Issues on Using Geosynthetics in Dams

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Introduction

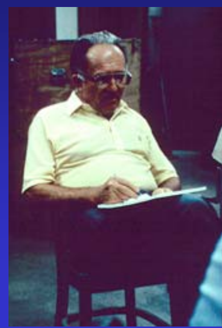
- Issues related to filtering, clogging, and providing drainage capacity requires some explanation of SCS (NRCS) filter study
- Filter function related to preventing concentrated leak development
- Filter function related to supporting the soil discharge face, preventing movement of soil fines, and providing drainage
- Issues on using geotextiles –vs- sand for these functions
- Research or studies suggested

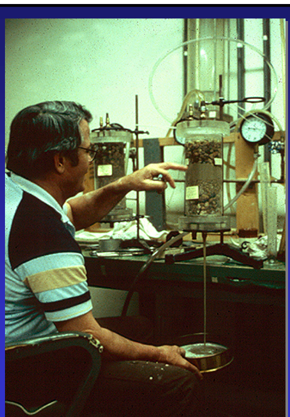
Introduction Continued

- Issues on using geomembranes to stop flow in embankment cracks
- Use of geomembranes as reservoir liners
- Use of geotextiles, geogrids, and related materials as separator and reinforcement

SCS (NRCS) Performed A Study on Filters

1980 to 1985 the late James L. Sherard worked with SCS to study filters for protection of embankment dams from concentrated leak development caused by erosion in cracks





- **Study had 2 parts:**
- **Determine basic properties of filters**
- **Filters for Silts and Clays – Prevent concentrated leaks through dam cores**
- **Picture: High velocity water running through base soil (sand) and filter – sieve used to catch particles that get through filter and test for size of these particles**

Schematic of test apparatus for the slot test. Approximately 40 psi of water pressure was used for high pressure tests. Success or failure of the filter determined very quickly with no doubt

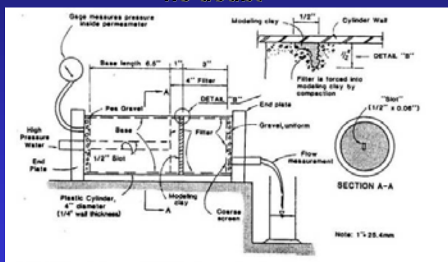


FIG. 2—High Pressure "Slot" Test Apparatus Details (Schematic, No Scale)

A 10-inch diameter apparatus was used for gravelly base soil containing particles up to 2 inches in diameter

The small and large tests were run in vertical and horizontal positions with the same results

We tried several different tests with the same results and finally decided on the No Erosion Test

No Erosion Filter Test

(No Visible Erosion)

The No Erosion Test setup

Successful filters seal the opening quickly to a drip or no flow

- Water under high pressure passes through the simulated crack & the filter
- Eroded particles of the base soil collect at the filter face and stop flow in the crack

•Hydraulic Fracturing caused filter cake to extend some distance on each side of the simulated crack

•Filter beyond – no filter cake, open for seepage collection

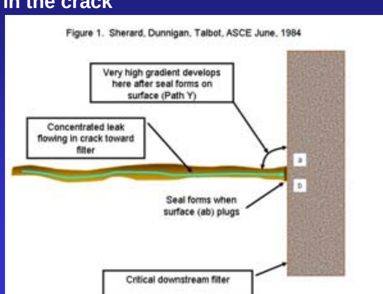


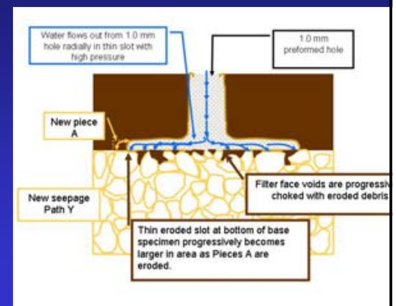
Figure 1. Sherard, Dunnigan, Talbot, ASCE June, 1984

Filter failure in the large test

Successful filter test for gravelly clay soil in large test

NRCS Filter Study

- Eroding soil catches at the face of the filter and seals it
- The filter face seals at the opening and some distance to each side
- The remaining filter is open to receive seepage



The soil particles collected at the filter face penetrate about 1 to 2 mm into the filter only for some width beyond the crack

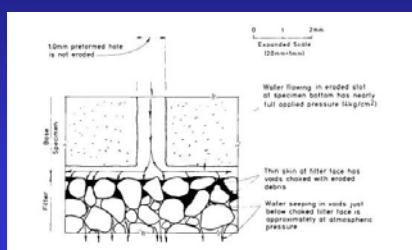


FIG. 5. Detail *A* (Fig. 4) Condition at End of Successful Test on Fine Silt or Clay (Enlarged Scale)

Results show D_{15} of filter = 9 times d_{85} of base soil (sand) with good correlation – results found by changing filter with same base and by changing base with same filter

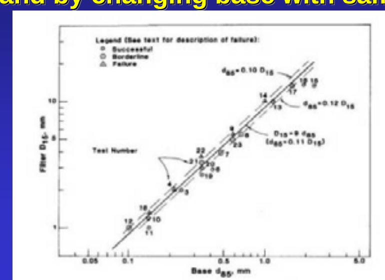


FIG. 4.—Relationship between D_{15} and d_{85} in SCS Filter Tests

- Results of filter testing for silts and clays – plotted points are boundary between success and failure
- Boundary shown is beyond all plotted points
- Can test for your soil and filter combination

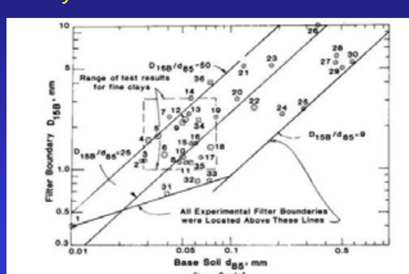
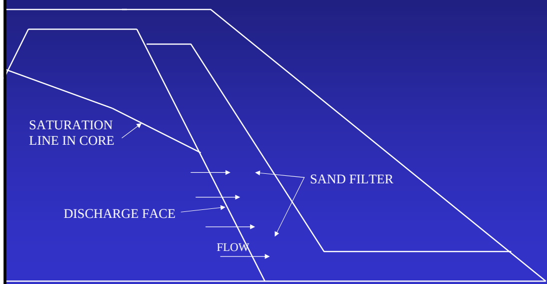


FIG. 5.—Summary of Test Results

- Edward Perry of USACE made long-term tests on specimens of soil using our successful filters – no simulated crack
- These are not his setups – he used relatively high gradients
- Successful filters had no soil migration.
- Coarser filters had soil migration – turbid effluent and erosion of base soil in long term testing

Sand flows to the soil discharge face and supports it with a positive pressure on the soil surface



SAND FILTER CHARACTERISTICS

- Sand flows to the discharge face and applies a positive pressure – thus supporting the discharge face.
- The points of pressure on the discharge face are spaced according to the gradation of the sand
- Testing has shown that filters graded according to criteria developed in SCS study does not allow soil migration
- Arching between points of contact keep finest soil particles from moving

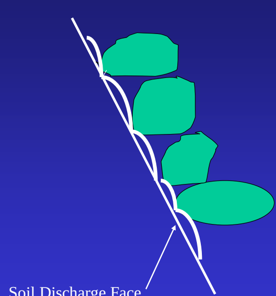
Limitations of Geotextile Fabrics

- Geotextile fabrics, by themselves, do not support the soil discharge face as a granular filter does
- Fabrics need to have intimate contact with the soil discharge face with distance between contact points similar to a granular filter, or soil particle movement will occur, clogging the fabric

Limitations of Geotextile Fabrics

- Non-woven fabrics have random spacing between filaments – woven fabrics are perhaps more uniform
- The distance between contact points on the soil discharge face is likely more dependent on the material on the downstream side of the fabric than on filament arrangement
- Coarse granular fill on the D.S. side of fabric generally does not provide uniform pressure with close contact points as does a sand filter – same for geocomposite material

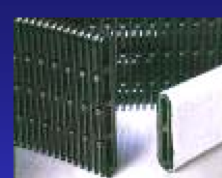
Limitations of Geotextile Fabrics



Coarse drainfill on downstream side of geotextile provides wide spacing of contact points on soil discharge face

Limitations of Geotextile Fabrics

- Geocomposites for filtering and drainage are usually made with a grid of some type wrapped with geotextile
- The grid spacing and configuration will determine the distance between contact points on the soil discharge face – much different from filter sand
- Tests have shown properly designed filter sand will provide support so soil particles do not move with water flow through the pores of the soil



Limitations of Geotextile Fabrics

- One-inch gravel on the left
- 3/8-inch gravel on the right
- Foam-core board between – approx. ¼ inch thick
- Note contact points of each material

Picture Courtesy of Danny McCook

Limitations of Geotextile Fabrics

- Uniform No. 20 sieve size sand on left
- Uniform 1/2 –inch size gravel on right
- Left similar to sand filter
- Foam-core board between – approx. ¼ inch thick
- Note difference in distance between contact points

Picture courtesy of Danny McCook, NRCS

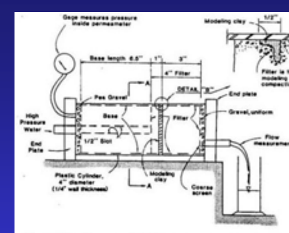
Limitations of Geotextile Fabrics

Examples – my experience

- Geotextile behind gabion wall with water seepage from the soil bank behind the wall – geotextile clogged, water pressure buildup, wall tipped over
- USACE work on Tennessee Waterway – geotextile under riprap clogged – water pressure buildup, riprap slid to bottom of slope

Research Suggested

- Setup designed to test geotextile on soil discharge face with various common materials on DS side
- High pressure (high gradient), long-term tests
- No opening or simulated crack
- Determine if clogging of geotextile occurs



- Testing with and without simulated crack could be included

Limitations of Geotextile Fabrics

- When used inside the dam, fabrics will have very large soil pressures on both sides of the fabric that will hold it firmly in place with no chance to distribute stresses that are produced by differential movement within the soil mass along the plane of the fabric
- When a crack occurs in the dam, it will likely tear the fabric in the plane of the crack

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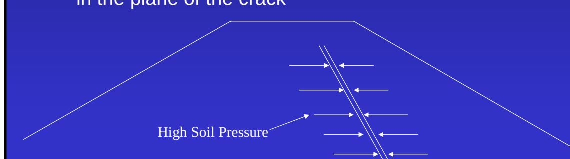
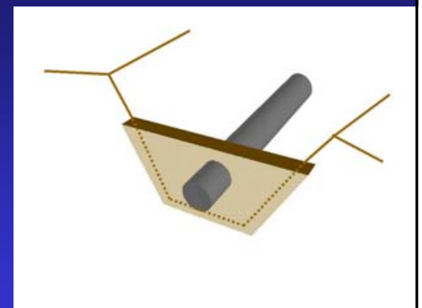


Limitations of Geotextile Fabrics

- Another limitation for geosynthetic fabrics deals with ease in damage during installation
- Damage can occur from equipment passing over the material, from protrusions in the underlying material, or from moving sheets of the fabric over a rough surface. Damage may not always be detected
- Structural integrity of the dam is dependent on complete continuity of the filter drainage zone and when constructed with a fabric, it must be without holes, tears, or defects

Seepage Control - Filter Diaphragms

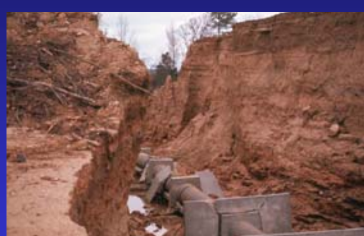
- Filter diaphragms are used instead of collars - placed where they will intercept any areas of poor compaction, cracking, or potential for concentrated leak development



Picture Courtesy of Danny McCook, NRCS

Seepage Control

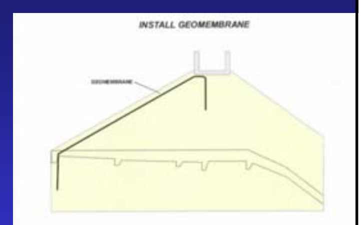
- Structural anti-seep collars used in the past
- Many failures using this method of seepage control
- Philosophy of anti-seep collars is to stop flow without pressure reduction



Picture Courtesy of Danny McCook, NRCS

Seepage Control – Flow in Cracks

- Upstream membranes proposed for seepage control in cracks on small flood control dams in Arizona
- Membrane is same philosophy as structural anti-seep collars



Picture courtesy of Tom MacDougall, Ninyo & Moore

•High gradient across bottom of membrane in plane of crack

Seepage Control – Flow in Cracks

•Sand Filter in center of dam better solution – intercepts cracks

•Filter cake forms over width of crack and some distance on each side stopping flow in crack and potential for concentrated leak

•Remainder of filter remains open to accept seepage through pores of soil – Water pressure in crack is dissipated as seepage finds its way from the crack to the filter/drainage system through the pores of the soil

Limitations for Geomembranes

- Smooth HDPE membranes have been shown to withstand some large stresses without tearing under pressures exerted by small or moderate size dams
- Membranes have been proposed by some for use inside dams to intercept flow in cracks or other openings and prevent development of concentrated leaks, tunnel erosion, and failure
- Membrane use to intercept a crack is similar in philosophy to using structural anti-seep collars around conduits. This method has not been fully successful in the past as water under full reservoir head encountering a structural barrier seems to find a way around it
- There is a very high gradient at the base of the membrane in the plane of the crack. With filter use to intercept a crack, water is attracted toward the filter and as clogging occurs, water can still seep through the pores of the surrounding soil and be carried away in the drainage system. Success has been better for filters – no known failures

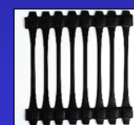
Geomembranes and Geogrids

•Geomembranes have been used successfully for some upstream blanket liner installations. Protection against puncture from protrusions under the membrane or equipment and/or animals running over the membrane is needed

• Geomembrane use as a reservoir liner or in other non-critical applications is Appropriate

Geomembranes and Geogrids

•Geogrids have been successfully used to provide overtopping protection during construction by providing a netting to hold downstream riprap in place during the overtopping



Issues on Using Geosynthetics in Dams

- Summary
- Fabrics may clog easier than sand filters because they do not provide a positive pressure on the soil seepage discharge face
- Geosynthetics inside a dam may tear when the dam cracks because of the high soil pressures on each side causing elongation across the crack
- Damage during installation is a common problem
- Membrane use for intercepting cracks may have high gradients at the base of the membrane causing failure
- Membranes have been used successfully as reservoir liners under certain conditions
- Geogrids have been successfully used as reinforcement and for overtopping protection during construction

Which Way Is Up?