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PERFORMANCE TESTING OF TRADITIONAL SLOPE EROSION CONTROLS

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Biography

C. Joel Sprague, Sr. Engineer - Mr. Sprague is a Senior Engineer for TRI/Environmental, Inc., Austin, TX. Mr. Sprague is based in Greenville, South Carolina where he also consults for Sprague & Sprague Consulting Engineers. He is a registered professional engineer in North and South Carolina, Georgia, and Texas. He has authored numerous articles and technical papers on the development, testing, and application of erosion and sediment control materials.

Peter Kemp, P.E., Sr. Engineer - Mr. Kemp is a licensed Professional Engineer with the Wisconsin Department of Transportation. Mr. Kemp chairs the AASHTO National Transportation Product Evaluation Program, Erosion Control Products Technical Committee which has developed and oversees NTPEP's erosion control product testing programs. Current programs include index and bench-scale quality assurance testing and large-scale performance testing.

Jay Sprague, Lab Director – Mr. Sprague supervises a staff of technicians, directs all site operations and testing, and is responsible for implementation of TRI's Quality Systems throughout all lab operations. Mr. Sprague's background includes developing markets and technologies associated with agricultural and erosion and sediment control products.

Abstract

Large-scale tests have been used extensively in recent years to evaluate the performance of manufactured erosion control products on slopes. When evaluating slope erosion, a full-scale slope is generally exposed to rainfall impact and associated seepage and sheet runoff forces resulting from a simulated rainfall event. Commonly, the testing includes both slopes covered by the candidate erosion control product and slopes without any protection, or control slopes. The amount of soil loss from the protected condition is compared to that of the unprotected, or control condition, in order to establish product performance. This ratio of protected to unprotected soil losses is referred to as the Cover Factor, or simply C-Factor, and is a variable in the Revised Universal Soil Loss Equation (RUSLE) contained in the USDA-ARS Agricultural handbook 703.

While this full-scale testing is useful in establishing the maximum benefit of a candidate erosion control product, such as a rolled erosion control product (RECP) or hydraulically-applied erosion control product (HECP), it can also be used to consider if sufficient protection is afforded by more traditional erosion control alternatives. Comparing RECP or HECP performance to that of traditional alternatives may be more meaningful than simply comparing to a control, or no protection, condition, especially when performing cost-benefit analyses.

This paper will present the results of large-scale standardized performance tests on the traditional erosion control systems of blown and tacked straw and crimped straw, as well as a summary of product test results using the same large-scale testing procedure, ASTM D 6459.

Keywords: RECPs, HECPs, erosion control, NTPEP, slope erosion testing, ASTM D 6459

1 Background

Sediment is the number one pollutant of US water resources even though best management practices,(BMPs), for erosion control are now commonly used. While a large amount of information on BMPs for erosion control currently exists, the information on actual design level performance and effectiveness has been difficult to find. This is changing as a result of standardized large-scale erosion testing being carried out with increasing frequency in recent years on the performance of manufactured erosion control products, including extensive testing through the National Transportation Product Evaluation Program. Test reports from independent testing of rolled erosion control products (RECPs) and hydraulically-applied erosion control products (HECPs) are readily available on-line (www.ntpep.org). This data is being used by regulatory agencies and site designers to qualify and compare candidate erosion control products.

While this full-scale testing is useful in establishing the maximum benefit of a candidate erosion control product, it can also be used to consider if sufficient protection is afforded by more traditional erosion control alternatives. Comparing RECP or HECP performance to that of traditional alternatives may be more meaningful than simply comparing to a control, or unprotection, condition, especially when performing cost-benefit analyses.

2 Erosion Control Products (ECPs) and Standardized Performance Testing

Erosion controls have been widely studied and have generally accepted quantitative design procedures. Generally recognized standard test methods provide a way for specifiers/designers to verify marketing claims or one-time field trials, or for innovators to test new products and compare against existing practices. They also assist the users of ECPs in establishing improved construction specifications. Owners and contractors can save money by installing the correct ECP for the expected site conditions, and product manufacturers have a clear, generally recognized methodology for establishing product capabilities.

3 Slope Testing of Traditional Erosion Control Products

When evaluating slope erosion, a full-scale slope is generally exposed to rainfall impact, associated seepage, and sheet runoff forces resulting from a simulated rainfall event. Commonly, the testing includes both slopes covered by the candidate erosion control product and slopes without any protection, or control slopes. The amount of soil loss from the protected condition is compared to that of the unprotected, or control condition, in order to establish product performance. This ratio of protected to unprotected soil losses is referred to as the Cover Factor, or simply C-Factor, and is a variable in the Revised Universal Soil Loss Equation (RUSLE) contained in the USDA-ARS Agricultural handbook 703.

3.1 Standard Test Method for Slope Erosion – ASTM D 6459

Standardized large-scale testing is performed in accordance with ASTM D 6459, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion*. Testing is done on 3:1 slopes using loamy soil test plots measuring 40 ft long x 8 ft wide. The simulated rainfall is produced by ten “rain trees” arranged around the perimeter of the test slope. Each rain tree has four sprinkler heads atop a 15 ft riser pipe. The rainfall system is calibrated prior to testing to determine the number of sprinkler heads and associated pressure settings necessary to achieve target rainfall intensities. The target rainfall intensities are 2, 4, and 6 in/hr and are applied in sequence for 20 minutes each. Three replicate test slopes covered by the submitted erosion control product (ECP) are tested. Erosion resistance provided by the tested ECP is obtained by comparing the protected slope results to control (unprotected) results. Tables and graphs of rainfall versus soil loss are generated from the accumulated data. Standardized testing of two traditional erosion controls – tacked straw and crimped straw – are presented herein. This testing was conducted for the Wisconsin Department of Transportation and reported by Sprague (2007a and 2007b). Figure 1 shows the testing facility, and Figure 2 shows a close-up of the typical straw coverage rate.

Figure 1. Slope Testing Facility - 2008

Figure 2. Close-up of Deployed Straw

3.2 Traditional Erosion Control #1 – Straw + Tackifier

Straw was placed at the target rate of 1.5 tons/acre and then tacked, or sprayed with an adhesive tackifier. Figure 3 shows the straw and spraying of tackifier used in testing.

3.3 Traditional Erosion Control #2 – Blown-Crimped Straw

Straw was placed at the target rate of 1.5 tons/acre and then crimped, or pushed into the soil with rolling disks spaced at 6 inches. Figure 4 shows the straw and crimping device used in testing.

Figure 3. Tackifier Being Applied to Straw

Figure 4. Straw Being Crimped Into Soil

3.4 Test Soil

The test soil used in the test plots had the following characteristics.

Table 1. TRI-Loam Characteristics

Soil Characteristic	Test Method	Value
% Gravel	ASTM D 422	3
% Sand		60
% Silt		23
% Clay		14
Liquid Limit, %	ASTM D 4318	34
Plasticity Index, %		9
Soil Classification	USDA	Sandy Loam
Soil Classification	USCS	Silty Sand (SM)

3.5 Preparation of the Test Slopes

The test slopes received a standard preparation procedure prior to each slope test. First, any rills or depressions resulting from previous testing were filled in with test soil. The entire test plot was then tilled to a depth not less than four inches. The test slope was then raked to create a slope that was smooth both side-to-side and top-to-bottom. Finally, a steel drum roller was rolled down-and-up the slope 3 times proceeding from one side of the plot to the other. The submitted erosion control system was then installed as directed by the client.

3.6 Installation of Erosion Control on Test Slopes

3.6.1 Blown-Tacked Straw

For this testing, straw was hand-placed in a uniform layer simulating a ½- to 1-inch thick layer of blown straw, or an application rate of 1.5 tons/acre. The layer of straw was then sprayed with a tackifier. The tackifier was composed of FINN HydroStik (a guar gum based tackifier), recycled paper and water. The mix/coverage rate used was 120 lb of dry adhesive and 620 lb of recycle newsprint per 3225 gallons of water per hectare of coverage. A close-up of the prepared slope is shown in Figure 5.

3.6.2 Crimped Straw

For this testing, straw was also hand-placed in a uniform layer simulating a ½- to 1-inch thick layer of blown straw (1.5 tons/acre) and then hand-crimped to a depth of 1-1/2 to 2 inches using the device shown in Figure 2. The crimper disks were spaced 6-inches apart. The prepared slope is shown in Figure 6.

Figure 5. Close-up of Tacked Straw

Figure 6. Straw Crimped into Slope

3.7 Specific Test Procedure

Immediately prior to testing, soil moisture samples were taken and rain gauges were placed at the quarter points on the slope. The slope was then exposed to sequential 20-minute rainfalls having target intensities of 2, 4, and 6 inches per hour. All runoff was collected during the testing. Additionally, periodic sediment concentration grab samples were taken and runoff rate measurements were made. Between rainfall intensities, the rainfall was stopped and rainfall depth was read in the three rain gauges, valves were adjusted to facilitate the subsequent rainfall intensity, and empty collection vessels were positioned to collect subsequent runoff.

After allowing for sediments to settle, water was decanted from the collected runoff. The remaining solids were used to determine soil loss by drying all collected sediments or by drying a “representative sample” of collected sediments and deriving total dry sediment weight based on the representative moisture content. Drying was accomplished in a forced air oven at 110°C for a minimum of 24 hours. Weighing was done with laboratory scales accurate to ± 0.01 lbs, unless weights in excess of 50 lbs were collected, for which scales having accuracy of ± 2 lbs were used.

Figures 7 and 8 show typical “grab” and volumetric flow sampling.

Figure 7. Typical “Grab Sample” for Sediment Concentration

Figure 8. Typical Volumetric Flow Rate Sample

Pictures of the initial and eroded slopes are shown in Figures 9 thru 10. Actual testing was done between 7 pm and 11 pm to take advantage of still air current conditions, as can be seen in the “after” pictures.

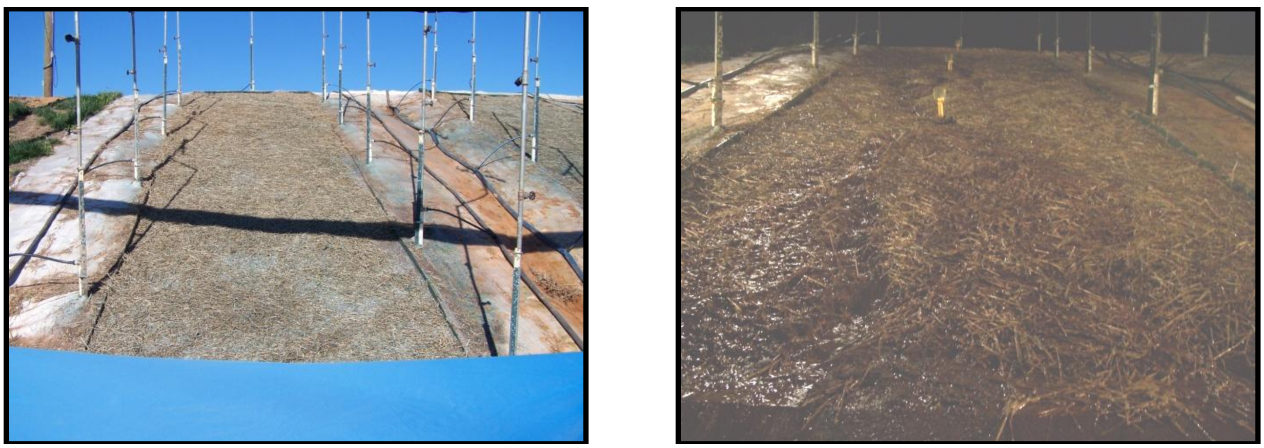

Figure 9. Typical “Tacked Straw” Test Slope – Before Test and Nearing Test Completion

Figure 10. Typical “Crimped Straw” Test Slope – Before Test and Nearing Test Completion

3.8 Test Results

The Cover Management (C) Factor from the Revised Universal Soil Loss Equation (RUSLE) of the USDA-ARS Agricultural handbook 703 is the reported performance measure for slopes determined from this testing. The C-Factor and R-Factor reported herein are related through RUSLE by the following relationship:

A = R x K x LS x C x P

where: A = the computed soil loss in tons per acre (measured/calculated from test);
R = the rainfall erosion index (measured/calculated from test);
K = the erodibility of the soil (calculated from test – see Figure 12);
LS = the topographic factor (2.78 for 8 x 40 ft slope);
C = the cover factor = ratio of protect soil loss to control soil loss (1.0 for control); and
P = the practice factor (1.0 for all test slopes).

Total soil loss and the associated rainfall depth measured during the testing are the principle data used to determine the C Factor. The cumulative C-Factors shown in Tables 2a and 2b are the ratio of the soil loss from the protected condition at a calculated cumulative R-Factor divided by the cumulative soil loss from the control plot (Figure 12) at that same R-Factor.

In all cases, the soil loss and associated rainfall data for both protected and control conditions are used to develop a normalized cumulative graph of R-Factor versus C-Factor (R factor = total kinetic energy of the storm (E) times its maximum 30-minute Intensity (I)).

The maximum average normalized cumulative R-Factor calculated for the target test events: 2 in/hr for 20 minutes + 4 in/hr for 20 minutes + 6 in/hr for 20 minutes, is R = 231. The C-Factor associated with this normalized maximum average result is the reported performance value. This facilitates product-to-product comparison of test results at a common point of the storm event.

Graphs of R-Factor versus C-Factor for the protected conditions and Soil Loss versus R-Factor for the control condition are shown in Figures 11 and 12, respectively. Figure 11 includes the best regression line fit to the test data to facilitate the determination of the C-factor. The figures also allow users of this report to evaluate performance at other points in the model storm by selecting the R factor (and the corresponding C Factor) that may fit local conditions.

Linear (R^2=0.61 & 0.57), power (R^2= 0.92 & 0.62), polynomial (R^2 = 0.65 & 0.63), and exponential (R^2= 0.87 & 0.87) fits were evaluated for both conditions, and the best fit (i.e. highest R^2) was chosen

The overall C-Factor information shown in Table 3 are derived from the best fit curves in Figure 11 and relate the C-Factors and associated R-Factors given in Tables 2a and 2b.

Table 2a. Summary Data Table – Slopes Protected with Tacked Straw

Run #	Test # (run # - target intensity)	Rainfall Depth, in	Rainfall Intensity, in/hr	Cumulative R-factor	Soil Loss, lbs/slope	Soil Loss, tons/acre	Cumulative Soil Loss (T/A)	Cumulative C-Factor
1	1-2	0.867	2.6	16.07	0.01	0.00	0.000	0.0001
	1-4	1.533	4.6	102.25	0.71	0.05	0.049	0.0022
	1-6	2.200	6.6	297.53	58.87	4.01	4.056	0.0629
2	2-2	0.667	2.0	9.21	0.00	0.00	0.000	0.0002
	2-4	1.333	4.0	71.36	0.54	0.04	0.037	0.0024
	2-6	2.267	6.8	271.36	36.02	2.45	2.489	0.0423
3	3-2	0.867	2.6	16.07	0.00	0.00	0.000	0.00008
	3-4	1.367	4.1	86.98	2.88	0.20	0.196	0.01042
	3-6	2.267	6.8	289.02	157.12	10.70	10.890	0.17396

Table 2b. Summary Data Table – Slopes Protected with Crimped Straw

Run #	Test # (run # - target intensity)	Rainfall Depth, in	Rainfall Intensity, in/hr	Cumulative R-factor	Soil Loss, lbs/slope	Soil Loss, tons/acre	Cumulative Soil Loss (T/A)	Cumulative C-Factor
1	1-2	0.767	2.3	12.41	0.01	0.00	0.001	0.0002
	1-4	1.433	4.3	86.15	0.17	0.01	0.012	0.0006
	1-6	2.133	6.4	268.60	75.03	5.11	5.119	0.0880
2	2-2	0.700	2.1	10.23	0.01	0.00	0.001	0.0004
	2-4	1.367	4.1	76.14	0.20	0.01	0.014	0.0009
	2-6	2.000	6.0	236.84	190.87	13.00	13.006	0.2535
3	3-2	0.733	2.2	11.30	0.07	0.00	0.005	0.00187
	3-4	1.333	4.0	75.51	0.18	0.01	0.017	0.00104
	3-6	1.983	6.0	233.03	225.83	15.38	15.388	0.30486

Table 3. Overall C-Factor – Tacked Straw

Product	C-Factor at R = 231	C-Factor Equation
Tacked Straw @ 1.5 tons/acre	0.039	$C = 0.00000052R^{2.06041262}$
Crimped Straw @ 1.5 tons/acre	0.094	$C = 0.00024767e^{0.0257R}$

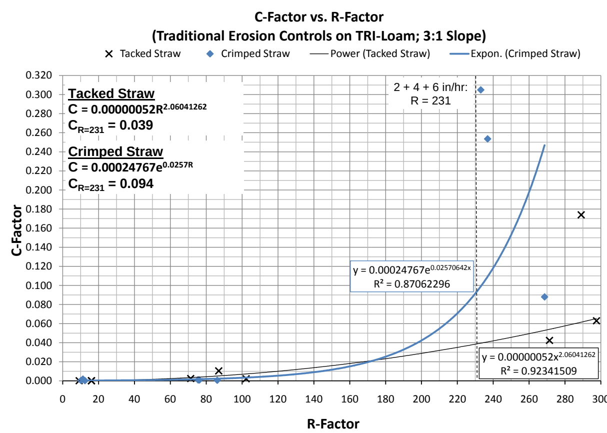

Figure 11. R-Factor vs. C-Factor – Tacked Straw System & Crimped Straw System

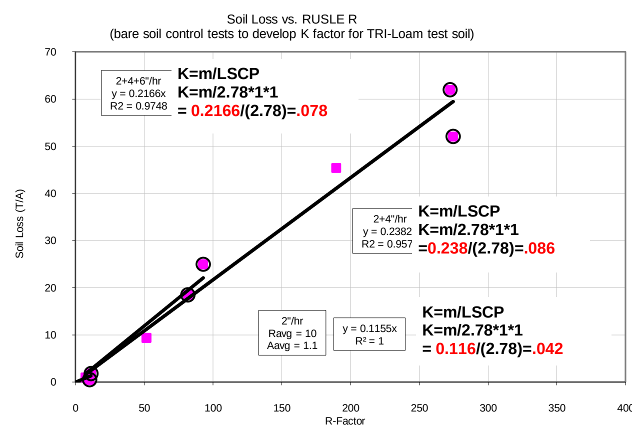

Figure 12. R-Factor vs. Soil Loss – Control Tests

4 RECP Performance via ASTM D 6459

As noted earlier, a significant body of independently developed performance data on ECPs is available at www.ntpep.org. Figure 13 combines the results of this testing with the large-scale results to-date from the NTPEP program for RECPs and HECPs per Sprague, et.al. (2012). Along with the traditional erosion controls detailed herein, the summary includes both hydraulically-applied base mulches and bonded fiber matrices (HECP-BaseMulch and HECP-BFM) as well as a range of RECPs, including single net excelsior (1NX), single and double net straw (1NS and 2NS), double net straw-coconut (2NSC), and double net coconut (2NC).

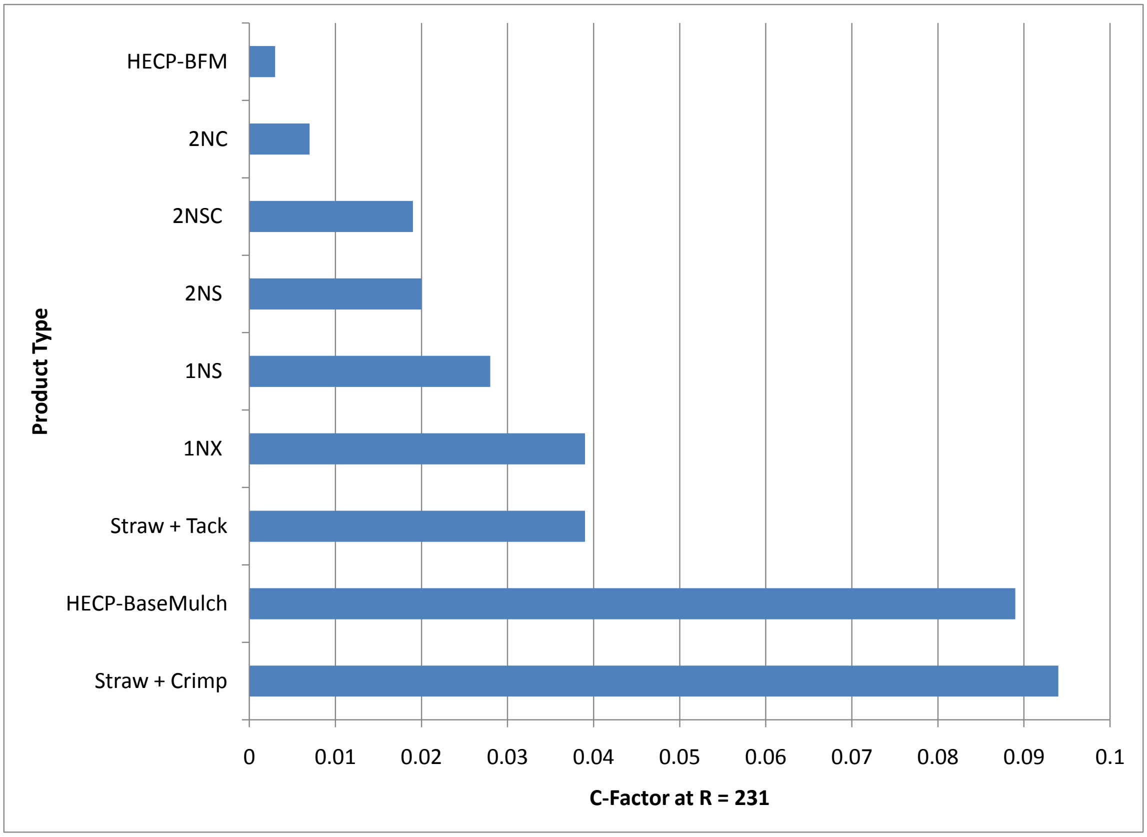

Figure 13. Summary of Large-scale Independent Test Results, including NTPEP Testing 2009-2011+

5 Conclusions

This paper has presented the results of large-scale standardized performance tests on the traditional erosion control systems of blown and tacked straw and crimped straw, as well as a summary of product test results using the same large-scale testing procedure, ASTM D 6459, same test facility, identical data evaluation and reporting.

While this full-scale testing is useful in establishing the maximum benefit of a range of candidate erosion control products, including rolled erosion control products (RECPs) and hydraulically-applied erosion control products (HECPs), it can also be used to consider if sufficient protection is afforded by more traditional erosion control alternatives. Standardized large-scale performance tests to-date indicate that while substantial erosion protection can be obtained using traditional systems, RECPs and HECPs can be selected to provide superior protection. Additionally, this comparable data facilitates product-to-product comparisons and cost-benefit analyses.

6 Reference

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