Inlet Protection using Geosynthetic Sediment Retention Devices

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ABSTRACT

Many systems have been developed to intercept stormwater runoff and to retain suspended sediments while allowing cleaner water to proceed. Inlet protection sediment retention devices (SRDs) using geotextiles as a screen to reduce sediment migration while allowing water passage were tested using the large-scale procedure ASTM D7351 with a modification to present a concentrated flow, rather than sheet flow, to an area inlet. Both pre-manufactured products and site-built systems were tested. The SRDs were installed adjacent to or inside the inlet opening and exposed to simulated (concentrated) runoff. The measurement of water and sediment that passed through, over, and/or under the SRD compared to the amount in the upstream flow was used to quantify the effectiveness of the SRD in retaining sediments while allowing continued seepage. The test results appear to establish appropriate relative performance characteristics for a range of SRDs using the modified ASTM D7351 procedure for inlet protection testing.

INTRODUCTION

Government agencies around the world have developed regulations to limit, under law, the amount of fugitive sediments produced from storm induced erosion and runoff. In response, systems have been developed to help reduce the amount of sediment reaching US waterways. Historically, natural materials such as straw bales and rock have been used in developing the sediment control systems and technologies commonly utilized to achieve the regulatory goals set forth. More recently, the inclusion of geosynthetics in sediment control systems has proven to provide significant advantages when used in place of, or in combination with, these "traditional" natural materials by helping to perform unique and quantifiable functions. For instance, a traditional sediment barrier comprised of bales of straw or piles of brush or gravel are often ineffective at slowing, ponding, or filtering sediment laden water due to inadequate structural integrity, unanticipated leakage, or insufficient storage capacity. However, by containing these materials within a geosynthetic fabric or replacing them entirely with 100% geosynthetic systems, greater structural integrity, uniform flow, and quantifiable flow rates and storage capacity can be achieved.

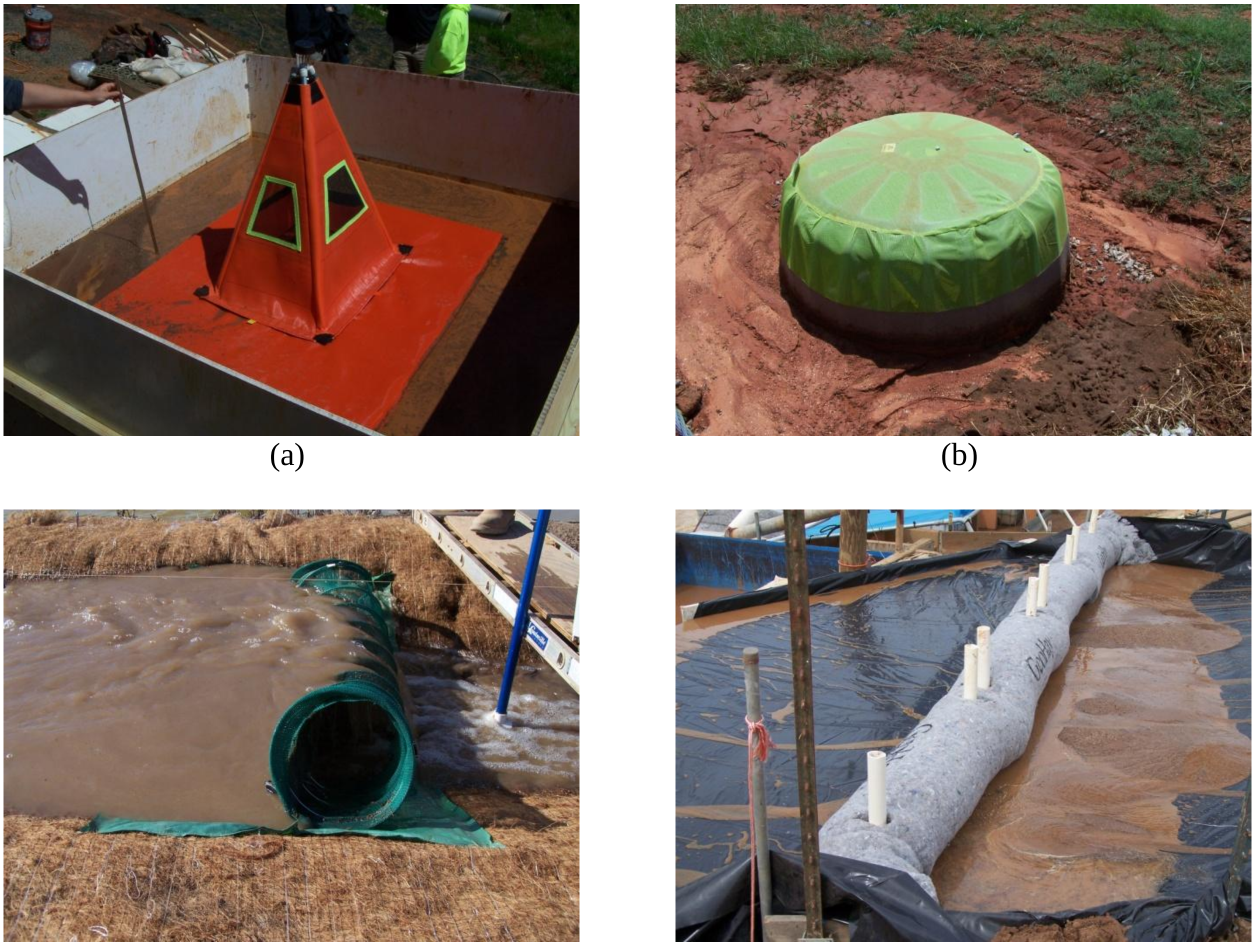
GEOSYNTHETICS IN SEDIMENT CONTROL AND RETENTION.

Geosynthetic-enhanced SRDs include natural materials encapsulated in geosynthetic fabrics, meshes, or nettings and are known as wattles, filter logs, or compost socks. SRDs composed entirely of geosynthetics include commonly used silt fences and turbidity curtains, as well as, various types of storm water sediment barriers and inlet protectors as shown in Figure 1.

In general, the benefits of geosynthetic sediment control systems over traditional structures include: minimal labor required to install; low cost; high efficiency in removing sediment; durability and, occasionally, re-usability. SRDs, such as silt fences, typically cause the following to happen:

- The SRD initially screens silt and sand particles from runoff.
- A soil filter is formed adjacent to the upstream face and reduces the ability of water to flow through the fence.
- This leads to upstream ponding, which serves as a “stilling” basin to collect suspended soils from runoff water.

To perform satisfactorily as an SRD, the geotextile component must have properly sized openings, which initiate the formation of a soil filter. Also the strength and storage capacity of the SRD must be adequate to contain the volume of water and sediment anticipated during a major storm. Hydraulic loading during a storm event is commonly the primary loading considered. Filtering efficiency, flow rate and tensile strength are relevant properties of SRDs and should also be considered. In addition, due to the extended outdoor exposure of most SRDs, UV resistance of the geotextile component is a critical parameter.



(a) (b)

(c) (d)

Figure 1. Innovative Geosynthetic SRDs

SRD PERFORMANCE TESTING

Large-scale performance tests are able to simulate the “as installed” performance of SRDs. Products are installed per the product manufacturer’s published installation recommendations, and the results of these tests are indicative of actual field performance and are acceptable for use in performance specifications and, often, in design calculations. The primary large-scale performance test procedure for SRDs is ASTM D7351, “Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications”. ASTM D7351 is a large-scale standard test method for the evaluation of SRDs in sheet flow applications (i.e. when an SRD is installed at the toe of a slope). It quantifies both sediment removal and associated flow rate through an SRD, so the potential for either excessive sediment loss or the back-up of runoff can be assessed. Yet, many SRDs are not used in sheet flow applications, rather they are exposed to concentrated flow (i.e. when used to protect a median or curb storm sewer inlet). For this type of application, a modification to D7351 is needed.

ASTM D7351 Modified for Inlet Protection is a large-scale test for performance verification of storm sewer inlet protection, and can be done using a slight modification to ASTM D7351. The modification is to discharge the initial sediment laden water as concentrated flow to a simulated inlet instead of as sheet flow to a toe-of-slope installation. The simulated inlet is comprised of a manhole opening positioned at the center of a containment area. The SRD is installed adjacent to, or inside, the opening and sediment-laden water is discharged into the fully contained area around the inlet opening and allowed to run up to and seep through, over, and/or under the SRD protecting the inlet. The measurement of sediment and seepage that passes the SRD compared to the amount in the upstream flow is used to quantify the effectiveness of the SRD in retaining sediments while allowing continued seepage. The test setup for D7351 in sheet flow applications and D7351, modified for concentrated flow (inlet protection), are shown in Figures 2 and 3, respectively.

Figure 2. ASTM D7351 full-scale test.

Figure 3. D7351 modified for inlet protection testing.

INLET PROTECTION SRD PERFOMANCE TESTING – GSWCC.

Sprague, et al (2015) reported on a SRD performance testing program commissioned by the Georgia Soil and Water Conservation Commission (GSWCC) using Method D7351-modified for inlet protection. The specific SRDs tested included what the GSWCC refers to as inlet sediment traps, or inlet protection. The testing included both simulated paved road inlets and unpaved area inlets. The following systems were evaluated (* Note that the geotextile used in testing had an AOS = 0.60mm, a flow rate of 200 gpm/ft^2, and a percent open area = 30%.):

- Concrete block and stone
- #57 Stone and wire mesh backing
- Post-supported silt fence* with welded wire fabric (WWF)
- Geotextile*-wrapped 8-inch blocks
- Geotextile*-wrapped #57 stone

For this testing, a simulated area inlet installation comprised of an approximate 24-inch x 24-inch opening simulating a manhole inlet positioned at the center of a containment area was used. The SRD was installed adjacent to the opening and exposed to simulated runoff. Sediment-laden water was piped and discharged into the fully contained area around the inlet opening and allowed to run up to and seep through, over, and/or under an installed inlet sediment trap SRD protecting the inlet. The amount of sediment-laden flow, by weight, was measured both upstream and downstream of the SRD. The measurement of both sediment and water that passes through, over, and/or under the SRD compared to the amount in the upstream flow is used to quantify the effectiveness of the SRD in retaining sediments while allowing continued seepage. A complete test on each installed SRD with each type of runoff included 3 repeat flows, or events, separated by not less than 4 hours.

Test Setup. The test procedure requires relatively large equipment and area to accomplish the full-scale testing of inlet sediment trap SRDs. The suggested system includes the following components:

- A tank with an internal paddle mixer device mounted on scales capable of holding/weighing 4500 kg of sediment-laden water.
- A source of water and associated pumping equipment to repeatedly fill the mixing tank.
- A tank mounted on scales of sufficient volume to collect all runoff passing the SRD.

For this testing the setup presented concentrated flow to a simulated storm drain inlet located between the mixing and collection tanks. Sediment-laden water was conveyed by pipe and discharged into a fully contained area around the inlet. The simulated inlet includes a retention zone surrounding an installation zone. The installation zone is about 1.5 feet wide and encircles the inlet opening and is comprised of prepared soil subgrade to allow full-scale installation of the SRD to be tested. The discharged sediment-laden water is allowed to run up to and seep through, over, and/or under an installed SRD protecting the simulated inlet. The seepage migrates through the inlet opening and drains into the collection tank.

Preparation of the Installation Zone and Inlet Sediment Trap SRD Installation. The installation zone sandy loam subgrade soil is placed and compacted. Compaction is verified to be 90% (± 3%) of Proctor Standard density using ASTM D2937 (drive cylinder method). The soil is placed in lifts not exceeding 8 inches. Between tests, the top 4 inches (minimum) of soil – which has been saturated by infiltration - are removed, replaced and compacted.

The inlet sediment trap SRD is installed in the installation zone which is comprised of the same soil used as sediment test soil. The soil depth is in excess of the depth of SRD installation and compacted to 90±3% of Standard Proctor maximum dry density, at a soil moisture within ±3% of optimum moisture content per ASTM D-698. The SRD length exposed to flow depends on whether an unpaved or paved application is being evaluated. In unpaved applications, the SRD completely surrounds the inlet opening. In paved applications, the SRD extends the full width of the retention zone (approx. 8 ft) along one side of the inlet opening. Because special effort is needed to seal where the SRD meets the wall, only about 7 ft of SRD is exposed to runoff.

Each inlet sediment trap was installed as directed by the GSWCC. Pictures of each installed inlet sediment trap SRD are shown in Figures 4 thru 9. Figures 4, 5, 8 and 9 are unpaved area applications, and Figures 6 and 7 are paved road applications.

Figure 4. Block and Stone

Figure 5. Stone and Wire Mesh backing

Figure 6. Geotextile-wrapped Blocks
(Pigs-In-A-Blanket)

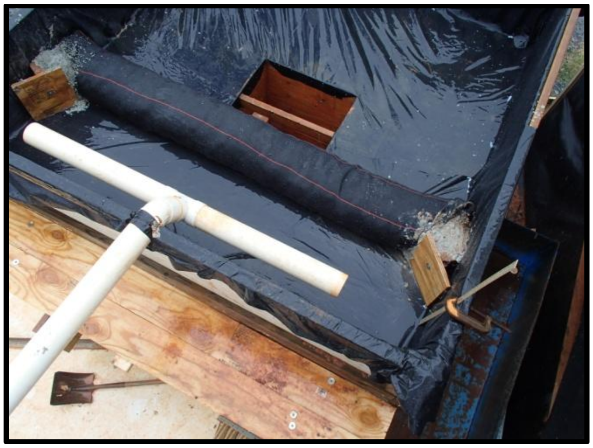


Figure 7. Geotextile-wrapped #57 Stone

Specific Test Procedure. After the SRD is installed, a sediment-laden runoff is then created by combining water and soil in the mixing tank. Sediment-laden runoff was created by combining water and soil in the mixing tank and agitating during the test. 1814 kg of water and either 109 kg (dry weight) or 22 kg (dry weight) of sandy clay soil were combined to create the sediment-laden runoff of either 6% (60000 mg/L) or 1.2% (12000 mg/L), respectively. This amount of water and sediment simulates runoff from a slope presenting the following "default" scenario:

- With and without an upstream toe-of-slope SRD in place;
- A 2-yr, 24-hr storm event (mid-Atlantic region of US) equal to a 100 mm rainfall;
- Approximately 25% of the storm would occur during the peak 30 minutes;
- 50% of the rainfall would infiltrate into the ground;
- A theoretical contributory area of 30 m slope length by 4.9 m wide;

Runoff and associated sediment were calculated using the Modified Universal Soil Loss Equation (MUSLE) as shown in D7351 which allows for calculating storm-specific quantities.

Agitation is maintained and discharge is released evenly for 30 minutes. The quantity of released runoff is measured at 5-minute intervals by noting the reduction in weight in the mixing tank, adjusting the valve on the tank outlet to increase/decrease flow to stay as close as possible to the target (1923 kg / 30 min = 64 kg / min). For this testing, the discharge flow is introduced to allow it to flow up to and around the SRD. Retention observations, ponding depths, and associated times are recorded during the test. Figure 9 shows a typical test in progress.

Figure 8. Silt Fence on Support Posts with Welded Wire Fencing (WWF)

Figure 9. Introduction of Initial Runoff

As runoff passing the SRD system is collected, the weight and volume of the collection tank is recorded and grab samples are taken at 5 minute intervals, providing a "time history" of filtration during the test. Cutoff time is the earlier of 90 minutes or when there is low-volume ponding and minimal seepage through the SRD. Grab samples are evaluated in a lab to determine turbidity using a Hach 2100 AN Turbidimeter and to determine percent dry solids content. Drying of collected sediments is accomplished in a forced air oven at 110°C for a minimum of 24 hours or until all moisture is driven off, whichever is greater. All weighing of sediments is done with laboratory scales accurate to ± 0.01 grams.

Test Results. Figure 10 summarizes the results of the GSWCC testing (Note: BMP is synonymous with SRD). The test results appear to establish appropriate baseline performance characteristics for standard SRDs used in either unpaved (deployed around the inlet) or paved (deployed along one side of the inlet) applications. Further, the results suggest that the test method effectively differentiates between SRDs that provide maximum sediment retention and those providing maximum seepage. This may facilitate separate application-specific specifications for SRD systems. Finally, results at both sediment concentrations were very similar in most cases, thus, as the lower concentration is more consistent with inlet flows downstream of toe-of-slope sediment barriers, testing only with the 12000 mg/L sediment concentration is appropriate to properly characterize inlet protection SRDs.

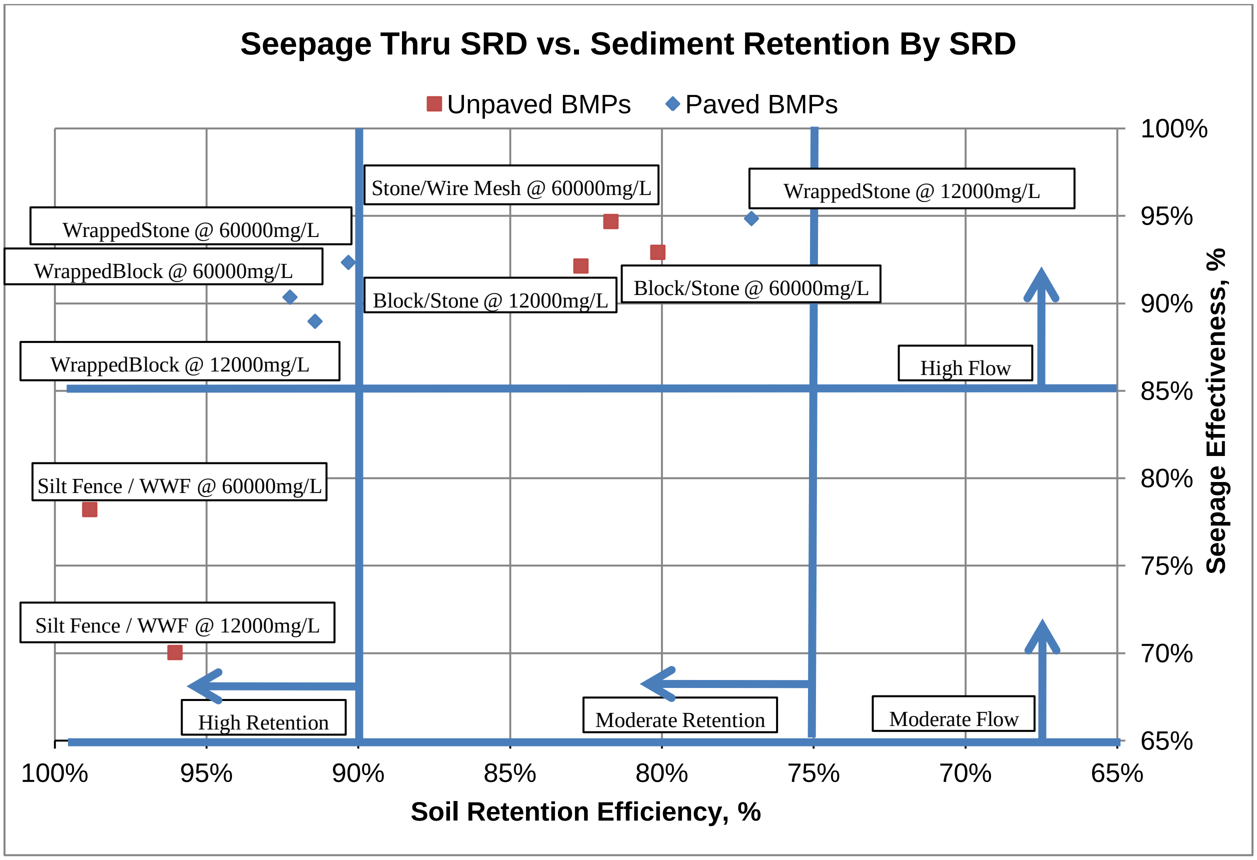


Figure 10. Summary of SRD Test Results

INLET PROTECTION SRD PERFOMANCE TESTING – NTPEP

Following the use of Method D7351-modified for inlet protection by the Georgia Soil and Water Conservation Commission, the National Transportation Product Evaluation Program (NTPEP) in the US added the procedure to their Work Plan for Erosion Control Product and Sediment Retention Devices. To-date, two product manufacturers (4 products) have been evaluated under this program which provides centralized product evaluations for member state DOTs. All of the products evaluated are inlet filter bags. They are inserted inside the stormwater manhole, underneath the cover grating and collect sediment from runoff as it drops into the manhole. Figures 11 and 12 show typical testing, and Table 1 presents the test results.

Figure 11. Inlet Filter Bag Testing

Figure 12. Inlet Filter Bag Close-up

SRD	Soil Retention Effectiveness %	Water Retention Effectiveness %	Seepage Effectiveness %
Inlet Bag 1	80.17	6.77	93.23
Inlet Bag 2	57.14	3.71	96.29
Inlet Bag 3	91.92	4.57	95.43
Inlet Bag 4	65.96	3.48	96.52

Table 1. Typical Inlet Filter Bag Test Results

CONCLUSIONS

This paper has presented standard (and proposed standard) testing procedures that are available to assist the users of SRDs in establishing improved construction specifications that will guide owners and contractors to install the correct SRD for the expected site conditions.   Additionally, product manufacturers can use these test methods for confidently establishing relevant product capabilities.

REFERENCES

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