A QUANTITATIVE COMPARISON OF SEDIMENT RETENTION DEVICES UNDER STANDARDIZED TEST CONDITIONS

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Abstract

Interest in Sediment Retention Devices (SRDs) and Storm Water Treatment Devices (SWTDs) has grown as more stringent storm water and environmental regulations have been enacted. Increased monitoring and enforcement activities have stimulated demand for more advanced and cost effective methods to control sediment and treat stormwater being discharged from construction related activities.

One of the greatest problems facing specifiers in achieving NPDES sediment reduction goals is the lack of quantifiable criteria for the performance of Best Management Practices (BMPs). Standardized methods to quantify effectiveness of sediment reduction devices and stormwater treatment devices have only recently been proposed and are currently under consideration by ASTM. During Stormcon 2004 a paper summarizing such standardization activities was presented by Joel Sprague and Tom Carpenter. Their paper offered a consistent and reproducible test method to objectively quantify the sediment retention efficiencies of various BMPs.

This paper will present additional comparative quantitative data gathered in 2004 using this (and a modified version) of this test methodology and offer suggestions for modifying the proposed ASTM standard for evaluating sediment retention and storm water treatment devices on slopes and in channels.

Background

Despite increased usage of sediment control BMPs, sediment remains the number one pollutant of US waterways. As a result, many agencies are developing storm water manuals to assist cities, states, owners, engineers, and contractors with implementing best management practices (BMPs) for site runoff controls. While there is lots of information on types of erosion control, sediment control and storm water BMPs, information on their performance effectiveness is often not well documented. To help achieve water quality and comply with site pollutant discharge limits; state agencies, cities, counties, developers and builders must have information and guidance regarding BMP performance under specific site and storm conditions.

Standardization Testing of Sediment Control BMPs

Available in the market place are numerous types of sediment retention devices (SRDs) which may be considered a subset of Storm Water Treatment Devices (SWTDs). A paper presented at Stormcon 2003 by Theisen and Woelkers offered a proposed classification system for SWTDs. Examples of SRDs include silt fences, channel silt dikes, wattles, fiber rolls, compost socks, and fiber filtration tubes. Currently some SRDs are selected without full knowledge of product performance, intended product application, and clear design criteria for determining the proper site layout and installation specifications. The lack of standardized evaluation procedures has consequently lead to unsatisfactory performance of SRDs and unexpected sediment runoff into streams and storm sewers.

An independent and well-documented large-scale testing procedure would assist the users of SRDs in establishing improved design and performance criteria. Owners, agencies and contractors would save money by installing the correct SRD for the required site controls. And, product manufacturers would have a clear, generally recognized methodology for establishing product capabilities.

Proposed Standard Test Method

Summary of Test Method
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 is measured both upstream and downstream of the SRD. 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 erosion control performance. SRD effectiveness is installation dependent and replication of field installation techniques in an important aspect of this test method. This test method is full-scale and therefore, appropriate as an indication of product performance, for general comparison of product capabilities, and for assessment of product installation techniques.

Apparatus
The test procedure requires a significant investment in related equipment to accomplish the full-scale testing of SRDs as shown in the testing system diagram shown in Figure 1. The 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 stockpile of soil in sufficient quantity to both create sediment-laden water and to create/replace subgrade in the installation zone.
- A front-end loader to dump a prescribed amount of soil into the mixing tank.
- A valve-controlled discharge hose that allows for controlled discharge from the mixing tank.
- Sampling jars (at least 12 per test) for taking "grab" samples periodically during the test.
- Earthmoving/compacting equipment to prepare/replace soil in the installation zone.
- A tank mounted on scales of sufficient volume to collect all runoff passing the SRD.

Retention Area
A non-permeable slope surface immediately below the mixer discharge shall be provided to spread the initial discharge and to provide a retention zone above the installation zone. An installation zone 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 should be placed in the center of the installation zone each time to replicate height of water as it relates to volume retained. The prepared soil subgrade will be compromised each test, so it will have to be reconstructed after each test. The area below the installation zone should be non-permeable to facilitate efficient transmission of runoff passing the SRD to the collection tank.

The Collection Area
The collection tank shall be at a lower grade than the installation area so that runoff passing the SRD will efficiently flow via gravity into the tank. A retaining wall between the installation zone and the collection tank is recommended.

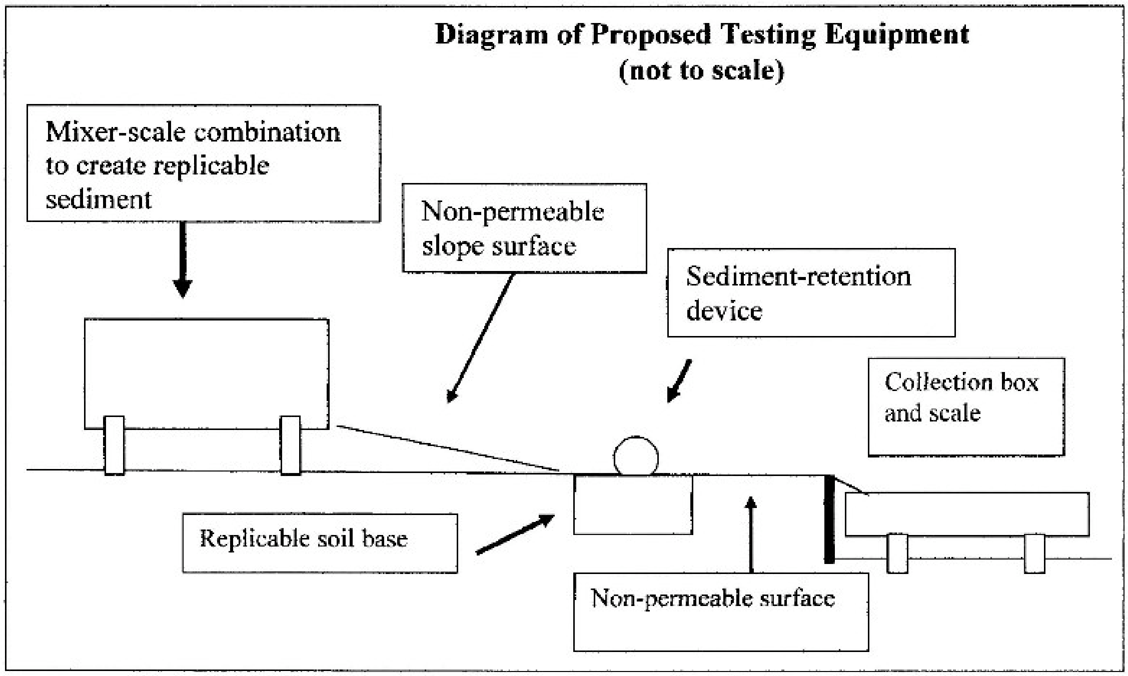

Figure 1 - Diagram of SRD Effectiveness Test Procedure

Procedure
<u>SRD Installation</u> - Prepare the installation zone using the same soil to be used as sediment, unless otherwise agreed with the client. The soil shall be place to a depth in excess of the depth of installation and compacted to greater than 90% standard Proctor. Install a representative sample of the SRD to be tested. The SRD sample shall be 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.

<u>Mixing, Releasing, and Collecting Sediment-Laden Runoff</u> - Procure screened soil in adequate quantities for the testing procedure, determine its characteristics for future replication needs, and cover to prevent contamination and rainfall degradation. Create sediment-laden runoff by combining water and soil in the mixing tank and maintain agitation during the test. Unless otherwise directed by the client, 5000 lbs of water and 300 lbs of soil shall be combined to create the sediment-laden runoff. This sediment-laden runoff is based on a 10-year, 6-hour storm event producing a 4 in (100mm) rainfall. It was assumed that 25% of the storm would occur during the peak 30 minutes, and that 50% of the rainfall would infiltrate into the ground. A theoretical contributory area of 100 ft (30 m) slope length by 20 ft (6 m) wide was selected to limit runoff to sheet flow conditions. Additionally, the associated sediment load was calculated using the Modified Universal Soil Loss Equation (MUSLE) that allows for calculating a storm-specific quantity of sediment. Release the discharge evenly for 30 minutes, measure the quantity of released runoff at no less than 10 minute intervals by noting the reduction in weight in the mixing tank. Adjust the valve on the outlet hose to increase/decrease flow.

Take grab samples at 10-minute intervals from the outlet hose discharge. Additionally, as runoff passing the SRD enters the collection tank , record the weight and height of runoff in the collection tank, and take grab samples of runoff entering the tank, also at 10-minute intervals. Cutoff time is 90 minutes, unless otherwise directed by the client. An earlier cutoff time is acceptable when there is low-volume ponding and minimal discharge.

Data Collection - Select a specific upstream and downstream location for taking all grab samples. Collect all samples in the same size container and in the same manner. Pre-mark each container and do not overfill or overrun the sample bottle. Concentrations may be small, thus poor sampling techniques may significantly affect results. Multiple measurements cause a hectic pace, so pre-marking and recording immediately insures consistency and accuracy.

Sediment-laden water in both the mixing and collection tanks is primarily measured by weight. An additional measurement in the collection tank is the height of the collected liquid. Also, it is important to make and record visual observations relevant to the testing, such as height of ponding, undermining, overtopping, etc. and the associated times.

Lab Testing - Grab samples shall be evaluated in a lab to determine percent solids content. Vacuum filtration is recommended.

Calculations

After recording all collected data in a table, noting the time of each sampling, calculate soil retention effectiveness by comparing the amount of soil loss during the test (solids passing the SRD) to the total amount of soil placed in the mixing tank. Table 1 provides an example of tabularizing data.

Table 1 - Example of Data Collected During Testing

Sample				Total Weight, g	Weight of Jar, g	Weight of Dirty Water, g	Weight of Seds., g	% Solids	Time Interval, min	Wtd. Avg Solids, %	Soil Retention, %	Time, mins.	Coll. Flow, lbs	Water Retention, %	Test Set-up
Date	Location	Test #	Spec #												
Nov-03	Upstream	124	std			5300.00	300.00	6.00%	30.000	6.00%					Sliced Silt Fence; 5-ft Post Spacing; Clay soil
Nov-03	Down-stream	124	5	589.53	57.31	532.22	10.49	2.01%	10.000	0.22%	77	10	245	32	
		124	15	597.11	56.38	540.73	20.41	3.92%	10.000	0.44%		20	730		
		124	25	602.34	56.85	545.49	11.43	2.14%	7.500	0.18%		30	1480		
		124	30	600.39	56.86	543.53	20.72	3.96%	7.500	0.33%		40	2175		
		124	40	606.26	57.90	548.36	4.36	0.80%	10.000	0.09%		50	2636		
		124	50	592.54	57.34	535.20	1.60	0.30%	45.000	0.15%		60	2950		
		124	90	End Flow			Avg =	2.19%	Sum:	1.41%		90	3444		
Nov-03	Upstream	125	std			5300.00	300.00	6.00%	30.000	6.00%					Silt Dike; Trenched; Available Backfill; Foot Compact; Clay soil
Nov-03	Down-stream	125	5	594.69	57.38	537.31	3.42	0.64%	10.000	0.07%	81	10	122	23	
		125	15	595.20	57.87	537.33	7.22	1.36%	10.000	0.15%		20	1290		
		125	25	591.69	56.35	535.34	5.99	1.13%	7.500	0.09%		30	3054		
		125	30	593.96	56.85	537.11	6.95	1.31%	7.500	0.11%		40	3308		
		125	40	585.54	57.03	528.51	6.52	1.25%	10.000	0.14%		50	3460		
		125	50	596.72	57.15	539.57	6.43	1.21%	45.000	0.60%		60	3578		
		125	90	End Flow			Avg =	1.15%	Sum:	1.17%		90	3900		

Results

2003-2004 Results. In 2003 approximately 36 tests utilizing 2 different soil types were performed, observations taken, and grab samples analyzed. The results were presented in papers by Sprague and Carpenter at the 2004 Stormcon and the International Erosion Control Association (IECA) conferences.

In the summer and fall of 2004 additional research was conducted at the Stormwater Lab under the direction of Profile Products, LLC. The purpose was to duplicate and validate prior research and to evaluate other SRDs. Initially a prototype fiber filtration tube was researched to determine performance properties under varying installation techniques. Comparative results from 2003 and 2004 are shown in Table 2.

Table 2 - Summary Results from 2003-2004 Testing

Technology	Retention Efficiency	Soil Retained
Sliced Silt Fence	88%	90%
Fiber Filtration Tube	86%	94%
Triangular Silt Dike	82%	86%
Excelsior Fiber Roll	56%	54%
Straw Wattle	49%	54%
Static Silt Fence	42%	49%

Subsequently a second round of testing was proposed to evaluate the benefits of more than one SRD installed in series as would be common in steep slope or low flow ditch or channel applications. The 2003 research demonstrated the superiority of higher profile, well-installed devices such as the sliced silt fence for applications such as perimeter sediment control. Since this type of device is designed to maximize ponding height, its usage in higher flowing channels would not be recommended.

For steep slope and low flow channel applications a series of lower profile devices may be more desirable. Although each individual device may not capture as much sediment as a higher profile device, there theoretically would be fewer problems associated with disruption of flow, undermining, water flowing around the device or ultimately the device being knocked over by the force of flowing water. In addition, the cumulative sediment capture of multiple low profile devices acting as “speed bumps” may actually exceed the sediment capture of fewer higher profile devices. In addition to sediment capture other considerations such as ease of installation, aesthetics, filtration, improvements in water quality and compatibility with complementary erosion and sediment control devices should be considered.

In the second round of evaluations a sandy loam soil test bed consisting of was configured to create a parabolic channel 50 feet long and 7 feet wide with gentle side slopes on a 2% gradient. Two devices were installed perpendicular to the direction of flow. The first device was set across the channel 15 feet below the hydraulic discharge point while the second device was installed 25 feet below the first. All devices were trenched in to a depth of 3-4 inches.

The mixing ratio of sediment to water was maintained at 6%. However, the discharge quantity was increased by 50% over the previous testing as 450 pounds of sediment and 7500 pounds of water were evenly discharged at the same rate for 45 minutes at an average turbidity value of 5200 NTU.

Additional parameters to be observed and evaluated were flow rate, filtration, ease of installation stability of the installation, and turbidity of the water entering and exiting the test channel.

2004 Results - The SRDs evaluated demonstrated varying degrees of performance and sediment capture effectiveness. Some of the tests are pictured in Figures 2 thru 5. A summary of initial test results is presented in Table 2. The initial tests suggest the following:

1. Under the chosen test conditions, the proposed test procedure established some relative effectiveness numbers to utilize for comparison, including:
   a. The 2004 findings were consistent with those in the 2003 study that compared SRD technologies using only one installed device.
   b. The fiber filtration tubes provided significantly greater sediment retention efficiencies than the other SRD technologies evaluated. The remaining four technologies provided similar sediment retention efficiencies.
   c. The fiber filtration tubes provided much lower turbidity levels than the other technologies. The straw/coconut and excelsior fiber rolls provided lower turbidity values than the straw wattles and compost socks.
2. The straw wattles, fiber filtration tubes and excelsior fiber rolls were easier to install than the compost socks and straw/coconut fiber rolls.
3. The excelsior fiber rolls, straw wattles and compost socks undermined and allowed water to flow beneath them, despite being trenched in.
4. Only the fiber filtration tubes provided three-dimensional filtration demonstrating complete saturation across the entire three-dimensional profile of the device.

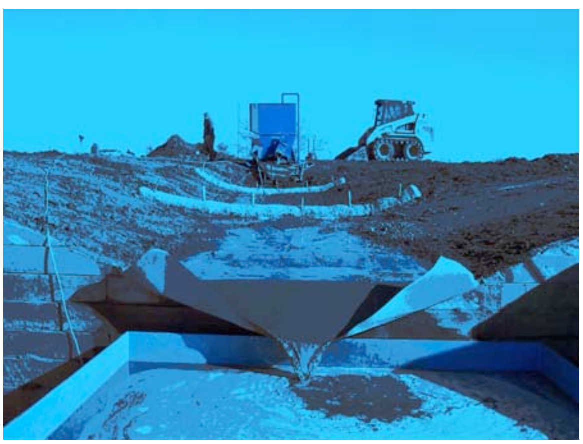

Figure 2 – Straw Wattle

Figure 3 – Excelsior Fiber Roll

Figure 4 – Compost Sock

Figure 5 – Fiber Filtration Tube

Table 3 - Sediment Retention Efficiency

Technology	Retention Efficiency
Fiber Filtration Tube	98%
Straw and Coconut Fiber Roll	76%
Compost Sock	70%
Straw Wattle	68%
Excelsior Fiber Roll	65%

Table 4 – Turbidity at 45 Minutes

Technology	NTU
Fiber Filtration Tube	300
Straw and Coconut Fiber Roll	4500
Excelsior Fiber Roll	5000
Straw Wattle	7000
Compost Sock	7500

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Biographies

Marc S. Theisen, M.S., CPESC is Director of Business Development for Profile Products, LLC. He has over 20 years of experience in the erosion and sediment control industry. He is a Certified Professional in Erosion and Sediment Control (CPESC), on the Board of Directors of the Erosion Control Technology Council (ECTC), and a long term member of the International Erosion Control Association (IECA). Theisen has authored numerous articles and technical papers on the development, testing, and application of erosion and sediment control materials.

Kevin Spittle is Vice-President of Research & Development for Profile Products LLC. He has over 20 years of experience in the erosion and sediment control industry. Spittle is Chairman of the ASTM D-18.02.08 Section on Sediment Control, a member of the IECA, and a former Director of the ECTC. He has developed numerous erosion and sediment control products and holds several manufacturing and application patents.