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Testing and Specifying Rolled Erosion Control Products

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ABSTRACT
Sediment continues to be a major pollutant of public water resources even though erosion control best management practices, BMPs, are now commonly used. In order to help protect water quality as it relates to sediments, regulatory agencies and site designers are increasingly asking how well specific BMPs will perform quantitatively relative to alternatives. While a large amount of information on erosion control products (ECPs) has been available for quite some time, the information has too often been non-standard, out-of-date, insufficient, or unable to be compared to alternative products, making it difficult for users to create generic construction specifications or qualified product listings of comparable products.

Standardized test procedures have been recognized as the means to develop comparable product data. Thus, a two decade effort by industry professionals has produced recognized tests for measuring relevant material properties as well as performance capabilities of ECPs – with most effort focused on rolled erosion control products (RECPs).
This paper discusses the details of these now commonly used standardized index, bench-scale, and large-scale tests for RECPs, along with a review of data from hundreds of independent tests performed on a range of RECPs under the auspices of the National Transportation Product Evaluation Program (NTPEP). Along with an assessment of the relevance and correlation of the various tests, recommendations will be made on the appropriate use of these test results in specifications for RECPs.

1.0 MANUFACTURED EROSION CONTROL PRODUCTS AND ASSOCIATED TESTING

1.1 Manufactured Erosion Control Product Types

While conventional erosion control materials ranging from loose straw to rock riprap continue to be used extensively, new developments in erosion control systems are being used, including the following types of rolled erosion control products (RECPs):

- Temporary RECPs - For applications where natural vegetation alone will provide sufficient permanent erosion protection.
  - Open Weave Textile (OWT). OWTs are a degradable product composed of processed natural or polymer yarns woven into a matrix. The most common of these are comprised of jute or coir.
  - Erosion Control Blanket (ECB). ECBs are composed of processed natural or polymer fibers mechanically, structurally or chemically bound together to form a continuous matrix.

- Permanent RECPs - For applications where natural vegetation alone will not sustain expected flow conditions and/or provide sufficient long-term erosion protection.
  - A turf reinforcement mat (TRM) is a permanent RECP composed of non-degradable synthetic fibers, filaments, nets, wire mesh and/or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness.

1.2 Quality Control, Quality Assurance and Performance Testing of RECPs

Basic index tests are typically needed to assure manufacturing quality control of RECPs. Not only are these tests useful for manufacturing quality control, but when used on the same materials deployed in bench-scale and large-scale performance tests, they serve to "bench-mark" the performance results to specific material properties. A variety of performance tests have been developed over the years to answer designers' and specifiers' questions regarding performance among different products and product categories.

Since 2003, the National Transportation Product Evaluation Program (NTPEP) has provided a program for independent testing of RECPs. The program has included both index tests and bench-scale "indexed performance" tests. The goal of the program is to minimize duplicative testing of erosion control products done by individual State Departments of

Transportation (DOTs) by providing a process where manufacturers and suppliers submit their products to the NTPEP for independent index and bench-scale testing. The results of the testing are then shared with participating DOTs. The results of the testing may be used for assessing product conformance to material specifications. Further, the testing results provide quantitative material data necessary for placing specific products on, or removing specific products from a DOT's qualified products list (QPL). The NTPEP program is intended to serve as a nationwide quality assurance (QA) program for the DOTs.

Additionally, in 2009, NTPEP began offering independently verified large-scale performance testing to complement on-going index and bench-scale testing. NTPEP (2011) describes the purpose and rationale for exclusive use of standardized test procedures in the programs.

1.2.1 Index Testing

Index tests are standard tests that may be used for manufacturing quality control and to compare the relative material properties of several different RECPs. Quality Control tests are index tests which are performed on a production basis to evaluate product integrity, quality and continuity, and to assess the impact of changes in production methodology on product properties. Quality control test results can be reported with statistical relevance when they are run with sufficient frequency. Recently, ASTM D4354, "Standard Practice for Sampling of Geosynthetics for Testing", has been revised to include appropriate sampling frequencies to achieve a 95% confidence level for RECP quality control, quality assurance, and conformance testing. Following are the index test methods used for RECPs:

Mass per Unit Area**:** ASTM D 6475, "Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets"**;** ASTM D 6566, "Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats"**.** The mass per unit area, also known as the "weight" per square yard of a sample, is an important quality control property. The ECB test uses ten 8"x8" specimens at ambient laboratory conditions. The TRM test uses five larger, typically 12"x14", specimens that have been dried at 50° overnight.

Thickness**:** ASTM D 6525, "Standard Test Method for Measuring Nominal Thickness of Permanent Rolled Erosion Control Products"**.** Thickness is another important quality control property which is measured after application of a 6-inch diameter presser foot under a 0.029 psi pressure.

Tensile Strength**:** ASTM D 6818, "Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats"**.** The ASTM tensile test method for RECPs uses at least 5 inch-wide grips.

Light Penetration: ASTM D 6567, "Standard Test Method for Measuring the Light Penetration of a Turf Reinforcement Mat (TRM)". Within a light box, a calibrated meter measures the amount of light that is able to pass through the specimen from a 150 watt light source on the other side of the specimen. The inverse of the percent of light passing through the specimen is termed the "% cover".

Water Absorption: ASTM D 1117 Section 5.4 and ECTC-TASC 00197, "Standard Guide for Evaluating Nonwoven Fabrics – Absorptive Capacity Test (for Larger Test Specimens)". Water absorption is a measure of a material's capacity to absorb water and is generally applicable to organic RECPs.

Specific Gravity: ASTM D 792, Method A, "Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement". Specific gravity is the ratio of the unit weight of a material to that of water.

1.2.2 Bench-Scale Testing

Bench-scale "indexed" performance tests are a class of tests that have been developed to focus on testing the RECP/soil system under carefully controlled "standard" conditions. Bench-scale tests have been developed for slope erosion, channel erosion, and vegetation enhancement for RECPs. Variations in the mass per unit area, raw materials, manufacturing processes, and other product and production components are a constant challenge to manufacturers of RECPs. Since performance of RECPs relies on the complex interaction of the RECP structure with the soil and the water impact/flow, it is helpful and beneficial to a quality assurance program to be able to examine the effects of product variability without having to rerun large-scale tests. Bench-scale testing facilitates lower costs and quicker testing for evaluating product conformance. However, it is critical to emphasize that bench-scale testing is not appropriate for use in design models unless correlated to large-scale testing. Bench-scale tests do not reflect product installation techniques or site conditions to which these materials are typically subjected. Therefore the results of these tests may not be indicative of a RECPs actual field performance.

*Slope Erosion and Runoff Reduction**:** ASTM D 7101, "Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff under Bench-*

Scale Conditions". This test method evaluates the ability of RECPs to protect soil from rain splash and immediate runoff-induced erosion. The critical element of this protection is the ability of the RECP to absorb the impact force of raindrops, thereby reducing soil particle loosening through "splash" mechanisms. The test method utilizes containers of both bare and RECP-protected soil that are exposed to simulated rainfall and immediate runoff for 30 minutes in the test apparatus. It is a sloped table enclosed by a curtain. Rainfall is simulated using a laboratory drip-type simulator capable of creating uniform drops with a median diameter of 3.0 to 3.5 mm from a drop height of 2.0±0.1 m and producing rainfall intensities as high as 150 mm/hr. The amount of soil that splashes or is washed out of the containers is collected and weighed. From this data, an appropriate soil loss ratio (SLR) can be calculated by comparing the RECP-protected soil loss to the control. The inverse of the SLR is comparable to the C-factor which is more commonly used to relate to performance, but should not be used as a true measure of performance without verification from large-scale testing.

Permissible Shear and Channel Erosion: ASTM D 7207, "Standard Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Sand from Hydraulically-Induced Shear Stresses under Bench-Scale Conditions". This test method evaluates the ability of RECPs to protect soils from flow-induced erosion. The test method utilizes containers of RECP-protected soil that are immersed in water and subjected to shear stresses caused by the rotation of a three-blade impeller for 30 minutes in the test apparatus. The shear stress test apparatus includes a tank, test well, motor, plastic lid, and impeller. The three-blade impeller is mounted in the cylindrical tank so that the lower edge of the blades is slightly above the floor of the tank. The sample test well is a recession in the floor of the tank that holds the pots of soil prepared for testing. When the pots are placed in the well, the test surface is flush with the floor of the tank. Pots holding soil and test specimens are normally 200 mm diameter plastic pipe sections with height of 100 mm. The amount of soil that erodes is found by weighing the containers under water. The results of the testing include the amount of soil lost at various shear stresses. From this data, an appropriate permissible shear can be calculated by assuming a critical amount of soil loss, typically 13 mm (1/2-inch). The index limiting shear stress value obtained is comparable to the "permissible shear stress" commonly used to relate to performance, but should not be used as a true measure of performance without verification from large-scale testing.

Germination/Vegetation Growth: ASTM D 7322, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Ability to Encourage Seed Germination and Plant Growth under Bench-Scale Conditions". This test method established procedures for evaluating the ability of RECPs to enhance the rate and quantity of seed germination and facilitate subsequent establishment of vegetation. Containers of soil are sown with a single indexed seed mix and then covered with an RECP. Additional containers are left uncovered as controls. Testing is conducted within a growth chamber where the light, water, and temperature are regulated and documented. The rate of germination is measured periodically throughout the test, and the weight of vegetation is calculated at the conclusion of the test. The testing results include the rate and total weight of germination after 21 days. From this data, a percent enhancement can be calculated by comparing results from the RECP-protected soil to the control.

1.2.3 Large-Scale Testing

Large-scale performance tests have been developed to simulate expected field conditions to report performance properties of "as installed" RECPs. Large-scale tests have been developed for slope erosion and channel erosion. The channel erosion test may be conducted un-vegetated or vegetated. Performance of RECPs relies not only on material properties but also on the installation techniques. Products are installed on the test slope or channel per manufacturer installation recommendations. The results of these tests are more indicative of actual field performance of RECPs and are acceptable for use in design calculations.

Slope Erosion: ASTM D 6459, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion". This large-scale test is conducted on one bare soil control and three replicate RECP-protected soil 3:1 slopes. Rainfall is simulated at target intensities of 2, 4, and 6 inches per hour which are applied in sequence for 20 minutes each. Runoff from each slope is collected and soil loss is measured. From this data, an appropriate soil loss ratio and associated C-factor can be calculated by comparing the RECP-protected soil loss to that of the control.

Channel Erosion: ASTM D 6460, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion". This large-scale test is conducted in a rectangular flume with at least four sequential increasing flows applied for 30 minutes each. Unvegetated RECP-protected soil is tested on a 10% slope flume. Vegetated RECP-protected soil is tested on a 20% slope flume. The limiting or permissible shear stress is defined as the shear stress necessary to cause an average of 0.5 inch of soil loss over the entire channel.

2. NTPEP TESTING TO-DATE.

As noted earlier, the NTPEP's nationwide quality assurance program for RECPs began in 2003 and uses three bench-scale "indexed performance" tests; as well as several index tests, including mass per unit area, thickness, tensile strength, percent cover (i.e. inverse of % light penetration), and water absorption (for ECBs) or specific gravity (for TRMs) to provide member DOTs with independent data on the RECPs entered into the program. Sprague and Nelson (2009) reported on the testing and how it is useful in identifying a hierarchy of product types for each performance measurement. Additionally the data can be used by the individual states to identify products that are excessively outside the expected average for a particular product class.

2.1 NTPEP Index and Bench-scale Testing To-Date

As noted earlier, the NTPEP's nationwide quality assurance program for RECPs began in 2003 and uses the index and bench-scale tests discussed above to provide member DOTs with independent data on RECPs entered into the program. Table 1 shows the number and types of the most commonly tested RECPs and the average index and bench-scale test results (and associated standard deviations) for each type of RECP. All the products, except the 2NFF (double net polyfiber matting), are ECBs. The 2NFF is a TRM. None of the few tested OWTs are included.

2.2 NTPEP Large-scale Testing To-Date

Not available until recently, large-scale performance testing information has now been added to the voluminous amount of index and bench-scale data found at www.ntpep.org to better characterize and differentiate between various RECP types. Table 2 shows the results of independent large-scale slope and channel testing done under the NTPEP program and the index property results that "bench-mark" the large-scale results. Also included in Table 2 are the index and bench-scale results for testing from 2009 thru early 2012 – the same years as the large-scale testing results. These are the data that will be reviewed and compared herein.

Table 1. Index and Bench-scale Results for NTPEP Testing 2003-2011+

Product Type**	Number of Products Tested	Mass/Area (osy)	Tensile Str. (lb/in)		Tensile Elongation (%)		Thickness (mils)	% Cover Perm. Shear	Absorption / Sp.Gravity	Channel Permissible Shear, psf	Slope Average SLR*	Average C-Factor*	Germination Improvement, %
			MD	XD	MD	XD							
1NS	59	8.0	9.6	5.6	26.3	24.1	396.7	1.5	426.9	1.5	9.2	0.108	306
	Std Dev	1.7	2.8	3.2	9.1	8.7	468.9	0.3	81.3	0.3	2.2	-	128.8
2NS	67	8.1	14.1	9.7	25.4	25.3	358.4	1.8	410.0	1.8	11.5	0.087	341.6
	Std Dev	1.5	4.1	4.2	9.0	10.4	308.2	0.4	69.4	0.4	5.6	-	132.0
1NX	16	8.8	8.4	5.3	20.8	21.5	353.4	2.1	236.2	2.1	7.2	0.139	381.3
	Std Dev	2.1	1.9	1.8	6.9	11.1	96.3	0.3	40.1	0.3	1.9	-	123.4
2NX	27	12.4	16.6	13.3	23.7	23.7	430.0	2.7	230.9	2.7	11.2	0.089	384.7
	Std Dev	4.1	8.7	11.5	11.6	7.4	120.6	0.6	55.0	0.6	7.1	-	90.7
2NSC	34	9.0	19.1	13.6	21.2	22.8	294.0	2.2	359.5	2.2	15.1	0.066	415.3
	Std Dev	1.8	7.6	9.4	8.8	8.0	63.5	0.3	109.0	0.3	5.4	-	131.4
2NC	37	8.8	24.7	17.8	22.6	27.2	250.4	2.7	242.8	2.7	19.9	0.050	361.8
	Std Dev	2.0	12.9	7.2	11.6	11.2	64.9	0.4	81.5	0.4	18.4	-	120.0
2NFF	40	11.8	33.4	27.5	25.9	29.8	380.4	2.8	0.9	2.8	11.1	0.090	329.4
	Std Dev	3.2	16.2	17.0	5.6	16.4	108.6	0.5	0.018	0.5	15.4	-	114.9

* SLR = soil loss ratio; C-Factor calculated as (1/(average of soil loss ratios at 50, 100, and 150 mm/hr))

Product Type Key:

1NS = single net straw blanket;
2NS = double net straw blanket;
1NX = single net excelsior blanket;
2NX = double net excelsior blanket;
2NSC = double net straw-coconut blanket;
2NC = double net coconut blanket;
2NFF = double net polyfiber matting;

Table 2. Index, Bench-scale, and Large-scale Results for NTPEP Testing 2009-2011+

Product Type	# of Tests	Statistic	Mass/Area (osy)	Tensile Str. (lb/in) MD	Tensile Str. (lb/in) XD	Tensile Elongation (%) MD	Tensile Elongation (%) XD	Thickness (mils)	% Cover	Absorption / Sp. Gravity	Channel Perm. Shear	Slope Avg C-Factor	Germination Improvement, %
1NS Bench-scale	18	AVG	8.6	10.1	4.9	25.2	24.2	308	86.0	418	1.6	0.110	334.7
		STDDEV	1.3	1.4	1.6	6.6	6.0	97	6.3	93	0.2	0.036	103.9
		MIN	7.0	8.1	3.2	10.9	11.1	217	75.3	296	1.2	0.071	186.0
		MAX	12.9	12.9	9.1	36.1	33.1	529	95.9	606	2.1	0.189	565.0
1NS Large-scale	4	AVG	8.1	8.7	3.7	34.5	27.1	430	88.0	391	1.8	0.028	
		STDDEV	0.5	1.9	0.8	4.4	3.0	77	8.6	61	n/a	0.022	
		MIN	7.7	6.7	2.6	28.0	22.7	355	75.6	344	1.8	0.012	
		MAX	8.7	10.3	4.5	37.8	29.1	496	95.6	471	1.8	0.053	
2NS Bench-scale	20	AVG	8.7	15.0	8.8	25.3	25.3	296	86.8	403	2.0	0.089	406.4
		STDDEV	1.3	4.0	3.1	6.8	5.8	81	5.3	60	0.3	0.033	104.7
		MIN	6.9	8.0	4.1	11.2	13.5	221	80.1	288	1.5	0.042	194.0
		MAX	12.3	28.9	17.4	38.0	35.2	548	99.1	523	2.9	0.154	590.0
2NS Large-scale	9	AVG	8.0	11.4	8.1	30.4	28.9	365	80.6	371	2.1	0.020	
		STDDEV	0.8	1.7	2.7	7.2	7.6	41	9.0	88	0.2	0.011	
		MIN	6.2	9.3	3.2	15.9	11.9	319	63.6	218	1.9	0.005	
		MAX	9.2	14.3	12.6	38.3	37.5	410	90.8	445	2.3	0.035	
1NX Bench-scale	4	AVG	9.0	9.3	4.8	21.2	33.0	241	63.4	266	2.1	0.139	419.0
		STDDEV	1.5	1.4	1.7	8.8	12.4	37	1.7	10	0.0	0.044	69.1
		MIN	8.0	7.4	3.2	12.8	15.7	216	61.1	258	2.1	0.113	361.0
		MAX	11.3	10.8	7.3	33.7	45.2	295	65.2	281	2.2	0.205	498.0
1NX Large-scale	1	AVG	8.5	6.7	2.3	28.5	22.9	391	55.1	189		0.039	
		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	
		MIN	8.5	6.7	2.3	28.5	22.9	391	55.1	189		0.039	
		MAX	8.5	6.7	2.3	28.5	22.9	391	55.1	189		0.039	
2NX Bench-scale	6	AVG	12.9	19.3	16.3	24.0	29.7	376	78.7	244	2.8	0.087	356.2
		STDDEV	3.5	11.8	18.5	7.8	4.7	111	7.3	59	0.6	0.034	68.6
		MIN	8.3	9.3	5.4	15.6	23.8	234	65.2	157	1.6	0.066	298.0
		MAX	17.1	42.5	52.8	36.7	36.4	560	87.3	314	3.2	0.159	481.0
2NX Large-scale	2	AVG	8.6	10.6	4.2	32.7	25.1	417	55.7	185	2.2		
		STDDEV	1.6	1.0	0.0	5.0	4.5	22	7.8	6	0.1		
		MIN	7.5	9.9	4.2	29.1	21.9	401	50.1	181	2.1		
		MAX	9.7	11.3	4.2	36.2	28.2	432	61.2	189	2.3		
2NSC Bench-scale	10	AVG	8.5	17.2	11.8	21.7	23.9	255.6	85.7	423.4	2.2	0.071	464.6
		STDDEV	0.9	4.0	3.3	6.9	6.9	43.2	4.2	90.4	0.3	0.017	126.7
		MIN	7.0	11.6	5.7	11.5	12.4	206.0	78.5	271.0	1.5	0.044	321.0
		MAX	9.8	22.1	15.6	31.8	32.0	349.0	93.4	523.0	2.8	0.098	763.0
2NSC Large-scale	4	AVG	8.0	14.0	10.8	31.6	27.8	314	89.8	353	2.1	0.019	
		STDDEV	0.8	2.5	3.2	2.3	3.4	32	3.1	56	0.1	0.018	
		MIN	7.2	10.8	6.3	30.1	24.0	286	86.5	295	2.0	0.006	
		MAX	8.8	16.6	13.5	35.0	32.1	359	92.6	429	2.2	0.031	
2NC Bench-scale	12	AVG	8.9	24.8	17.5	22.2	25.8	235	83.9	295	2.9	0.040	404.4
		STDDEV	2.0	7.1	5.6	8.7	8.6	45	5.1	62	0.3	0.022	139.2
		MIN	7.2	13.1	12.1	11.3	12.9	160	75.2	139	2.4	0.008	111.0
		MAX	14.5	39.8	31.2	40.0	39.5	309	97.0	379	3.5	0.086	583.0
2NC Large-scale	5	AVG	9.8	25.8	16.9	21.5	25.9	264	82.8	274	2.9	0.007	
		STDDEV	1.8	6.0	4.8	6.0	9.3	36	6.1	60	0.9	0.003	
		MIN	7.0	19.2	12.3	11.6	14.5	232	73.7	205	2.3	0.004	
		MAX	11.4	33.9	23.1	26.5	38.5	326	88.3	356	3.6	0.010	
2NFF Bench-scale	15	AVG	11.8	37.2	29.4	28.7	28.2	345	74.5	0.9	2.8	0.125	317.8
		STDDEV	2.9	23.4	25.2	4.1	7.4	78	15.6	0.0	0.4	0.023	71.9
		MIN	7.9	24.0	11.6	23.1	18.8	203	36.5	0.9	2.2	0.093	165.0
		MAX	19.9	119.7	119.0	37.2	40.8	468	90.1	0.9	3.7	0.168	428.0
2NFF Large-scale	4	AVG	10.3	35.6	20.6	28.0	29.9	316	68.1	0.9	2.4		
		STDDEV	1.0	7.9	5.3	3.4	11.5	70	20.0	0.0	0.4		
		MIN	9.0	24.5	14.5	24.9	18.4	231	38.3	0.9	2.0		
		MAX	11.5	41.4	25.2	32.4	45.9	384	79.8	0.9	2.8		

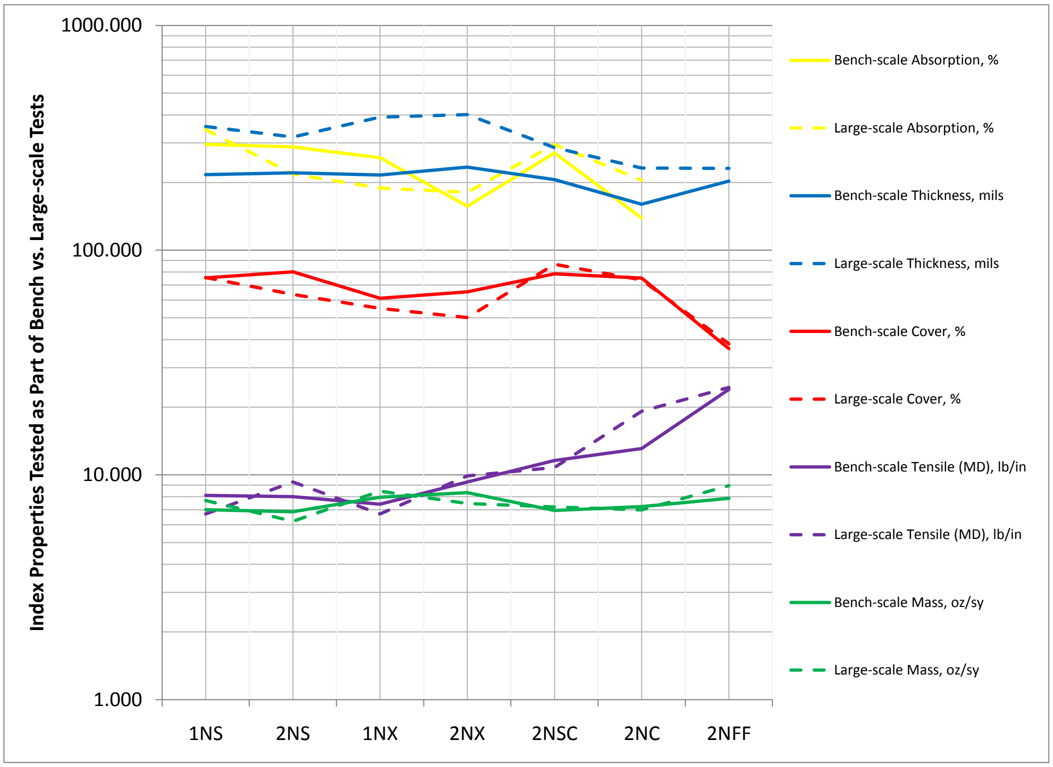

Figure 1. Comparison of Average Index Properties Measured
on Products used for Bench-scale vs. Large-scale Testing

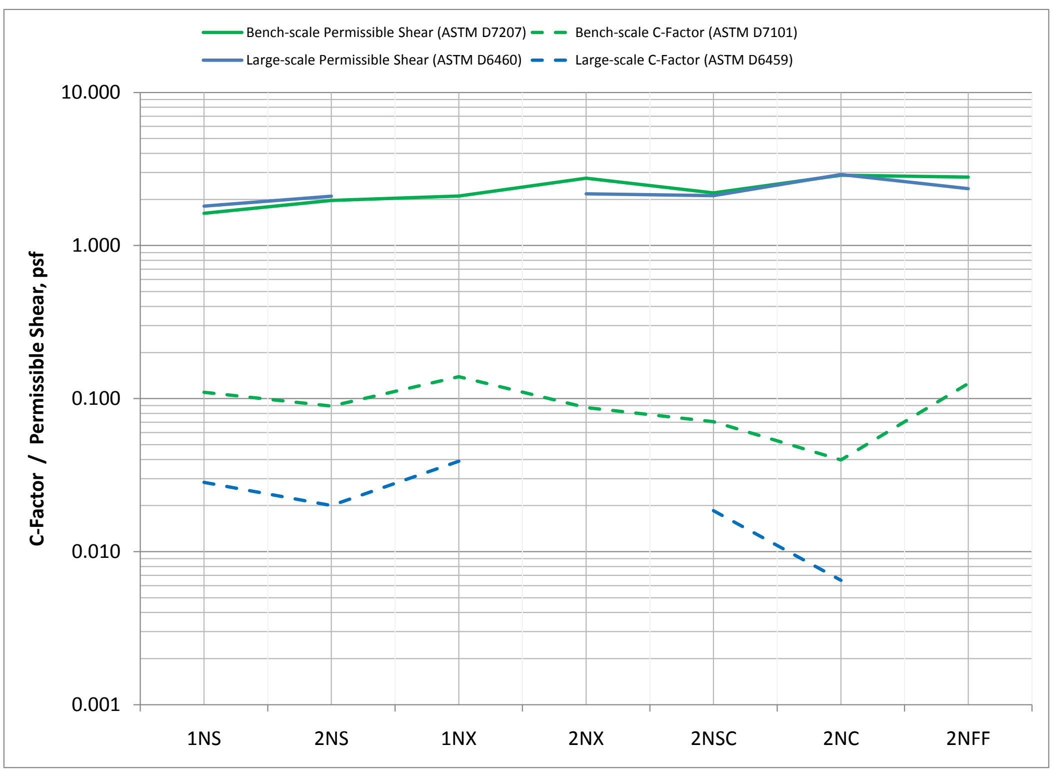

Figure 2. Comparison of Average Bench-scale vs. Large-scale Performance Results

2.3 Review of Index, Bench-scale and Large-scale Testing

The data presented in Table 2 has been graphically presented in Figures 1 and 2 to facilitate a visual comparison of the data. Figure 1 suggests that sufficient uniformity exists in associated index test results from products used in both the bench-scale and large-scale tests to support comparing performance results as shown in Figure 2. Still, one index property – thickness – demonstrates a clear bias toward lower values when tested as part of the index/bench-scale program. This may be because the index properties for the large-scale tests are performed on samples that have been removed from the roll at the large-scale laboratory, repackaged (but not tightly re-rolled) and shipped to the index laboratory, where they are once again unpackaged and cut into specimens. This likely allows the RECPs to "rebound" or even loosen leading to greater thickness and lower % cover.

The data was further evaluated to attempt to identify any meaningful correlation(s) between index (QC) tests and associated bench-scale and large-scale performance tests. If a correlation between properties, or at least a consistent relationship between properties and product types could be found, it would be easier to develop generic specifications for the range of products studied. To this end, possible relationships between index, bench-scale, and large-scale results were explored and are summarized in Table 3.

It quickly becomes clear, based on the correlation coefficients, that no strong credible correlations exist between any of the index properties and product performance as measured by the bench-scale and large-scale tests used. Still, there are "hints" that mass/area, thickness, and % cover may be related to performance. Yet, the correlations are spotty. All correlations are shown in Table 3.

Fortunately, Figure 2 demonstrates quite convincingly that there is a hierarchy of performance among the commonly available RECPs. Additionally, Figure 1 presents the typical index properties for each of these RECPs. Used together, the index and performance data facilitates the preparation of generic specifications that include performance criteria as well as minimum property "thresholds" to assure that only proven materials are used.

Table 3. Possible Index, Bench-, and Large-scale Correlations

Index Test	vs. Bench-scale Test	vs. Large-scale Test	Best Fit Equation	Correlation Coefficient, R^2
Mass/Area, D6475	Slope Erosion, D7101		C = -0.0021X + 0.1087	0.0161
		Slope Erosion, D6459	C = -0.0084X + 0.0937	0.3011
	Channel Erosion, D7207		τ = 0.227X + 0.0869	0.6053
		Channel Erosion, D6460	τ = 0.2513X + 0.0254	0.4877
Thickness, D6525	Slope Erosion, D7101		C = -0.0003X + 0.0006	0.2880
		Slope Erosion, D6459	C = -0.0002X – 0.0322	0.6960
	Channel Erosion, D7207		τ = -0.0014X + 2.7388	0.0260
		Channel Erosion, D6460	τ = -0.0046X + 3.858	0.6531
Tensile Strength, D6818	Slope Erosion, D7101		C = -0.0019X + 0.1235	0.3425
		Slope Erosion, D6459	C = -0.0015X + 0.0422	0.8478
	Channel Erosion, D7207		τ = 0.0462X + 1.4293	0.6121
		Channel Erosion, D6460	τ = 0.0214X + 1.8589	0.3819
Light Penetration, D6567 (% Cover)	Slope Erosion, D7101		C = -0.0024X + 0.2755	0.4776
		Slope Erosion, D6459	C = -0.0006X + 0.0678	0.4397
	Channel Erosion, D7207		τ = -0.0179X + 3.681	0.0852
		Channel Erosion, D6460	τ = -0.0023X + 2.4177	0.0069

3. SPECIFICATIONS FOR RECPs

Many different specifications for RECPs are in circulation, including proprietary specifications promoted by product suppliers, broad product "categorizations" published by industry groups, and generic specifications used by public agencies. To insure free and fair competition, there are at least three critical elements to a material specification for use on public projects – the focus of this effort. The elements include:

1. The specification must be generic. That is, it must be completely comprised of requirements that are not exclusive to a single product.

2. The specification requirements must be relevant. That is, that each requirement must be shown to relate to how the product is expected to perform or must be critical to assuring product quality.

3. Specification conformance must be verifiable. That is, it must be possible to corroborate every requirement within the specification via independent sampling and verification (a.k.a. conformance) testing. For properties requiring long-term testing, a test report from an independent, accredited laboratory may be acceptable.

3.1 Existing Specs

The most widely circulated "generic" specifications for RECPs are the categorizations presented by the ECTC (2006) and the Federal Highway Administration's FP-03 (2003) and are reproduced in Tables 4 and 5.

Table 4. Temporary Rolled Erosion Control Product (RECP) Specifications (per FP-03, Table 713-3)

Property	1.A(1)	1.B	1.C	1.D	2.A(1)	2.B	2.C	2.D	3.A(1)	3.B	4	Test Method
Typical functional longevity(2) (months)	3	3	3	3	12	12	12	12	24	24	36	N/A
Minimum tensile strength(3) (lb/ft)	5	5	50	75	5	50	50	75	25	100	125	ASTMD 4595
Maximum "C" factor(4)	0.10 at 1V:5H	0.10 at 1V:4H	0.15 at 1V:3H	0.20 at 1V:2H	0.10 at 1V:5H	0.10 at 1V:4H	0.15 at 1V:3H	0.20 at 1V:2H	0.10 at 1V:5H	0.25 at 1V:1½H	0.25 at 1V:1H	ASTM D6459(7)
Minimum permissible shear stress(5)(6)(lb/ft^2)	0.25	0.50	1.50	1.75	0.25	0.50	1.50	1.75	0.25	2.00	2.25	ASTM D6460(7)

(1) Obtain max "C" factor and allowable shear stress for mulch control nettings with the netting used in conjunction with pre-applied mulch material.
(2) Functional longevities are for guidance only. Actual functional longevities may vary based on site and climatic conditions.
(3) Minimum average roll values, machine direction.
(4) "C" factor calculated as ratio of soil loss from rolled erosion control product protected slope (tested at specified or greater gradient, v:h) to ratio of soil loss from unprotected (control) plot in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using ASTM D7101.
(5) Minimum shear stress the rolled erosion control product (unvegetated) can sustain without physical damage or excess erosion (> 1/2-inch soil loss) during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using ASTM D7207.
(6) The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.01 to 0.05.
(7) Or other qualified independent large scale test method determined acceptable by the CO.
Categories of Temporary RECPs : 1.A, 2.A, 3.A = mulch control nets; 1.B, 2.B = netless ECBs; 1.C, 2.C = single net ECBs and Open Weave Textiles; 1.D, 2.D = double net ECBs; 3.B, 4 = ECBs & Open Weave Textiles

Table 5. Turf Reinforcement Mat (TRM) Specifications (per FP-03, Table 713-4)

Properties(1)	Rolled Erosion Control Product Type			Test Method
	5.A	5.B	5.C	
Minimum tensile strength(2)(3) (lb/ft)	125	150	175	ASTM D4595
UV stability (minimum % tensile retention)	80	80	80	ASTM D 4355 (500-hr exposure)
Minimum thickness(2)(inches)	0.25	0.25	0.25	ASTM D 6525
Minimum permissible shear stress(4)(lb/ft^2)	6.0	8.0	10.0	ASTM D6460(5)

(1) For TRMs containing degradable components, obtain all property values on the non-degradable portion of the matting alone.
(2) Minimum average roll values, machine direction only.
(3) Field conditions with high loading and high survivability requirements may warrant the use of turf reinforcement mats with tensile strengths of 3,000 pounds per foot or greater.
(4) Minimum shear stress the turf reinforcement mat (fully vegetated) can sustain without physical damage or excess erosion (>1/2-inch soil loss) during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using ASTM D7207.
(5) Or other qualified independent large scale test method determined acceptable by the CO.

3.2 Proposed Generic Specs

Table 6 is a proposed specification that includes all of the critical specification elements listed above, reflects as much as possible the generally accepted specification requirements of Tables 4 and 5, and incorporates new knowledge gained (and discussed above) from the NTPEP program. This includes using minimum "thresholds", or lower limits, to protect against deficiently manufactured or underperforming product being furnished to the project. Shaded values in Table 2 are used to guide the choice of minimum "thresholds" recommended in Table 6.

Table 6. Proposed Generic Specification for RECPs

RECP Classification		Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Typical RECP Type (for guidance only)		1NS, 1NX (ECB)	2NS, 2NX (ECB)	2NSC (ECB)	2NC (ECB)	2NFF (TRM)	Other TRM	Other TRM
Durability (for guidance only)		Ultra Short-Term	Short-term	Extended Term	Long-Term	Permanent	Permanent	Permanent
		3 to 6 mos.	6 to 12 mos.	12 to 24 mos.	> 24 mos.			
C-Factor - ASTM D 6459		C ≤ 0.10	C ≤ 0.05	C ≤ 0.05	C ≤ 0.025	C ≤ 0.10	C ≤ 0.05	C ≤ 0.05
Max. Slope Gradient	Max. Slope Length (ft)	Permitted Use on Slopes (X)						
< 5:1	100	X	X	X	X	X	X	X
5:1 ≤ ___ < 4:1	80	X	X	X	X	X	X	X
4:1 ≤ ___ < 3:1	60		X	X	X	X	X	X
3:1 ≤ ___ < 2:1	40			X	X	X	X	X
2:1 ≤ ___ < 1:1	20				X	X	X	X
Permissible Shear, Unvegetated - ASTM D 6460		1.50	1.75	2.0	2.25	2.5	2.5	2.5
Permissible Shear, Fully Vegetated - ASTM D 6460		Not req'd	Not req'd	Not req'd	Not req'd	6.0	8.0	10.0
Tensile Strength (MD),lb/in	ASTM D6818	7.0	8.0	10.0	12.0	20.0	TBD	TBD
Tensile Elongation (MD),%	ASTM D6818	10	10	10	10	20	TBD	TBD
Tensile Strength (XD),lb/in	ASTM D6818	3.0	4.0	6.0	10.0	12.0	TBD	TBD
Tensile Elongation (XD),%	ASTM D6818	10	10	10	10	20	TBD	TBD
Mass / Unit Area, osy	ASTM D6475	7.0	7.0	7.0	7.0	8.0	TBD	TBD
Thickness, mils	ASTM D6525	200	200	200	200	200	TBD	TBD
Ground Cover, %	ASTM D6567	60	65	70	75	60	TBD	TBD
Water Absorption, % (ECBs); Sp. Gravity (TRMs)	ASTM D1117	200	200	200	200	0.9	TBD	TBD
Bench-scale Slope, Avg Soil Loss Ratio	ASTM D7101	5.0	6.0	10.0	10.0	5.0	TBD	TBD
Bench-scale Shear Permissible Shear, psf	ASTM D7207	1.25	1.5	1.75	2.0	2.25	TBD	TBD
Bench-scale Germination, % Improvement	ASTM D7322	200	200	200	200	200	TBD	TBD
UV Stability, % Retained at 500 hrs	ASTM D4355	n/a	n/a	n/a	n/a	80%	80%	80%
QC Data from daily testing must be provided with certification.		Product must be listed at www.ntpep.org.			Reports for large-scale testing must be provided from accredited independent laboratory.			

4. CONCLUSIONS

Commonly used index, bench-scale, and large-scale standardized tests have been discussed along with a review of results from independent testing performed on a range of rolled erosion control products (RECPs) under the auspices of the National Transportation Product Evaluation Program (NTPEP).

Using results to-date, potential correlations have been identified between commonly measured index properties and the ability of specific product types to protect against both rainfall-induced erosion and erosion associated with concentrated flows. Based on these identified relationships a generic specification has been presented for consideration.

5. REFERENCES

ASTM D 792, Method A, “Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement,” ASTM, West Conshohocken, PA.

ASTM D 1117, Section 5.4 and ECTC-TASC 00197, “Standard Guide for Evaluating Nonwoven Fabrics – Absorptive Capacity Test (for Larger Test Specimens),” ASTM, West Conshohocken, PA.

ASTM D 6459, Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Hillslopes from Rainfall-Induced Erosion,” ASTM, West Conshohocken, PA.

ASTM D 6460, Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion,” ASTM, West Conshohocken, PA.

ASTM D 6475, “Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets,” ASTM, West Conshohocken, PA.

ASTM D 6525, “Standard Test Method for Measuring Nominal Thickness of Permanent Rolled Erosion Control Products,” ASTM, West Conshohocken, PA.

ASTM D 6566, “Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats,” ASTM, West Conshohocken, PA.

ASTM D 6567, “Standard Test Method for Measuring the Light Penetration of a Turf Reinforcement Mat (TRM),” ASTM, West Conshohocken, PA.

ASTM D 6818, “Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats,” ASTM, West Conshohocken, PA.

ASTM D 7101, “Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff under Bench-Scale Conditions,” ASTM, West Conshohocken, PA.

ASTM D 7207, “Standard Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Sand from Hydraulically-Induced Shear Stresses under Bench-Scale Conditions”.

ASTM D 7322, “Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Ability to Encourage Seed Germination and Plant Growth under Bench-Scale Conditions,” ASTM, West Conshohocken, PA.

ECTC (2006), “ECTC Standard Specification for Temporary Rolled Erosion Control Products,” Erosion Control Technology Council, www.ectc.org.

ECTC (2006), “ECTC Standard Specification for Permanent Rolled Erosion Control Products,” Erosion Control Technology Council, www.ectc.org.

FHWA (2003), “Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects”, FP-03 (U.S. Customary Units), U.S. DEPARTMENT OF TRANSPORTATION, Federal Highway Administration.

NTPEP (2011), “ECP User Guide,” National Transportation Product Evaluation Program, AASHTO, www.ntpep.org.

Sprague, C.J. and Nelson, J. (2009), “Correlation of Bench-scale and Large-scale Performance Testing of RECPs”,Conf. XXXX, International Erosion Control Assoc., Reno, NV, (digital proceedings).