

Granular Filter Material: Quality Testing and Specification Considerations

National Dam Safety Program Technical Seminar | 2024



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Outline

- Background & Problem Statement
- Filter Material Quality Considerations
 - Durability
 - Mineral Constituents
 - Cementation – newly developed testing approaches
- Specification Considerations
 - Material Quality
 - Compaction



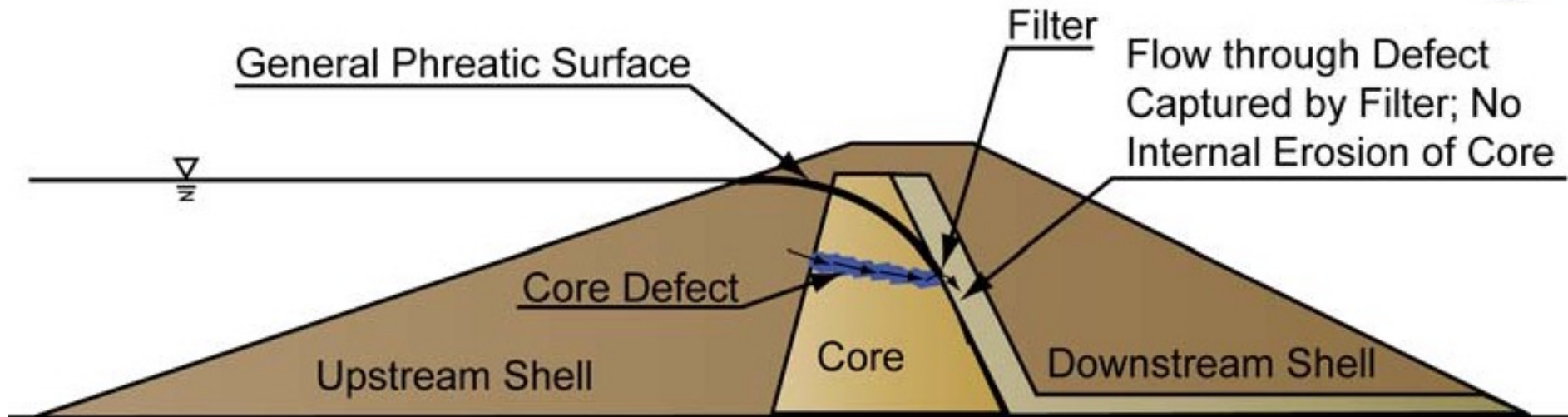
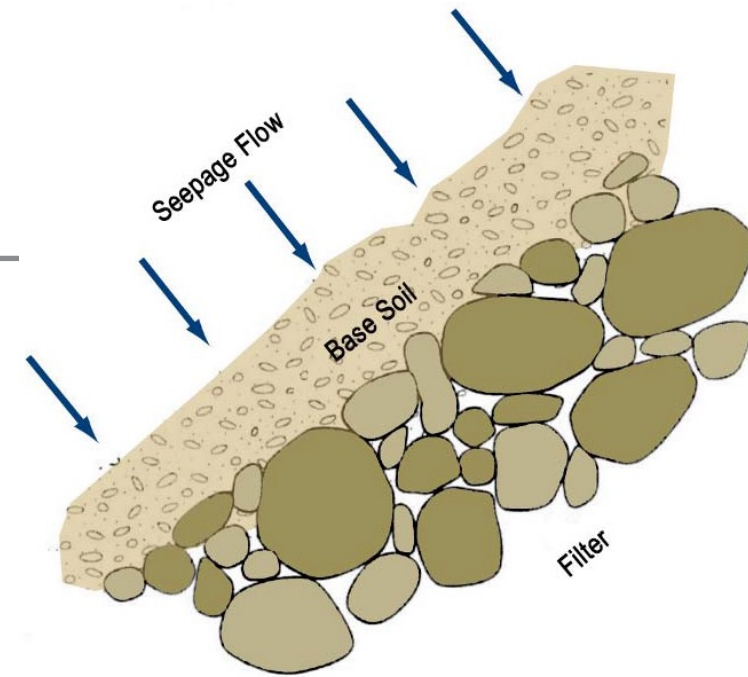
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Why Filter?

- Internal Erosion is the second most common cause of embankment dam failure
- Filters are a critical line of defense

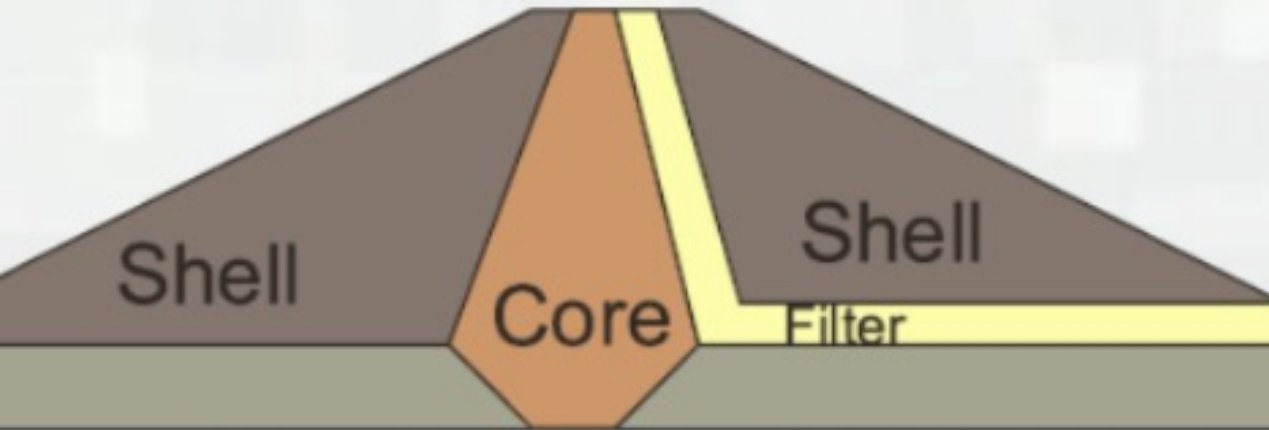


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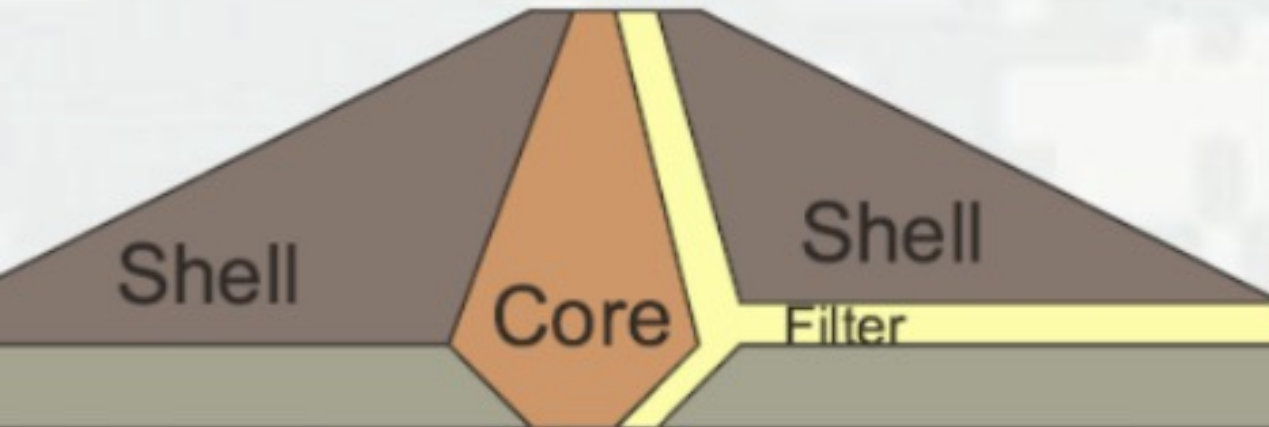


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Before Fontenelle



After Fontenelle



Problem Statement

Filter material quality is not designed for or around – it must be ensured through specification and inspection processes

- Criteria for specifying filter material need special consideration
 - Filter material must be of highest quality
 - High durability >>> limited mechanical breakdown
 - Limited deleterious constituents >>> Long-term chemical stability
 - Desire to limit Cementation Potential
 - Fines content limits alone not sufficient
- Specs have to be purpose built for embankment filter material

Filter Material Quality Concerns

- Durability/Soundness
 - Gradation - In-place, Post-compaction
 - Adequate permeability - Long-term mechanical and chemical stability
- Free-flowing, unbound material
 - Do not want filters to hold cracks
 - Need filter material to flow into, and heal cracks



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Filter Material Quality Concerns - Durability

- Standard Testing Suite, similar to concrete aggregate
 - Sodium Sulfate Soundness – ASTM C88
 - Specific Gravity – ASTM C128
 - Clay Lumps & Friable Particles – ASTM C142
 - Organic Impurities – ASTM C40
 - Lightweight Particles – ASTM C123



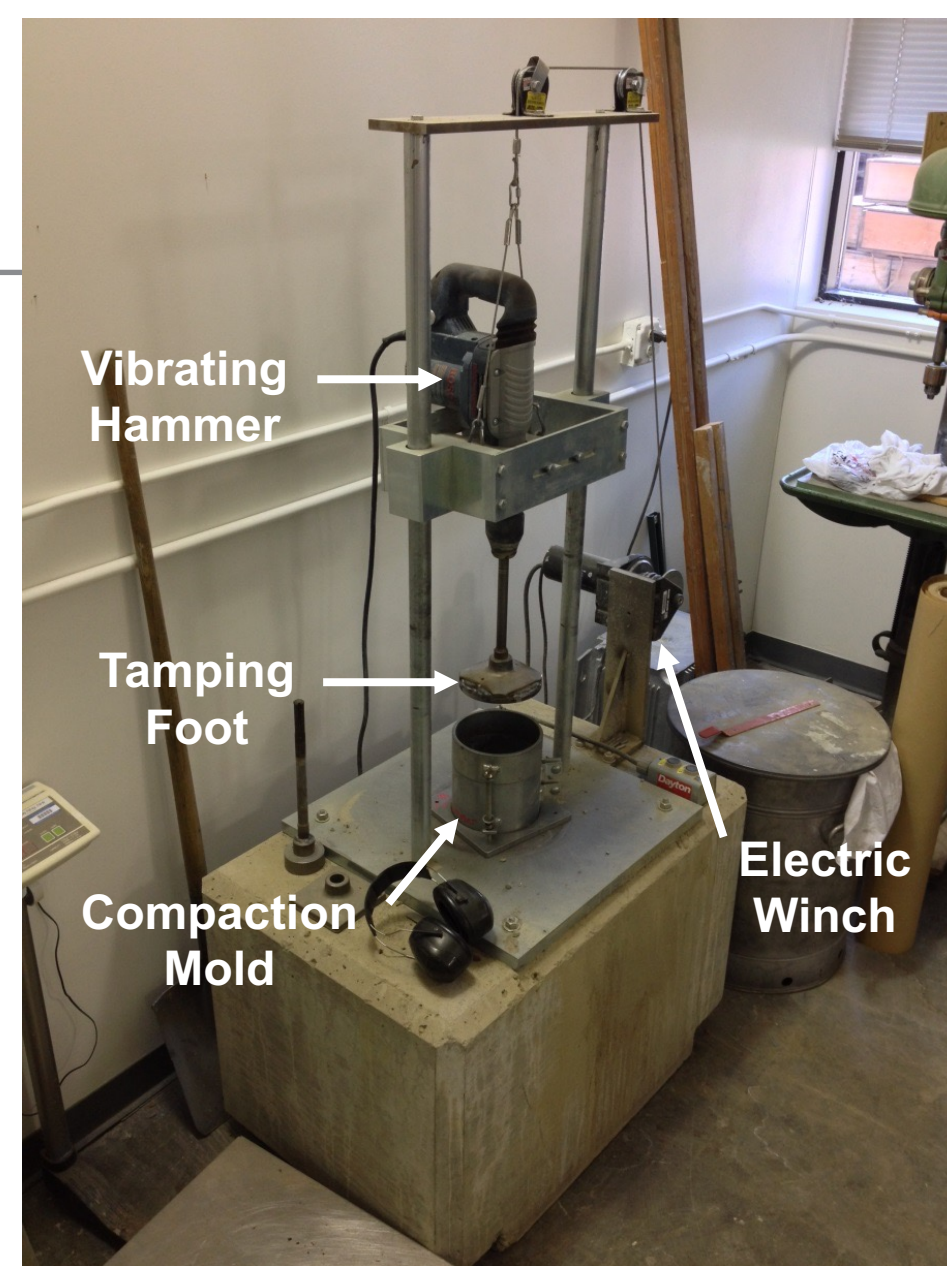
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Filter Material Quality Concerns - Gradation

- Perform as-received (i.e. stockpile) gradation
- Perform another gradation after compaction via vibratory hammer
 - Dry method
 - Wet (saturated) method
- Reclamation requires <math><3.0\%</math> fines in place
 - More than 2% breakdown on any sieve size is a red flag



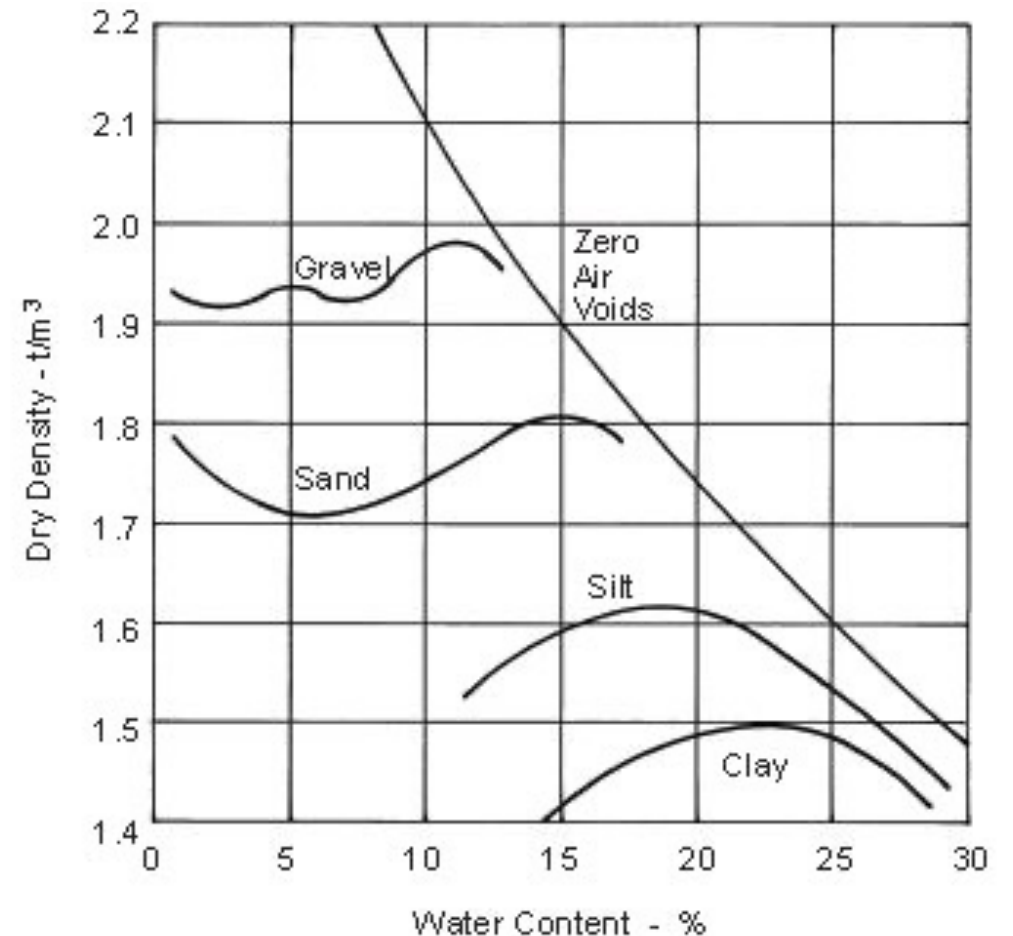
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...A Word about Compaction Tests

- Proctor (impact) compaction tests are not appropriate for free draining material
- Use Vibratory Compaction for:
 - SP, SW, GP, GW
 - <5% fines
 - SP-SM, SP-SC, GP-GM, GP-GC...maybe
 - 5-12% fines
 - SM...maybe
 - >12% fines



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Filter Material Quality Concerns – Chemical Stability

- Quantify Free Mica
 - USBR Particle Counting Procedure
 - Only concerned with “free mica”
- Consider X-ray Diffraction (XRD) to verify no other unwanted minerology



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Filter Material Quality Concerns - Cementation

- USBR performed research to develop new test methods to screen for cementation
- Modified Sand Castle Test (MSCT)
 - Examine cemented filter collapse times after wetting
- Dry UCS Test
 - Examine cemented filter dry strength
- Motivation
 - Quickly screen candidate sand sources
 - Standardized and repeatable
 - No rigorous tie to field performance



Filter Material Quality Concerns – Cementation (2)

- MSCT Specimen Preparation – worst case, but plausible
 - Compacted via vibrating hammer in saturated condition (usually 95-97% compaction)
 - Dried in 50°C (122°F) oven



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Filter Material Quality Concerns – Cementation (3)

- Incremental Soaking Test Procedure
 - Dried specimen leveled in test chamber
 - Water carefully introduced from bottom according to the following schedule:
 - $t = 0$ min: water depth increased to 1 in
 - $t = 20$ min: water depth increased to 2 in
 - $t = 100$ min: water depth increased to submerge specimen
 - Test complete when specimen collapses
 - Maximum duration of 24 hours



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Filter Material Quality Concerns – Cementation (4)



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Filter Material Quality Concerns – Cementation (5)



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Filter Material Quality Concerns – Cementation (6)

- 6 material classes:
 - Class I: failure within 5 min of start of test (depth = 1 in)
 - Class II: failure within 20 min of start of test (depth = 1 in)
 - Class III: failure within 5 min of increasing depth to 2 in (less than 25 minutes total elapsed time)

 - Class IV: failure within 80 min of increasing depth to 2 in (less than 100 minutes total elapsed time)
 - Class V: failure within 5 min of being submerged (less than 105 minutes total elapsed time)
 - Class VI: failure after 5 min of being submerged or no failure within 24 hours (>than 105 minutes elapsed time)



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Filter Material Quality Concerns – Cementation (7)

- Dry UCS Specimen Preparation
 - Vibratory hammer, saturated condition
 - 3” diameter x 6” tall mold
 - Compaction time varied to get same density as MSCT specimens
 - Same drying procedure
- UCS Test per ASTM D2166
 - Have tested value over 100 psi
 - Typically want to be below 20 psi



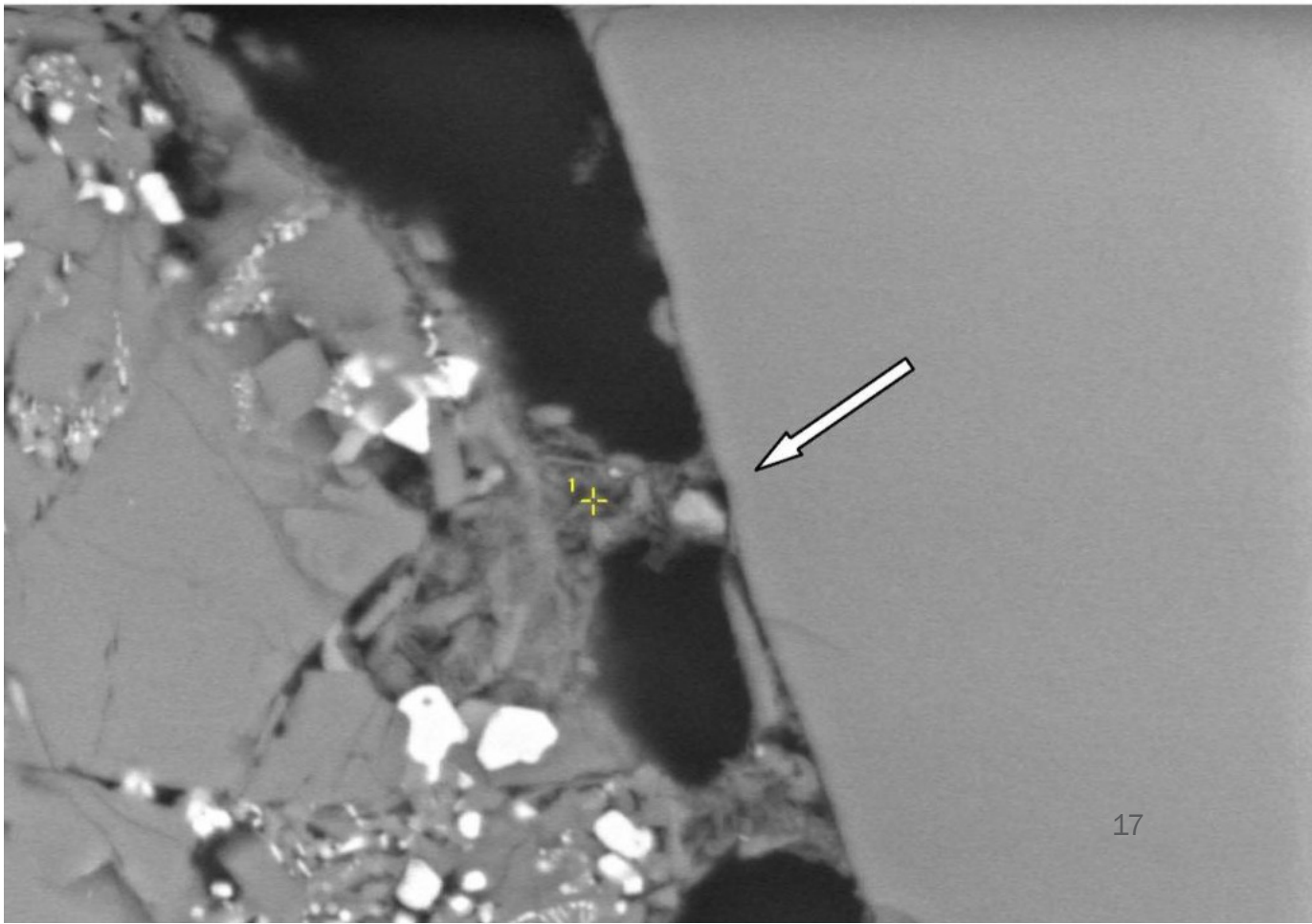
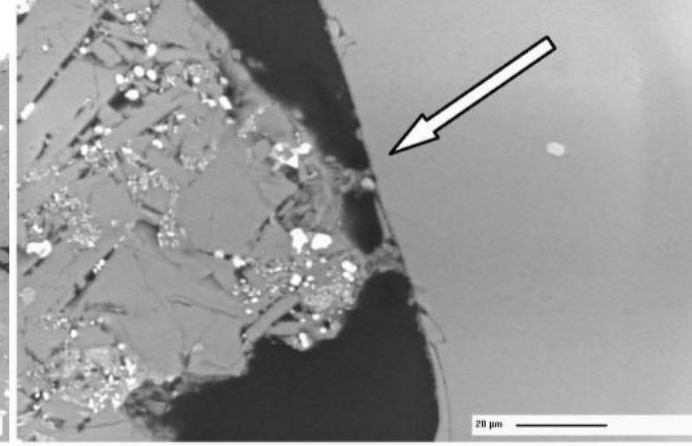
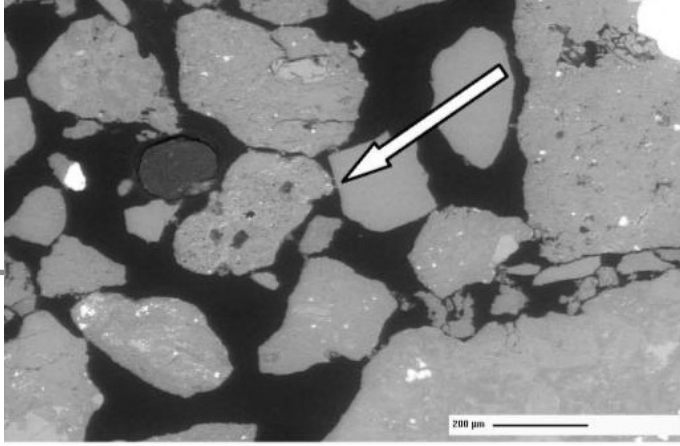
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...Some Observations on Cementation

- More angular, crushed materials generally more cementitious than more rounded, alluvial materials
- Water can matter – saturate with site water when possible
 - do not use DI water
- This cementation effect is real!
- Recycled Concrete and Limestone Sand are very bad news
 - Both are allowed by ASTM C33



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Specifications for Filter Material

- Don't rely on ASTM C33 – Specifications for Concrete aggregate
 - Allows either 3, 5, or 7% fines
 - Allows undesirable mineralogy
 - Doesn't specify limits for all deleterious material
 - Contains extraneous information; can be misinterpreted
- Specify Percent Compaction based on vibratory hammer
 - Dry method
 - Min and Max – e.g., 92-95% allowable
 - Develop site specific correlation for Relative Density if needed
- Prohibit recycled concrete and carbonate sources

Questions?

Robert Rinehart, Ph.D., P.E.

Group Manager

Bureau of Reclamation, Technical Service Center

Geotechnical Laboratory & Field Support Group

rrinehart@usbr.gov



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