td>Strong, welded joints, flexibility of perforation size and type</td>
<td>Highest cost, special ordered or hand drilled perforations</td>
<td>Highly</td>
</tr>
<tr>
<td></td>
<td>Corrugated</td>
<td>Single-Wall</td>
<td>Economical</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Double-Wall</td>
<td>Economical, successful applications, large perforation sizes</td>
<td>Moderately</td>
</tr>
<tr>
<td>PVC</td>
<td>Solid</td>
<td>Well Screen</td>
<td>Strong</td>
<td>Moderately</td>
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<tr>
<td></td>
<td></td>
<td>Dain Pipe</td>
<td>Economical</td>
<td>No</td>
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</tbody>
</table>

*Report DSO-09-01, Physical Properties of Plastic Pipe Used in Reclamation Toe Drains, Bureau of Reclamation, September 2009*
Camera inspection

- Numerous cases of damage during construction
- Camera inspections during construction
  - After initial burial – 3 to 5 feet
  - After completion of construction
- Design considerations for inspection
  - Pipe diameter
  - Access points
  - Pipe slope
#10 – Use two-stage filter / drain systems for collector pipes

- Slotted pipes embedded in filter sand often become plugged
- Full pipe capacity is not realized
Clogging of Slotted Drain Pipe Embedded in Sand Filter
Two examples

- Washakie Dam, WY
  - Flow increased from about 50 gpm to about 500 gpm

- Antero Dam, CO
  - Flow increased from about 5 gpm to about 50 gpm
Recommended Collector Pipe Configuration
More information

- Montana Dam Safety Technical Note No. 4

- Filters for Embankment Dams (NDSP)

- Plastic Pipe Guidelines (NDSP)
  - [http://www.fema.gov/library/viewRecord.do?id=3356](http://www.fema.gov/library/viewRecord.do?id=3356)
Questions?