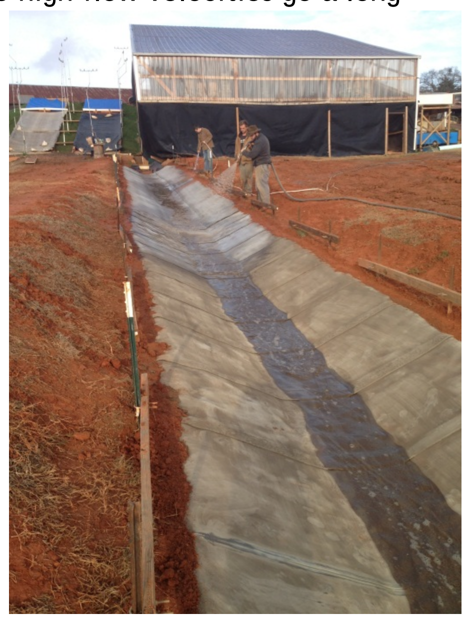
Milliken®
Concrete Cloth™

Technical Note
Hydraulic Flow Capacity of Concrete Cloth

Introduction:

Stormwater flow in drainage channel and flume applications may be subjected to high velocity water conditions generating high shear forces on the side slopes. These applications are designed with properties assigning roughness of the channel side slopes and bottom (Manning's "n" roughness coefficient). The power of flowing water cannot be denied, and materials used in these applications require the designer to have confidence in the parameters so that the proper installation details can be selected to assure a successful project.

Many applications are subjected to high velocity flows that can erode the unprotected channel side slopes. Experience with installations subjected to high flow velocities go a long way towards confidence in the ability of Concrete Cloth to survive those conditions and perform acceptably.



Channel design calculations require an estimate of the Manning's roughness coefficient, "n". To convey a given volume of water, rougher channel surfaces may require a larger cross-section than smooth surfaces. Conversely underestimating the roughness coefficient may result in under-sizing of a channel. As the Manning equation is used for these calculations, the coefficient "n" is important.

Milliken's Concrete Cloth has been used for erosion protection in drainage swales and ditches across the world. Its ease of use and speed of construction makes it an ideal material for this protection function. To determine Concrete Cloth's capabilities when used in these applications two series of hydraulic flume tests were conducted in January 2012, and again in January 2013. The 2012 tests were designed to ascertain the behavior of Concrete Cloth in a lined channel subject to high flow velocities and shear forces. The 2013 results were targeted at determination of Manning's "n" in a trapezoidal channel. Results of these test programs will be discussed here.

This technical note summarizes the results of this flume testing and presents experiences when subjected to high flow conditions. Guidance is provided in the selection of the appropriate "n" value for Concrete Cloth in open channel designs.

The Manning Equation

Water flowing in an open channel typically gains energy as it flows from a higher to lower elevation. This flow loses energy because of friction within the conveyance structure and when obstructions are present. Uniform flow occurs when the gravitational forces that are pushing the flow along the channel are in balance with frictional forces exerted by the wetted perimeter that are retarding the flow. The most commonly used resistance equation is Manning's equation as shown below.

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$$V = \frac{1.486 * R^{2/3} * S^{1/2}}{n}$$

Where:
- V = Mean velocity
- n = Manning's roughness coefficient
- R = Hydraulic radius
- S = Slope

The roughness coefficient "n" reflects the resistance to flow along the side slopes and bottom of the wetted area. Selection of a value for "n" can be used to estimate the resistance to flow in a given channel, which is really a matter of intangibles (Chow, 1959).

This value can be estimated in several ways including: (USDA 2007)

1. Consult a table of typical n values for channels of various types
2. Examine and become acquainted with appearance of some typical channels where those roughness coefficients are known,
3. Perform actual testing simulating channel flow conditions and back calculate the coefficient.

Typical values of Manning's n are listed below:

Description	Minimum	Normal	Maximum
Earth		0.020	
Concrete - finished	0.011	0.012	0.014
Steel, riveted & welded	0.013	0.016	0.017
Rubble masonry, cemented	0.018	0.025	0.030

Table 1 – Typical values of Manning's "n" (Chow 1957)

UNIFORM FLOW IN OPEN CHANNELS

Chow states that for uniform flow to exist:

- Mean velocity is constant from section to section
- Depth of flow is constant from section to section
- Area of flow is constant from section to section.

Thus to derive Manning's "n" from channel testing these conditions should exist. In January 2013 testing was conducted in a trapezoidal channel under modest slope conditions and water flow volumes. Considering the length and velocities encountered during the January 2013 large scale TRI testing, these test results approximate these three conditions. The consistency in "n" calculated from the testing is encouraging.

MILLIKEN CONCRETE CLOTH TESTING SUBJECTED TO HIGH VELOCITY

In January 2012 Concrete Cloth was subjected to hydraulic flow testing at the TRI's Denver Downs Research Facility outside of Clemson, SC. This testing was performed in accordance with ASTM D6460 "Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater Induced Erosion". Originally developed for soil loss assessment of turf reinforcement mats, this procedure allowed for the application of water velocities over a rectangular channel lined with Concrete Cloth. The channel was 40 ft long, and at a 20 percent slope.

CC-TRI FLUME TESTING SIDE VIEW

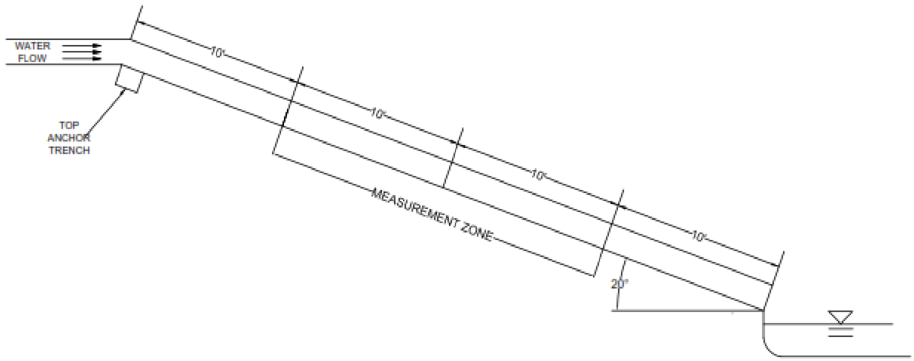

Figure 1 – Cross section depicting flume testing profile for flume testing (TRI 2012 Report)
Two parallel channels were tested and Concrete Cloth installed with seams longitudinally down the channel, and transverse to the centerline. Varying overlap and seaming connections were installed as follows:

- Gravity overlap,
- Screwed overlap
- Screwed and adhesively bonded overlap
- Finally, a patch was installed near the end of the flume to assess capacity of a patched installation.

These conditions were to assess the capability of alternative lapping procedures in high velocity conditions.

Results revealed that under flow velocities as high as 28 ft per second with shear forces as high as 12 psf there was no movement of any of the concrete cloth. All overlaps showed no distress from testing.

Photo 1: Channel 1 before testing

Photo 2: Channel 1 during high flow conditions

Table 1 – 20 % slope flume test results (TRI - 2012)

Channel #	Description	Maximum velocity	Maximum bed shear Stress	Observations
#1	Transverse seams: • Gravity • Screwed • Screwed and glued	28.3 ft/sec	12 psf	No observable seam movements.
#2	Longitudinal seams: • Gravity • Screwed • Screwed and glued • Patch	27.3 ft/sec	11.78 psf	No observable seam movements. Patch area held.

TESTING FOR MANNING'S "n"

In 2013 this test facility was revisited and a trapezoidal channel was constructed strictly to determine Manning's "n" under controlled flow conditions. Photos 3 and 4 show a view of this channel. Manning's equation defines the hydraulic radius, R_1 for trapezoidal channels as the channel area divided by the wetted perimeter. This channel length was divided into two sections, one with transverse laps, the other longitudinal seams. A comparison follows of the two sections of this installation using assumptions of a trapezoidal channel 2 ft wide at the base, at a 5% slope. Testing was performed at 4 increasing flow depths with velocity and depth measured.

Photo 3: Longitudinal seam installation

Photo 4: Transverse seam configuration

Table 2 – Results for trapezoidal channel flow testing (TRI 2013)

Channel section	Description	Average water depth	Manning's "n" coefficient	Summary
Upper 40 ft.	2-ft wide bottom x 2:1 side slopes (Trapezoidal) x 40-ft long; 5% bed slope • Longitudinal seams	0.12 0.17 0.25 0.31	0.010 0.011 0.012 0.012	Overall Average Manning's *n* 0.011
Lower 40 ft.	2-ft wide bottom x 2:1 side slopes (Trapezoidal) x 40-ft long; 5% bed slope • Transverse seams	0.12 0.17 0.22 0.29	0.010 0.011 0.011 0.012	Overall Average Manning's *n* 0.011

DISCUSSION

- Concrete Cloth was tested under the maximum flow conditions possible at the TRI Denver Downs hydraulic testing facility in 2012. It was subjected to high velocities to assess its performance under these flow conditions. The product performed well, showing no adverse effects or movement even when subjected to velocities greater than 25 fps and shear stresses of 12psf.
- Determination of Manning's "n" from the 2013 testing was achieved under controlled flow conditions and is believed to be representative of this product for smooth installations.
- Calculated results from this testing appear to be consistent with published values when compared with published values for concrete and even corrugated steel culvert Manning's "n" values.

References:

1. Ven Te Chow "Open Channel Hydraulics", 1959 - McGraw Hill Book Company
2. USDA Department of Agriculture, "Stream Restoration Design Handbook", Chapter 6, August 2007
3. TRI Report on Concrete Cloth testing at the TRI Denver Downs facility in Clemson, SC January 2012
4. TRI Report on Concrete Cloth testing at the TRI Denver Downs facility in Clemson, SC January 2013

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