Independent Research On Fabric Clogging

- What really counts in long-term filtration performance?
  Woven - Nonwoven - AOS/EOS - Percent Open Area
- Which of the four most standard fabric types best resists clogging?
- What test is the best current means available to evaluate and quantify clogging potential of geotextiles?

Comparative Hydraulic Performance Evaluation of Geotechnical Fabrics, 1980
Philip D. Wood, Cecilia Hayes Shappee, T. Allan Haliburton
Haliburton Associates, Stillwater, Oklahoma, U.S.A.

Evaluation of the U.S. Army Corps of Engineers Gradient Ratio Test for Geotextile Performance - Proceedings of Second International Conference on Geotextiles, Las Vegas, Nevada, U.S.A., 1982
Haliburton, T.A.
Haliburton Associates, Stillwater, Oklahoma, U.S.A.
Wood, P.D.
McClelland Engineers, St. Louis, Missouri, U.S.A.

Synopsis of Reports

Introduction

The first recorded use in the U.S. of a geotechnical fabric for erosion control occurred in 1958, when the owner of Carthage Mills developed a permeable synthetic woven filter fabric to replace a graded granular filter in a waterfront structure in Florida. Since that time, Carthage Mills has provided woven monofilament geotechnical fabrics used in thousands of projects in the U.S. and abroad. Carthage Mills also pioneered the use of woven geotechnical fabrics in French drains, wrapped around perforated drainage pipe, and scour protection around bridge piers, in addition to conventional river and harbor slope protection and soil erosion control [1]. However, in recent years, various other types of geotextiles, both woven and nonwoven, have become available in the marketplace and have been offered as substitutes for Carthage Mills original monofilament products.

Until 1980, comparatively little experimentation and evaluation had been done to determine which properties of a geotextile will lead to successful long-term performance in filtration, drainage and erosion control applications. Insufficient data existed to determine whether or not the more expensive monofilament fabrics offered significant performance advantages over less expensive woven and nonwoven geotechnical fabrics in filtration/drainage. If a significant performance advantage accrues from use of monofilament fabrics, as compared to other fabrics, this advantage would more than justify any cost differential. Obviously, long-term successful performance is the main criterion desired by both the designer and the user in any fabric application.

To initiate this effort, the Erosion Control Division of Carthage Mills retained Haliburton Associates to investigate the properties that influence geotechnical fabric filtration, drainage, and erosion control behavior, and to evaluate, on a comparative basis, Carthage Mills monofilament fabrics and competitive fabrics. This series of tests was conducted on six geotextiles (four woven, two nonwoven). The test procedures proposed by Haliburton Associates for fabric evaluation were originally developed by the U.S. Army Corps of Engineers, with primary emphasis upon determining fabric performance under soil loss (piping) and fabric clogging conditions.

Background

In 1972, Calhoun developed testing equipment and procedures to evaluate woven filter fabrics for U.S. Army Corps of Engineers use in filtration, drainage, and erosion control [2]. The method used uniform Ottawa 20-30 Sand (ASTM C-190) and various specific fractions of Vicksburg silt loess in a constant-head testing apparatus. Fabrics were evaluated by measuring head loss at various points through the soil-fabric system. This was designated as the Clogging Ratio, and was used to indicate the degree of fabric clogging [2]. In 1977, the Corps modified Calhoun's procedure to specify measurement of the soil-fabric Gradient Ratio, a direct measurement of the fabric clogging potential applicable to both woven and nonwoven fabrics, and established a limiting Gradient Ratio for recommended fabric use. Gradient Ratio values exceeding 3.0 were found to signify excessive fabric clogging, and a limiting value of 3.0 was established by Corps fabric acceptance specifications [3]. Haliburton Associates carefully recreated the Corps of Engineers test equipment and procedures, to provide an independent assessment of fabric performance using the field verified test procedures of the Corps.

Methodology

The testing program was designed to evaluate the comparative hydraulic performance of geotechnical fabrics, with primary emphasis on fabric clogging potential. Six geotextiles, representing the basic types of standard geotextiles on the market, were used in the test program. Descriptions and relevant properties of the geotextiles are shown below:

Description	AOS/EOS	Percent Open Area (%)
Nonwoven heatbonded	70-100	--
Nonwoven needlepunched	70	--
Woven slit film	40	<1%
Woven monofilament	70	5%
Woven monofilament	70	20%
Woven monofilament	40	30%

In order to compare geotextile clogging resistance using Corps of Engineers criteria, four units of the Calhoun test apparatus were constructed for the test program [2]. Ottawa sand and Vicksburg silt loess test soil mixtures of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, and 80% silt by weight were prepared. Soil mixtures were tremmied in dry and placed to a 4 inch thickness. Each unit was slowly filled from the bottom with ordinary tap water, to minimize soil disturbance.

Water used in the testing program was first distilled and then deaired by vacuum pump. The outflow standpipe elevation remained constant for all fabrics at each silt percentage and was changed with each silt percentage. Piezometer readings were taken every 15 minutes until they stabilized and initial and final flow rate measurements were recorded.

After testing, soil samples were taken from each test unit, over intervals of 0 mm - 6 mm (0 in. - 0.25 in.), 6 mm - 25 mm (0.25 in. - 1 in.), and 50 mm - 75 mm (2 in. - 3 in.) above the geotextile, and the final silt percentage distribution determined.

Test Results and Evaluation

Geotechnical fabric clogging resistance is the most important fabric property needed for long-term field performance. The Gradient Ratio, as defined by the U.S. Army Corps of Engineers [3] was used to determine the quantitative performance of each fabric. The Corps of Engineers specification allows a maximum value of 3.0 for the Gradient Ratio. This is related to the fact that the Gradient Ratio increases rapidly with small changes in silt percentage after a value of 3.0 is reached [3]. Gradient Ratio values for each soil-geotextile combination were computed as the average of four individual tests and are plotted versus Percent Silt in Figure 1. The various geotextiles exceeded the maximum GR of 3.0 at the following silt percentages:

Geotextile	Maximum Allowable Soil Silt Percentage (GR $\leq$ 3.0)
Woven Slit Film	0% (Clean Sand)
Nonwoven Heatbonded	0.5%
Nonwoven Needlepunched	18.5%
Woven Monofilament - 5% Open Area	25%
Woven Monofilament - 20% Open Area	60%
Woven Monofilament - 30% Open Area	Could not clog - Maximum GR = 1.1 at 80% Silt

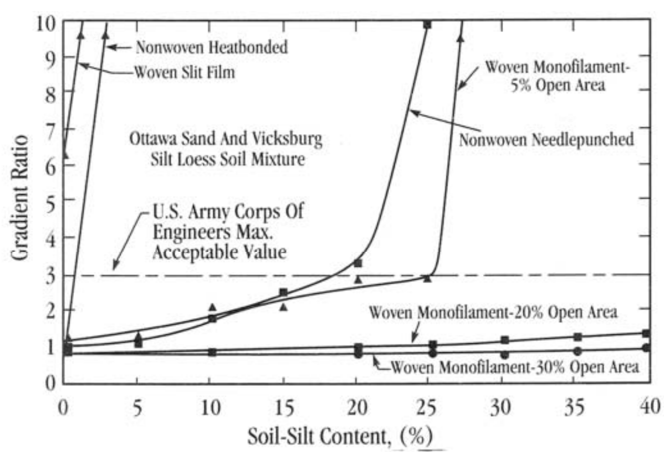

Figure 1: Gradient Ratio as a function of Soil-Silt Content for geotextiles tested.

Review of the various test data indicated that:

a. AOS/EOS values for the six tested fabrics varied from 40 to 70 and all fabrics satisfied both the original 1972 Calhoun [2] and 1977 Corps of Engineers [3] piping criteria. This was confirmed during testing, as no appreciable piping through the fabrics was noted for any fabric or soil combination.

b. The 1977 U.S. Army Corps of Engineers Gradient Ratio test is an acceptable method to evaluate and quantify the clogging potential of geotextiles. Geotextiles should definitely not be used in severe/critical design applications where soil-geotextile system Gradient Ratio exceeds 3.0.

c. Geotextile AOS/EOS was found to have no relationship to geotextile clogging behavior, but a direct relationship between percent open area and clogging behavior exists. The larger the percent open area for the fabric, the better its performance, especially at higher silt contents, substantiating Calhoun's original Corps of Engineers conclusions [2].

d. Once a GR of 3.0 was exceeded, noticeable amounts of silt were found deposited on or in all geotextiles. However, despite the gap-graded nature of the test soils, significant changes in soil-silt content were found to occur only in the 6 mm (0.25 inches) above the geotextile. For all samples and all silt percentages where silt loss occurred, loss occurred only during the initial 10 min.-15 min. of the test, with the majority of loss occurring in the first 5 min.. When the GR was $\leq$ 3.0, a slight <u>increase</u> in soil-geotextile system permeability was noted to accompany the soil loss. The Clogging Ratio changed as each test progressed, indicating the initial silt migration and, consequently, changing system permeability, but as silt migration ceased, permeability stabilized, and the Clogging Ratio became constant. This was the first indication that a "mini-graded filter" had formed in the soil immediately behind the geotextile, as originally suggested by Calhoun [2].

e. The woven slit film fabric allowed some migration of silt, but the openings in the fabric are widely scattered and the fabric had <1% open area. The 40 EOS openings allow some migration, but the flow is still restricted in areas where there are no openings. This behavior was the basis for Calhoun's original recommendation of $\geq$4% open area for any filtration/drainage use [2].

f. The nonwoven heatbonded fabric allowed little migration and the silt that did migrate was not passed through the fabric, probably because of the tight "weave" produced by heatbonding the fibers and the relative small number of actual (or equivalent) openings.

g. For the nonwoven needlepunched fabric, some small initial migration of silt occurred at 10% silt content. Flow was concentrated through the needlepunched AOS/EOS 70 holes but these openings are variable in diameter and concentrated in small areas. Although the GR of 3.0 was not exceeded until 18.5% silt, this fabric was found to cause some <u>decrease</u> in soil-fabric system permeability during testing. Such behavior is undesirable in protective filter applications. At 25% silt (GR of 10.43) a continuing increase in Clogging Ratio was noted to occur, <u>without</u> the release of silt and reduction in clogging. These data indicate that the mini-graded filter was forming <u>inside</u> the fabric.

h. The three woven monofilament geotextiles had the best clogging resistance among the six fabrics tested. Although they were initially clogged by silt migration, the silt was almost immediately lost through the fabric, causing the formation of a "mini-graded filter" in the soil and reducing fabric loading. Clogging resistance increased with increase in woven fabric percent open area, substantiating Calhoun's original Corps of Engineers conclusions [2].

i. Results of soil-fabric system permeability measurements showed that both the woven slit film and nonwoven heatbonded fabrics had, after clogging, one or more orders of magnitude less permeability than the test soils. This indicated that the fabrics constituted the least permeable part of the soil-fabric system and violate the accepted design concept that the filter fabric should be more permeable than the soil. Of the balance of the fabrics, only the woven monofilament geotextiles allowed an increase in soil-fabric system permeability for <u>all</u> tested silt percentages, indicating the filter (fabric) was and remained more permeable than the soil.

j. Based on test data for the woven monofilament geotextiles, the Silt Percentage which caused a GR of 3.0 is plotted versus the woven geotextile Percent Open Area in <u>Figure 2</u>. This Figure may be used to estimate the Minimum Woven Geotextile Percent Open Area required for acceptable clogging resistance at the various Silt Percentages noted for a given site-specific silt-soil content.

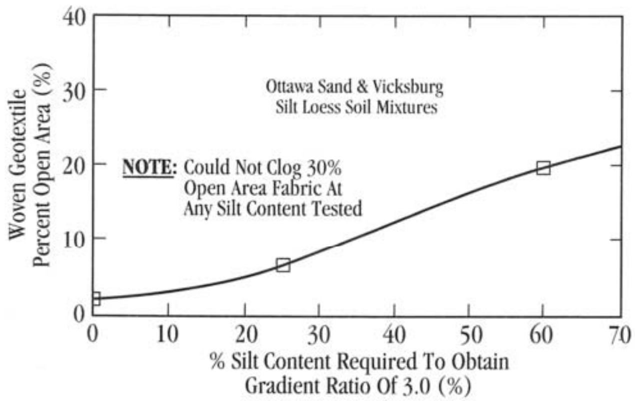

Figure 2: Woven Geotextile Percent Open Area vs. Percent Silt to develop Gradient Ratio of 3.0

<u>Summary and Conclusions</u>

The testing program was designed to evaluate the comparative hydraulic performance of various geotextiles under soil loss (piping) and fabric clogging conditions, with primary emphasis on clogging potential. Test equipment, procedures, sand/silt mixtures, and performance criteria developed by the U.S. Army Corps of Engineers were used for this study and lead to the following conclusions:

1. The **nonwoven heat-bonded** and the **woven slit film** fabrics <u>both clogged</u> at silt-soil fractions of <u>1/2% or less</u>. In fact, significant clogging occurred with clean uniform sand and these fabrics are judged unsuitable for long-term filtration/drainage use with soils having any silt fraction.

2. The **needlepunched nonwoven** geotextile experienced <u>internal clogging</u> in the felt-like portion of the fabric. Outflow continued but was concentrated at the needlepunched holes which caused it to act more like a woven than a nonwoven. If these holes had not been present, fabric performance would have undoubtedly exceeded U.S. Army Corps of Engineers maximum allowable Gradient Ratio of 3.0 at a much lower silt-soil content.

3. Fabric **AOS/EOS** was found to have <u>no relationship</u> to fabric clogging behavior. The woven slit film, which had the largest AOS/EOS (40), also had the worst clogging performance and developed the largest Gradient Ratios among the tested fabrics.

4. The greater the **percent open area** of the fabric, the better the filtration performance and resistance to clogging. This confirms original 1972 Corps of Engineers findings concerning percent open area.

5. The **woven monofilament** tested were the only fabrics that allowed the soil-fabric system permeability to <u>increase</u> through bridging and cake formulation in the soil immediately behind the fabric, creating a mini-graded filter.

6. All tested fabrics satisfied both the 1972 and 1977 U.S. Army Corps of Engineers **AOS/EOS piping criteria**, and minimal in-service piping was observed for all fabrics at all silt contents.

7. The 1977 U.S. Army Corps of Engineers **Gradient Ratio** test is an acceptable method to evaluate and quantify the clogging potential of geotextiles.

References

[1] Dallaire, Gene, "Filter Fabrics Can Cut Costs of River-Bank and Shore Protection Structures", Civil Engineering, American Society of Civil Engineering, New York, March, 1977

[2] Calhoun, C.C., "Development of Design Criteria and Acceptance Specifications for Plastic Filter Cloths", Technical Report S-72-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 1972

[3] U.S. Army Corps of Engineers, "Plastic Filter Cloth", Civil Works Construction Guide Specification No. CW-02215, Office, Chief of Engineers, Washington, D.C., 1977

[4] Copeland, J.A., "Fabrics in Subdrains: Mechanics of Filtration and the Measurement of Permeability", Transportation Research Report No. 80-2, to Federal Highway Administration by Department of Civil Engineering, Oregon State University, Corvallis. 1980

The late **T. Allan Haliburton** (BSCE, MSCE, Ph.D.) held the rank of Professor of Civil Engineering at Oklahoma State University, was a Registered Professional Engineer in ten states, and was President and Managing Director of Haliburton Associates, Inc., a research and consulting firm. Dr. Haliburton was a member and held various offices in ASCE, ASEE, TRB, ASTM, and ISMFE; was the author of numerous professional papers, governmental reports and engineering reports; and enjoyed an international reputation as a researcher and practicing civil engineer, particularly in the field of soil mechanics. He was deeply involved in geotextile engineering activities starting in 1972, and conducted research for the U.S. Army Corps of Engineers, U.S. Air Force, and American Association of Railroads in geotextile usage.