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SUSTAINABLE TECHNOLOGIES

TechLink Research Summary #3311

Design Height, Flow Through Rate and Slope Spacing of Filtrexx® SiltSoxx™ and Silt Fence

Design for slope spacing between runoff control, slope interruption, or sediment control devices is dependant on three broad parameters: site and soil characteristics (e.g. slope angle, surface roughness, initial abstraction/water absorption, cover or erosion control practice), rainfall characteristics (designated storm intensity and duration or total rainfall and duration for a specified return period, e.g. 24 hr 25 yr return), and control device characteristics (flow through rate or flow restriction, and design or effective height) - assuming that sediment and/or pollutant removal efficiency of the device is effective and acceptable. The maximum slope spacing between control devices is determined by the point at which overtopping of runoff occurs from a given watershed area under a given rain storm (e.g. a predetermined or standard set of soil, site, and rainfall characteristics), as the sediment control function is no longer at an optimum performance level.

To determine maximum slope length (or maximum spacing between control devices) once soil, site, and rainfall characteristics are known (i.e. environmental conditions are constant), the two variables become the height of the design tool and the runoff flow through rate of the control device, assuming sediment removal rates are similar - greater sediment removal rates which result in greater sediment accumulation behind the device, ultimately reduces the effective height of the control device, which will then cause runoff to overtop the device more quickly.
Design and Effective Height

Design height of silt fence and Filtrexx® SiltSoxx™ is different from the effective height used to control runoff and sediment once installed and subject to field conditions. While silt fence is available in 18, 24, 30, and 36 in design heights, the amount of fabric trenched into the ground is generally 8 (GA SWCC, G DOT, KY EP&SC, VA DCR) to 12 in (Iowa SUDAS, Iowa DNR, MN DOT, OH DOT, SC DOT, NC DENR), and once a constant head of water pressure (from surface runoff) is applied to the silt fence it sags between an average of 3 in (24 in silt fence) and 6 in (36 in silt fence) (Keener et al, 2006). Wire or fence reinforced silt fence only sags about 3 in (for 36 in silt fence). Therefore the effective height of a 24 in silt fence is 13 in; the effective height of a 36 in silt fence is 18 to 22 in; and the effective height of wire reinforced silt fence is 21 to 25 in.

Filtrexx® SiltSoxx™ is available in 8, 12, 18, 24, and 32 in design diameters and once installed and a constant head of water pressure is applied (from surface runoff) they sag (or bow) between 1 in (8 in) and 5 in (24 in). Therefore the effective height of a 12 in sock is 10 in and an 18 in sock is 15 in.

<u>Flow Through Rate of Silt Fence</u>

Flow through rate for silt fence has been reported between 0.3 gal/ft2/min to 100 gal/ft2/min. The USEPA (2005), Virginia Highway and Transportation Research Council (VHTRC) and Virginia E&SC Field Manual (VDCR, 1995) and a study by Wyant (1981), used to create ASTM D-5141 Standard Test Method for Determining Filtering Efficiency and Flow Rate of a Geotextile for Silt Fence Application Using Site Specific Soil, all report a flow through rate of 0.3 gal/ft2/min using sediment laden water (2890 mg L-1) & 10 gal/ft2/min using clean water with no sediment concentration.

ASTM D-5141 uses a 12 in silt fence, a 12:1 slope, runoff sediment concentration of 2890 mg L-1, 50 liters of total runoff volume, in boxes 48 in long (slope length) by 34 in wide (length of filter), and the silt fence is pre-wet using 50 L of clean water.

The Minnesota DOT (2000) reports a flow through rate for silt fence at 100 gal/ft2/min and use ASTM D-4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity. This standard test method uses a 2 in diameter cut section of filter fabric placed at the base of a vertical column. The rate in which 50 mL of clear water (no sediment) flows vertically through the column (and fabric) is determined, and mathematically corrected to represent one square foot of silt fence filter fabric. This test method and the one below (GDT-87) report the flow of water per area of filter fabric (ft2) NOT per area of land (ft2). ASTM D-4491 should not be used to estimate flow through rates under field conditions and therefore should not be used in design spacing specifications.

The Georgia DOT (G DOT, 2006) and Georgia Erosion and Sediment Control Manual (GA SWCC, 2000) report flow through rates for silt fence at 25 gal/ft2/min for Class A and B silt fence and 70 gal/ft2/min for Class C, although the openings in the filter fabric are the same (determined by AOS - apparent opening size ASTM D-4751). The G DOT uses its own test method, GDT-87 (G DOT, 2006), for determining the flow through rate of silt fence. It is nearly the same as ASTM D-4491 except it uses a 4 in diameter cut section of silt fence. To calculate flow through rate GDT-87 uses the formula,

Q = 983/T
Where: Q = flow through rate, T = seconds to drain 50 mL

<u>Flow Through Rate of Filtrexx® SiltSoxx™</u>
Standard test methods for determining flow through rates and the values reported for flow through rates for silt fence are extremely variable. Because of this variability and because the standard test methods were developed specifically for geotextile filter fabric it is more beneficial to evaluate flow through rates for Filtrexx® Sediment control (or any sediment control device) in a side-by-side comparison with silt fence, under the same set of test conditions - until a new standard test method is developed to accommodate all runoff and sediment control devices. Without a standard test method that can accommodate tubular devices and silt fence it is impossible to compare and evaluate these devices except under a side-by-side experiment (preferably conducted by a non-biased third party, using multiple replicates and an experimental design and method easily replicable for others). Additionally, it is important to test these control devices, 1) using sediment-laden runoff conditions that represent real field conditions - as this effects flow through the filter especially over time, 2) with horizontal runoff flows (not vertical) applied to the effective length (not area) of a control device. This is important because the pressure created from horizontal flow on a device is different from vertical flow, and horizontal flow rarely makes contact with the entire surface area of the control device, as it is usually concentrated (not dissipated) to a specific area. Research results conducted by the USDA ARS and The Ohio State University using these criteria are discussed below.

Table 1: Time to overflow at three flow rates* for silt fence and Filtrexx® SiltSoxx™

	Flow Rate		
Sediment Control Device	**1 gpm/linear ft**	**5 gpm/linear ft**	**7.5 gpm/linear ft**
36 in silt fence	6.5 hrs	2 hrs	45 min
30 in silt fence	5 hrs	1.5 hrs	30 min
24 in silt fence	3.5 hrs	1 hr	20 min
18 in Filtrexx® SiltSoxx™	11.5 hrs	4 hrs	1 hr
12 in Filtrexx® SiltSoxx™	7.5 hrs	2.5 hrs	30 min
8 in Filtrexx® SiltSoxx™	5 hrs	1.5 hrs	10 min

** Sheet flow runoff with 10,000 mg L-1 of suspended solids consisting only of silt and clay.*

The USDA Agricultural Research Service (Sadeghi et al, 2006) has reported that flow through rates for Filtrexx® Sediment control is 50% greater than silt fence. The USDA ARS test method uses a 5:1 slope, an 8 in Filtrexx® Sediment control, a 24 in silt fence, a simulated rainfall intensity and duration of 3 in/hr for 30 min - which produces a runoff sediment concentration of 100,000 mg L-1 of silt loam, in soil boxes 44 in long (slope length) by 14 in wide (length of filter). Soil is compacted and pre-wet prior to rainfall.

The Ohio State University (Keener et al, 2006) test method uses 17% and 37% slopes, runoff flow rates of 1.5, 2, 2.5, and 7.5 gal/linear ft/min, and runoff sediment concentration of 10,000 mg L-1 of only clay and silt, in flumes 8 ft long by 2 ft wide.

The Ohio State University has also reported that flow through rates for Filtrexx® Sediment control is 50% greater, relative to silt fence, and ponding depth behind the silt fence can be as much as 75% greater. At an actual flow rate of 7.5 gal/linear ft/min a 24 in silt fence overtopped after 20 min, while a 12 in Filtrexx® Sediment control did not overtop until 30 min (see Table 1). However, if sediment was excluded from the runoff (i.e. clean water), flow through rates for the silt fence were 25% greater than the Filtrexx® Sediment control; which shows that to determine representative flow through rates sediment must be added to the runoff or results can be extremely inaccurate (if the purpose is to simulate or predict field conditions). Accurate flow-through results are critical in determining slope spacing/length for sediment and runoff control devices.

Because flow through rates using runoff with sediment reduce overtime as sediment begins to accumulate behind (or inside) the filter (restricting flow), determining slope length and distance between control devices must accommodate for this real world fact - flow through rates are not constant nor do they reach a steady state (whereas with clean water a constant steady state can be achieved). To account for sediment accumulation and its affect on flow restriction over time the following formula was developed by engineers at The Ohio State University to model ponding depth behind a sediment/runoff control device.

$df = A(qf)t + B(qf)$

Where:
df = pond depth (in)
qf = sediment-laden flow rate (gal/linear ft/min)
t = time (min)
A(qf) = rate of increase in depth as a function of runoff flow rate (sediment-laden) and suspended solids concentration of runoff (in/min)
B(qf) = initial pond depth behind filter before sediment clogging occurs (in)

Based on results from the research at The Ohio State University and this formula the following calculations were developed to estimate time to overflow a silt fence and a SiltSoxx™.

Silt Fence: $t = df - (1.1932qf + 1.2993)/0.0132\, qf + 0.029$

Filtrexx® Sediment control: $t = df - (0.8282\exp 0.2564qf)/0.014\exp 0.3132qf$

Slope Length and Control Device Spacing

Spacing between control devices and/or the maximum allowable slope for a particular control device is generally determined based on design height (although it should be based on effective height) and the accurate flow through rate of the device. Because reported flow through rates of silt fence are widely variable (0.3 to 100 gal/ft2/min), allowable slope length and device spacing specifications in state erosion and sediment control (E&SC) manuals vary widely. Table 2 compares slope spacing specifications from selected state E&SC manuals.

Table 2: Spacing length (ft) specifications on slopes for 36 in silt fence in selected E&SC manuals*

Slope %	Iowa DNR	GA SWCC	G DOT	Iowa SUDAS	KY TC	Penn DOT / PA DEP**	USEPA/ VADCR	OH DOT/ OH EPA	SC DOT	NC DENR
<2	150	100	100	100	ND	1000	1000	220	100	100
2 to 5	ND***	75	50	100	ND	500	ND	110	100	75
5 to 10	100	50	50	100	125-200	300	ND	110	100	50
10 to 20	60	25	50	60	125-200	250	ND	110	100	25
25	50	15	50	50	100-150	150	ND	55	100	15
33	40	15	50	40	ND	90	ND	55	100	15
50	ND	15	50	ND	75-125	50	ND	55	100	15
>50	ND	15	50	ND	50-100	ND	ND	ND	100	15

** Iowa DOT - Iowa Department of Natural Resources/Construction Site Erosion Control Manual; GA SWCC - Manual for Erosion and Sediment Control in Georgia/Georgia Soil and Water Conservation Commission; G DOT - Georgia Department of Transportation; Iowa SUDAS - Iowa Statewide Urban Design and Specifications Manual; KY TC - Erosion Prevention and Sediment Control Field Guide/Kentucky Transportation Cabinet; Penn DOT/PA DEP - Pennsylvania Department of Transportation & PA Department of Environmental Protection E&SPC Manual; USEPA - United Sates Environmental Protection Agency/VADCR - Virginal Erosion and Sediment Control Field Manual/Virginia Department of Conservation; OH DOT/OH EPA - Ohio Department of Transportation/Ohio Environmental Protection Agency; SC DOT - South Carolina Department of Transportation, NC DENR - North Carolina Department of Environment and Natural Resources. ** Silt fence with wire reinforcement. ***ND - No data available.*

Design Tool Created by The Ohio State University

An MS Excel™ based interactive design prediction model was created by engineers at The Ohio State University so designers determining runoff/sediment control device spacing on slopes can easily determine this based on real site and rainfall conditions. The design tool allows the user to choose the appropriate design height/diameter control device and to compare the performance of each effective height/diameter for silt fence and Filtrexx® Sediment control. Site and rainfall input parameters that the user can manipulate include: total rainfall (in)/duration (hrs), rainfall intensity (in/hr)/duration (hr), area of watershed (ac) or slope width (ft) and length (ft), percent slope, potential runoff reduction (%) for soil/vegetation/erosion control/management practices, effective length of filter used to drain watershed area, diameter of Filtrexx® Sediment control, and height of silt fence. The output tells the user whether the silt fence and/or Filtrexx® Sediment control will fail based on the input parameters and how long (hrs) it took or will take for each control device to overflow. The design tool was built based on the flume research, ponding formula, and calculations described above for silt fence and Filtrexx® Sediment control, coupled with equations for site and rainfall/runoff characteristics described below in Figure 1. A copy of the design tool created by The Ohio State University can be obtained from Filtrexx International.

The equations for runoff are:

$Q = [I\ W\ L \cos(s)\ 7.48 / (60 * 12)] = 0.01039\ I\ W\ L \cos(s)$

$Q = 0.01039\ I\ W\ L \cos(s)$

$qf = Q/W$

where:

Qf = flow rate to filter, gpm

I = rainfall intensity, in/hr

W = width, i.e. length of filter, feet

L = length of slope, feet

s = angle of slope, degrees

df = depth of water at the filter measured to slope, inches

qf = flow rate to filter, gpm/f

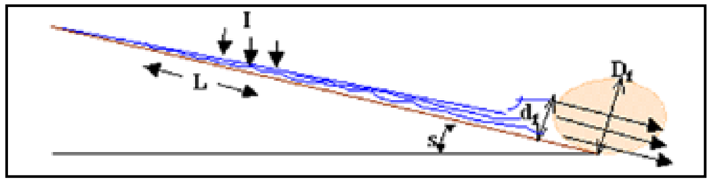

Figure 1. Diagram representation of control structure in operation and listing of variables used to calculate water runoff rates from a slope.

Conclusion

Filtrexx has provided adequate data to show that responsible and effective design criteria are available for the use of our products in situations where we specify them. In addition, we have shown that there are several reasonable questions about existing responsible and effective design criteria from currently accepted tools like silt fence. We simply ask that the specifications for Filtrexx product uses are adopted in full, without alteration, unless a). More research about similar products (tubes, socks) has been conducted to show that our results are invalid or b). Calculations prove this research presented is inaccurate.

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