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PERFORMANCE TESTING OF SEDIMENT RETENTION DEVICES

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Biography

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Abstract

One of the greatest problems for specifiers in achieving NPDES sediment reduction goals is the lack of quantifiable criteria for the performance of available Best Management Practices (BMPs). The effectiveness of the many different types of sediment control BMPs, including silt fence and other sediment retention devices (SRDs), has not been adequately quantified. There are little performance data available for most SRDs because there has been no recognized standard test procedure for measuring relevant performance criteria. SRD material components can be accurately evaluated for hydraulic properties using the bench-scale standard test method, ASTM D 5141, “Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device Using Site-Specific Soil”. Yet, the effectiveness of many SRDs is system or installation dependent, therefore a large-scale test that can incorporate full-scale “as installed” conditions is the ideal evaluation procedure. Recently these needs have been addressed with the issuance of a large-scale standard test method ASTM D 7351, “Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications.” The test method quantifies both sediment removal and associated flow rate thru an SRD, so that the potential for either excessive sediment loss or the back-up of runoff can be assessed.

This paper details both the bench-scale and the large-scale test procedures and presents data on tests run on a variety of silt fence styles to demonstrate the ability of standardized testing to differentiate product performance and, in so doing, to enable a specifier to “engineer” the system to provide the desired balance between flow and sediment retention.

Key words: SRDs, sediment control, NPDES, performance testing, specifications

1 Background

Sediment is the number one pollutant of US water resources even though sediment control best management practices, BMPs, are now commonly used. While a large amount of information on types of storm water BMPs for erosion and sediment control currently exists, the information on actual performance effectiveness is difficult to find and not well documented. In order to help protect water quality as it relates to sediments, regulatory agencies and site designers will increasingly need to know how well specific BMPs will perform when exposed to sediment-laden flows.

2 Sediment Retention Devices (SRDs) and Standardized Performance Testing

While sediment ponds have been widely studied and have generally accepted quantitative design procedures, this is not the case for most other BMPs, including sediment retention devices (SRDs). SRDs include silt fence, wattles, filter logs, compost socks, compost and earth berms, as well as various types of storm water inlet protectors. SRDs offer the potential to prevent water pollution without the large area requirement and safety concerns of a sediment pond. Unfortunately, SRDs are frequently selected without an objective, quantitative means of knowing if the device can be expected to be sufficiently effective. There is no generally recognized way for specifiers/designers to verify marketing claims or one-time field trials, or for innovators to test new products. Standardized testing procedures assist the users of SRDs in establishing improved construction specifications. Owners and contractors can save money by installing the correct SRD for the expected site conditions. And, product manufacturers have a clear, generally recognized methodology for establishing product capabilities.

3 Available Standard Test Methods

3.1 ASTM D 5141

3.1.1 Summary of Test Method ASTM D 5141 for Material Performance.

A standard performance-related index test (ASTM D 5141) is commonly used to characterize SRD efficiency. In the test method, sediment-laden water is allowed to flow up to and thru an installed sediment retention device (SRD). At a minimum, the amount of sediment-laden flow and associated sediment passing thru the SRD is measured. The measurement of sediment that passes through the SRD compared to the amount in the upstream flow is used to quantify the effectiveness of the SRD in retaining sediments. This test method quantifies the ability of a sediment retention device (SRD) to retain eroded sediments caused by flowing water under bench-scale conditions. This test method may also assist in identifying physical attributes of SRDs that contribute to their sediment control performance, and it is useful for comparison of products. Since the effectiveness of SRDs is also installation dependent, this test method may not be completely indicative of product performance.

3.1.2 Apparatus.

The test apparatus can accommodate a vertical SRD, such as a silt fence or wattle, by placing it across the mouth of the inclined box "flume". Additionally the test apparatus can incorporate a horizontal "box" extension to the end of the flume to facilitate the evaluation of a horizontal SRD, such as an inlet filter. The full test apparatus is shown in Figure 1. The typical setup for silt fence testing is shown in Figure 2.

3.1.3 Procedure.

After positioning the SRD and assuring that it is sealed around the edges, create sediment-laden runoff by combining water and soil in the mixing tank and agitating prior to the test. The amount of water (50 L / 13.3 gal) and sediment (0.15 kg / 0.33 lb) is prescribed in the standard. The soil can be either site-specific, or a default sand, with a maximum particle size of 2mm (#10 sieve). The sediment-laden flow passing thru the SRD is collected, and the time to the end of flow is recorded. Vacuum-assisted filtration of the collected seepage is used to obtain the passed sediments. Filtered sediments are dried and weighed. The weight of collected sediment is compared to the initial amount put into suspension to determine the filtering efficiency.

Figure 1. Bench-scale Sediment Control Testing Apparatus (with Horizontal "Box" Extension for Testing Inlet Filter Systems)

Figure 2. Close-up of Silt Fence Testing Setup

3.2 ASTM D 7351

3.2.1 Summary of Test Method ASTM D 7351 for SRD System Performance.

A standard full-scale performance index test (ASTM D 7351) is commonly used to characterize SRD system performance, including sediment and flow retention, and structural behavior under hydraulic loading. As with bench-scale testing, sediment-laden water is allowed to flow up to and thru an installed sediment retention device (SRD). At a minimum, the amount of sediment-laden flow and associated sediment passing thru the SRD is measured. The measurement of sediment that passes through the SRD compared to the amount in the upstream flow is used to quantify the effectiveness of the SRD in retaining sediments. This test method quantifies the ability of a sediment retention device (SRD) to retain eroded sediments caused by flowing water under full-scale conditions. This test method may also assist in identifying physical attributes of SRDs that contribute to their sediment control performance, and it is useful for comparison of products. Since the effectiveness of SRDs is installation dependent, this test method is indicative of actual field performance.

3.2.2 Testing "System".

The test procedure requires a significant investment in related equipment to accomplish the full-scale testing of SRDs. The suggested system includes the following components:

- A tank with an internal paddle mixer device mounted on scales capable of holding/weighing 10,000 lbs of sediment-laden water.
- A sufficient source of water and associated pumping equipment to repeatedly fill the mixing tank in a timely manner.
- A tank mounted on scales of sufficient volume to collect all runoff passing the SRD.

The mixing and collection tanks are separated by areas, or zones, as shown in Figure 3. A non-permeable slope surface immediately below the mixer discharge spreads the initial discharge and provides a retention zone above the installation zone. The installation zone is about 5 feet wide by the width of the retention zone comprised of prepared soil subgrade to allow full-scale installation of the SRD to be tested. The center of the installed SRD is typically placed in the center of the installation zone. The area below the installation zone is non-permeable to facilitate efficient transmission of runoff passing the SRD to the collection tank.

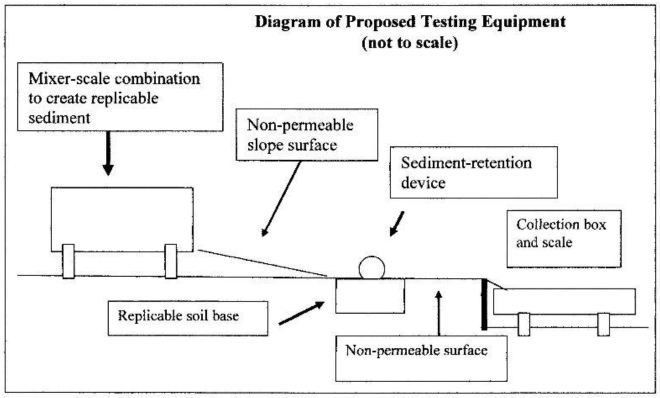

Figure 3. Diagram of SRD Effectiveness Test Procedure

3.2.3 Procedure.

A representative sample of the SRD to be tested is installed in accordance with the manufacture's recommendations or, lacking recommendations, in accordance with generally accepted construction procedures. The installation should extend beyond the width of the retention zone sufficiently to assure that runoff does not run around the ends. A sediment-laden runoff is then created by combining water and soil in the mixing tank and maintaining agitation during the test. For the testing reported herein, 1816 kg (4000 lbs) of water and 109 kg (240 lbs) of soil were combined to create the sediment-laden runoff. This sediment-laden runoff is based on the peak 30 minutes of a 10-year, 6-hour storm event producing a 100 mm (4 in) rainfall, allowing for 50% infiltration. Also assumed is a contributory area of 30 m (100 ft) slope length by 5 m (16 ft) wide and the associated sediment load calculated using the Modified Universal Soil Loss Equation (MUSLE). The discharge is released evenly for 30 minutes.

Periodic grab samples are taken as seepage flows into the collection tank, and the depth and weight of the collected seepage is measured and recorded at the same intervals. Visual observations relevant to the testing, such as height of ponding, undermining, overtopping, etc. and the associated times are also recorded. The grab samples are evaluated in a lab to determine percent solids content assisted by vacuum filtration. Figures 4 and 5 show a typical test in progress.

Figure 4. Full-scale Sediment Control Testing "System" with a High Flow Silt Fence System

Figure 5. Full-scale Sediment Control Testing "System" Showing Modest Impoundment with a High Flow Silt Fence System

4. Experimental Program

Two programs have been carried out on a range of silt fence materials using the soil gradations show in Figure 5. The first program tested a range of fabrics via ASTM D 5141 using both sand and loam soils. The second program tested the same fabrics, in a full-scale installation, in accordance with ASTM D 7351 using only loam. The soils are described in Figure 6 and the fabrics tested are described in Table 1.

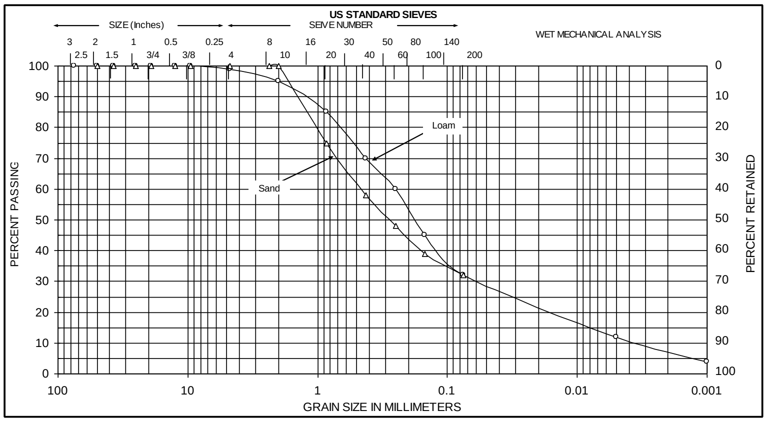

Figure 6. Sediments used in experimental programs

Table 1. Tested Silt Fence Fabrics and Applicable MARV Properties

Silt Fence Fabric	Fabric Construction	Description	Flow Rate, gpm/ft^2	AOS, mm	Light Passage, %
#1	W-SF	Woven Slit Film	10	0.60	0.45
#2	NW	Nonwoven	145	0.25	1.84
#3	W-MF-C	Woven, Monofilament, Calendared	18	0.21	2.02
#4	W-MF	Woven, Monofilament	145	0.43	7.81


Figure 7. Silt Fence #1


Figure 8. Silt Fence #1 + Wire Backing

Experiment #1. The first experiment included a range of silt fence fabrics. No wire backing was included. The fabrics were each exposed to both sand and loam dispersed in water, in separate tests, in accordance with ASTM D 5141. The typical silt fence test setup was shown in Figure 2. Table 2 summarizes the test results.

Experiment #2. The second experiment included the same range of silt fence fabrics as used in Experiment #1, but the fabrics were only exposed to loam dispersed in water, and tested in accordance with ASTM D 7351. The silt fence installation was in accordance with ASTM D 6462 with posts placed at 6-ft spacing. Three of the fabrics were tested with an alternate support system – wire fencing support. Figures 7 - 11 show the different fabrics in the large-scale test. Table 3 summarizes the test results.

Figure 9. Silt Fence #2 + Wire Backing

Figure 10. Silt Fence #3

Figure 11. Silt Fence #4 + Wire Backing

Table 2. Experiment #1 Results

Experiment	Silt Fence	Soil Type	Flow Rate (gpm/ft^2)	Retention Efficiency (%)	Filtration Efficiency (%)
#1 ASTM D 5141	#1	Sand*	0.332	51.8	91.9
	#2	Sand*	1.041	1.6	88.4
	#3	Sand*	0.917	0.1	84.6
	#4	Sand*	5.355	0.0	71.4
	#1	Loam*	0.332	53.4	94.5
	#2	Loam*	0.320	53.4	93.7
	#3	Loam*	0.419	41.8	96.7
	#4	Loam*	0.743	14.2	81.5

* sieved through No. 10 sieve

Table 3. Experiment #2 Results

Experiment	Silt Fence	Soil Type	Retention Efficiency (%)	Filtration Efficiency (%)
#2 ASTM D 7351	#1 w/ wire backing	Loam	69.81	94.8
	#1	Loam	70.73	96.9
	#2 w/ wire backing	Loam	43.84	91.6
	#3	Loam	72.41	90.2
	#4 w/ wire backing	Loam	9.07	85.1

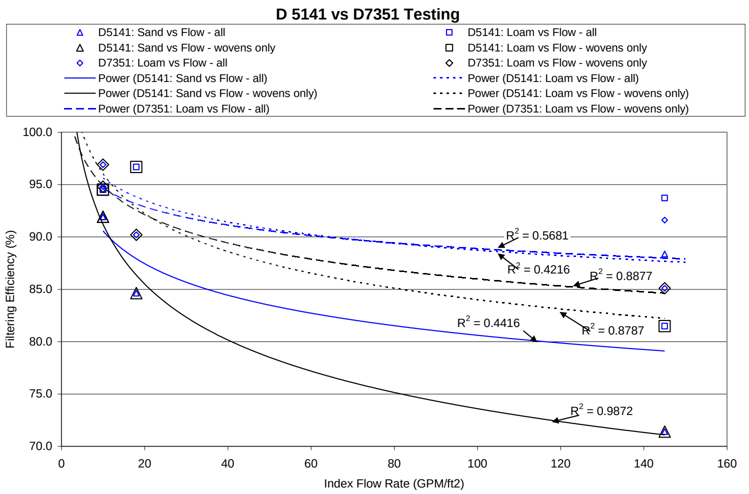

Figure 12. Filtration Efficiency vs. Index Flow Rate

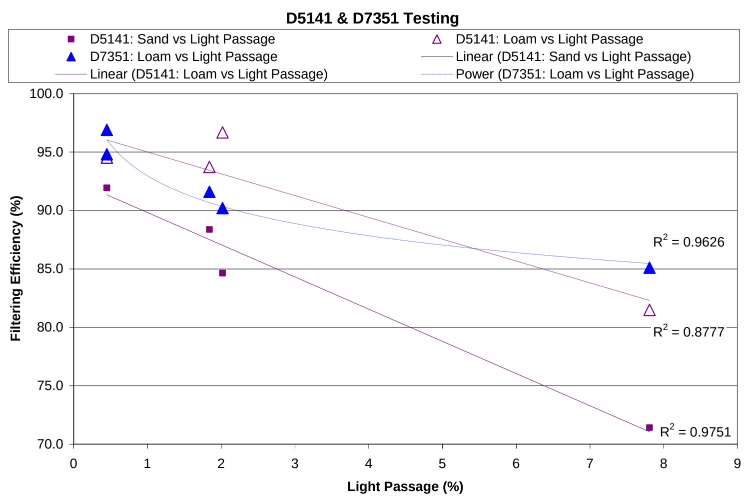

Figure 13. Filtration Efficiency vs. Light Passage

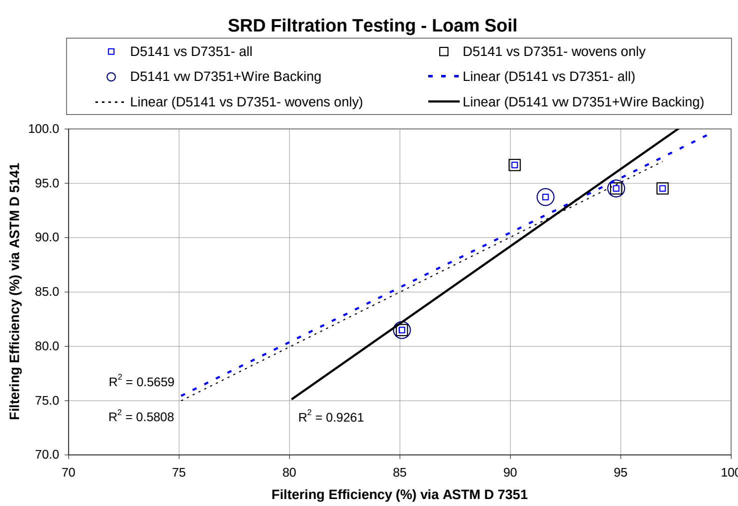

Figure 14. Filtration Efficiency: D5141 vs. D7351

5 Conclusions

Sediment retention is arguably the most important performance property of a sediment retention device (SRD). Similarly, it is common to use certain hydraulic properties to specify SRDs for construction projects. Thus, it is important to try and understand if common hydraulic properties of SRDs do, in fact, relate to actual field performance.

The testing reported herein presents one type of SRD in a study of properties and performance. The study included silt fence fabrics with a wide range of "index" hydraulic characteristics, including opening characteristics ranging from less than 1 to nearly 8 percent open area and flow capacities ranging from 10 to 145 gallons per minute per square foot. These fabrics were exposed to bench-scale (ASTM D 5141) and large-scale (ASTM D 7351) performance tests in an effort to identify relative performance of the fabrics and to attempt to correlate performance results to index hydraulic properties. The best correlations are presented in Figures 12, 13, and 14.

As shown in Figures 12 and 13, the data suggests that there may be a useful relationship between two index properties – water flow and light penetration – and the ability of a silt fence to retain sediments, also known as filtration efficiency. Figure 12 shows a very good correlation between index water flow and filtration efficiency associated with sand for woven silt fence fabrics tested in ASTM D 5141. When the nonwoven fabric is included, the correlation reduces somewhat. Good correlations are also suggested by both ASTM D 5141 and D 7351 tests for woven fabrics exposed to loamy sediments. Figure 13 suggests that a very good correlation exists between light passage and filtration efficiency for all fabric types and for both sandy and loamy sediments. The correlations were found with both bench- and large-scale performance testing.

Still, Figure 14 suggests that ASTM D 5141 and D 7351 are not interchangeable for measuring all silt fence performance. While a very strong correlation exists between the filtration efficiency measured in D 5141 and that measured in D7351 when the fabric is supported by wire backing, the same cannot be said if fabrics without wire backing are included. Unfortunately, this is more the rule than the exception. Thus, it has to be concluded that for unsupported silt fence, at least, large-scale testing is necessary to assess actual field performance. This is easy to understand if one compares Figures 7 and 8. In Figure 7 the loaded silt fence is stretched and its openings tightened, while in Figure 8 it is clear that the load is transferred to the wire backing preventing the distortion of the fabric structure.

Finally, this study supports the use of index properties such as minimum flow rate (ASTM D 4491) and light passage (ASTM D 6567) in SRD construction material specifications, along with ASTM D 5141 or D 7351 for desired filtration performance.

6 Reference

ASTM D 5141, "Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device Using Site-Specific Soil".

ASTM D 7351, "Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications".