Vmax³® Tech Facts

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NORTH AMERICAN GREEN®

EROSION CONTROL *Products* • *Guaranteed* SOLUTIONS

THREE PHASE DESIGN ENSURES COMPLETE TRM PERFORMANCE

In order to provide complete channel protection, a turf reinforcement mat (TRM) must function to provide effective erosion control and turf reinforcement through the three phases of a reinforced vegetative channel lining's development. In Phase 1 the TRM must control soil and seed loss immediately after installation to ensure the successful development of a permanent vegetative stand. In Phase 2, defined as that period of time from seed germination until a mature stand of vegetation is established, the matting must continue its role by supplementing the erosion protection provided by the vegetation as well as structurally reinforcing the developing plants against high shear stress water flows. Finally, in Phase 3 when the vegetation has become mature, the matting must provide stem reinforcement and root zone protection. To quantify the total performance of North American Green's Vmax³® composite turf reinforcement mats (C-TRMs), comprehensive large-scale channel lining research has recently been completed at Colorado State University's (CSU) hydraulics laboratory. The following results of this research demonstrate the exceptional immediate erosion control and permanent turf reinforcement capabilities of the Vmax³ products including the SC250,® C350® and P550.®

The steep flume (50% gradient) utilized at Colorado State University's hydraulics laboratory was required to generate extreme shear stress on the fully vegetated (Phase 3) Vmax³ turf reinforcement mattings.

All Vmax³ C-TRMs utilize a patented composite design consisting of a permanent three-dimensional net structure incorporated with a fibrous matrix. The Vmax³ fibrous matrix options include a mixture composed of 70% straw and 30% coconut fiber in the SC250, 100% coconut fiber in the C350, or 100% polypropylene fiber in the P550. Incorporation of these matrices into the permanent netting structures provides for instant soil cover in Phase I immediately after installation. The fiber matrix greatly increases seed germination and plant growth by retaining moisture and regulating temperature at the soil surface to ensure the establishment of reinforced vegetation for the site's permanent erosion control. The innovative design of the Vmax³ mats also eliminates the need for soil in-filling procedures required with many TRMs. Vmax³ mats are applied after the application of seed and soil amendments to the soil surface to enhance the vegetation's overall resistance to flow through stem reinforcement with the ancillary benefit of root reinforcement.

CHANNEL TESTING PROTOCOL

In the large-scale channel/flume at Colorado State University's hydraulics laboratory, the Vmax³ products were tested in all three phases of vegetative channel lining development. Test procedures utilized by the CSU laboratory were similar to those established in ASTM standardized test method D6460 entitled *Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion*. The Vmax³ TRMs were installed over a highly erodible sandy loam soil and exposed to one-hour and ten-hour flows generating escalating levels of hydraulic force/shear stress. The research was designed to simulate field conditions normally experienced in the unvegetated, partially vegetated and fully vegetated stages of a reinforced vegetated channel lining. The objective was to determine the magnitude of flow-induced shear stress – the hydraulic pulling force on the matting and/or soil – at which excessive erosion will occur.

Excessive erosion was defined as removal of an average of 0.5 inches (1.27 cm) of soil from beneath the mats and/or through the

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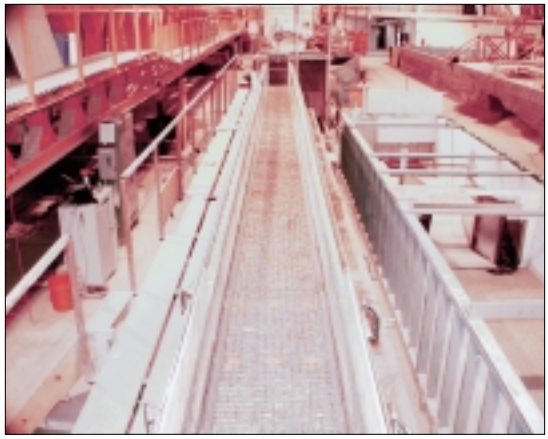


The surface applied Vmax³ mats after installation in test flumes.

Flow generating 9.5 lbs/ft² (454 Pa) of shear stress with an average velocity of nearly 15 ft/s (4.6 m/s) over unvegetated P550 resulted in NO physical damage to the matting. While this value should not be used for design purposes, it does demonstrate the physical durability of the P550.

*(**CHANNEL TESTING PROTOCOL**, continued)*

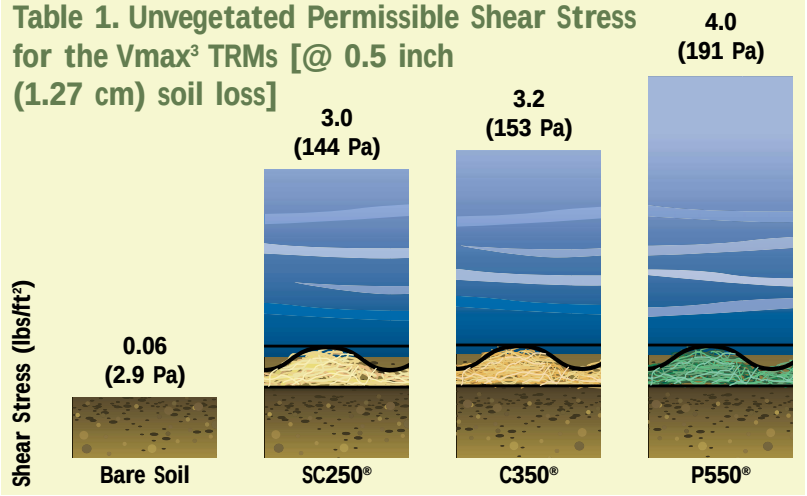
mat-reinforced vegetation. Soil migration was measured and recorded using established standards and methodology outlined in the Clopper Soil Loss Index as noted in section 8.2.6 of ASTM D6460 to establish soil loss values from beneath the nettings. Numerous pre-determined locations across and along each plot were measured for soil loss prior to and after each flow using a point gauge instrument. The testing did not proceed to the next flow level unless the Vmax³ matting or Vmax³ reinforced vegetation reduced soil loss to less than one-half inch (1.27 cm) while incurring NO physical damage or fiber loss. Additionally, stem and leaf density counts were conducted before the flows commenced and after each flow as a means to ascertain vegetation reinforcement from the Vmax³ products.

PHASE 1 – UNVEGETATED Vmax³ PERFORMANCE

In unvegetated testing, the Vmax³ C-TRMs were exposed to flows generating incrementally greater shear stresses from 0.5 lbs/ft² (24 Pa) up to 9.5 lbs/ft² (454 Pa) (P550 only). After each one-hour flow, the channel's soil profile was surveyed for soil loss and the matting structure was assessed for physical damage and fiber loss.

Unvegetated, all the Vmax³ products reduced soil erosion from the channel surface to less than 0.5 inches (1.27 cm) at shear stresses ranging from 3 – 4 lbs/ft² (144 – 191 Pa). Without Vmax³ protection the test soil experienced excessive erosion at a shear stress of only 0.06 lbs/ft² (2.9 Pa). Data from this most recent testing, in conjunction with past performance research, was used to update the design values for the unvegetated North American Green Vmax³ mats as reported in Table 1 and utilized in Version 4.3 of North American Green's Erosion Control Materials Design Software (ECMDS®).

Table 1. Unvegetated Permissible Shear Stress for the Vmax³ TRMs [@ 0.5 inch (1.27 cm) soil loss]



Vegetation becoming established through the permanent netting structure of the SC250. The degradable straw/coconut fiber matrix of the SC250 was left out of the product for testing to simulate "worst case" Phase 2 conditions.

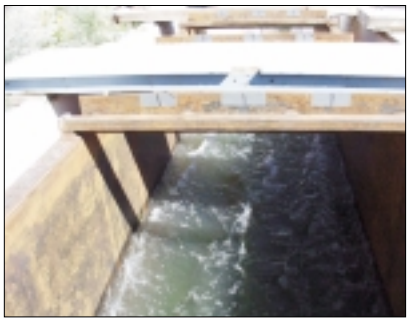
The Kentucky Bluegrass has established up through the Vmax³ C-TRMs after one growing season. Vmax³ reinforced vegetation is ready for Phase 2 testing.

PHASE 2 – PARTIALLY VEGETATED Vmax³ PERFORMANCE

To establish vegetation in the test plots, the Vmax³ mats were surface applied (no soil in-filling) over a highly erodible, sandy loam soil seeded with Kentucky Bluegrass. To simulate "worst case" conditions of the composite mats during Phase 2, only the permanent three-dimensional reinforcement structures of the mattings (no organic fibers) were installed. The plots were then allowed to vegetate for one year and placed into the 4 ft (1.2 m) wide by 40 ft (12.2 m) long test flume and tested at a 7% gradient. The final stand of Kentucky Bluegrass achieved and tested is defined by the Federal Highway Administration Hydraulic Engineering Circular No. 15 (FHWA HEC 15) as a Retardance Class "C" vegetative stand. Retardance Class "C" grass is generally described as having a stand height of 6 inches (15 cm), and fair to good overall density (approximately 50 – 75%). This class of vegetation was chosen for testing because it best characterizes a vegetative stand often encountered in a partially vegetated channel lining application [FHWA Retardance Classes range from "E" for less than 2.0 inches (5.0 cm) tall, to "A" for stands exceeding 24 inches (61 cm) in height].

Once partially vegetated, the Vmax³ mats were exposed to flows generating incrementally greater shear stresses up to 12 lbs/ft² (574 Pa). After each flow, the channel's soil profile was surveyed for soil loss. The vegetation, as well as the underlying matting structure, was closely inspected for physical damage. *It is important to note that when flow testing occurred, the grass was growing up through the Vmax³ mats' permanent, three-dimensional reinforcement structures, a scenario generally referred to as "stem reinforcement."*

The SC250 stem reinforced vegetation (Retardance Class "C") just after plot placement in the test flume.

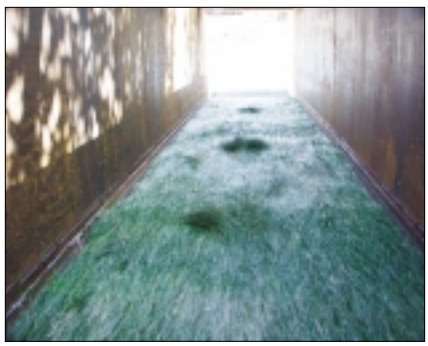


SC250 reinforced vegetation sustaining a test flow generating 8.0 lbs/ft² (384 Pa) of shear stress at an approximate velocity of 17 ft/s (5.2 m/s). This magnitude of shear stress is great enough to move 24 inch (60 cm) rock riprap.

The SC250 reinforced vegetation temporarily lays horizontal following the 8.0 lbs/ft² (384 Pa) shear stress flow. NO significant soil loss or damage to the SC250 reinforced vegetation was measured or observed.

The P550 reinforced vegetation (Retardance Class "C") just after plot placement in the test flume.

A P550 test flow generating 12 lbs/ft² (574 Pa) of shear stress at an approximate velocity of 20 ft/s (6.1 m/s) maximizes the 7% gradient test flume discharge capabilities.



The P550 reinforced vegetation sustained the extreme 12 lbs/ft² (574 Pa) shear stress flow with little soil loss and NO significant damage to the P550 or vegetation.

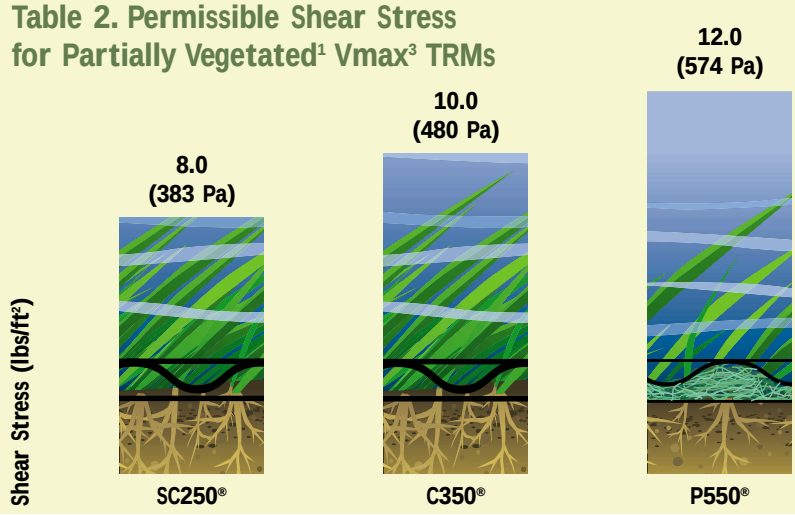
Partially Vegetated Vmax³ Mats – Pushing the Limits of Vegetation Past 30 inch Rock Riprap

In the partially vegetated portion of the CSU research, the Vmax³ mats achieved unprecedented levels of erosion control and vegetation reinforcement. The maximum test flow on the P550 reinforced vegetation was achieved at a discharge of 120 ft³/s (3.4 m³/s) and a velocity of approximately 20 ft/s (6.1 m/s) with a 1.5 ft (0.46 m) flow depth. A flow of this magnitude resulted in 12 lbs/ft² (574 Pa) of shear stress being generated in the flume on the Vmax³ reinforced vegetative linings. Even when exposed to this extremely erosive flow, the P550 reinforced lining experienced no soil loss, no damage to the vegetative stand, and no physical damage to the matting itself. Shear forces of this magnitude, as noted in the FHWA HEC 15, are capable of moving rock riprap with a D_{50} diameter exceeding 30 inches (76 cm). Testing was halted at this point because the maximum discharge capabilities of the 7% test flume had been reached. For comparison, the same Retardance Class "C" vegetation without P550 reinforcement would likely have experienced extreme soil and vegetation losses at a much lower level of shear stress. In fact, the FHWA recommends a maximum permissible shear stress of only 1.0 lb/ft² (48 Pa) for an unreinforced Retardance Class "C" vegetation.

Phase 2 – Partially Vegetated Vmax³ Design Values

The results of this research, in conjunction with other performance testing data, were used to update the design values for Phase 2 Partially Vegetated Vmax³ mats as reported in Table 2 and utilized in ECMDS Version 4.3.

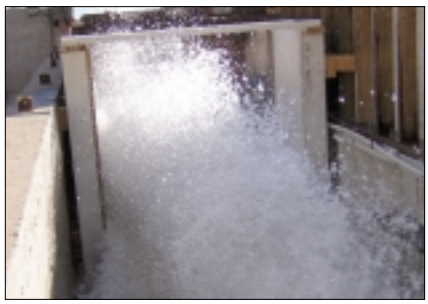
Table 2. Permissible Shear Stress for Partially Vegetated[1] Vmax³ TRMs



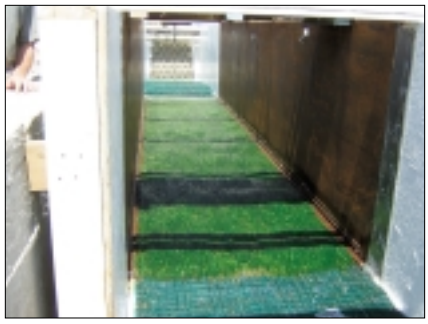
[1] FHWA Class "C" vegetation at 50 – 75% density. Design values will vary with vegetative stand height and density. Consult North American Green's ECMDS design software for Class specific design values.

NOTE: Phase 2 vegetation reinforcement research conducted for the SC250 and C350 with only the permanent three-dimensional net structure present.

Vmax³ reinforced vegetation just prior to Phase 3 testing.



The P550 reinforced vegetation was exposed to a maximum flow generating a shear stress of nearly 20 lbs/ft² (960 Pa).



No physical damage or soil loss was observed in the P550 reinforced vegetation after the flow exerting nearly 20 lbs/ft² (960 Pa) of shear stress.

PHASE 3 – FULLY VEGETATED Vmax³ PERFORMANCE

During the fully vegetated Phase 3 testing, the same Vmax³ test plots subjected to flows during Phase 2 testing were allowed to grow another season until the vegetation reached full maturity. When the test plots reached a density of approximately 75 to 90%, they were cut to a 6-inch (15 cm) height and placed into a test flume with a gradient of 50%. The steeper gradient was required in this phase of testing to generate shear stresses well in excess of those previously achieved on the Vmax³ reinforced plots during the Phase 2 testing. It is important to note that only the permanent three-dimensional structures of the SC250 and C350 composite mats provided reinforcement for the vegetation during fully vegetated testing.

Short Duration Flows

Extremely high shear stress flows were then introduced and maintained for consecutive one-hour flow events to determine the short-duration performance of the reinforced vegetative linings. The Vmax³ products maximized flume capabilities during the final test at a discharge of 100 ft³/s (2.8 m³/s) and a velocity approaching 25 ft/s (7.6 m/s) with a flow depth of 1.0 ft (0.3 m), generating shear stresses approaching nearly **20 lbs/ft² (960 Pa)**.

Long Duration Flows

Additional research was conducted on the Vmax³ products for long duration flows in the steep flume during this phase of testing. Soil has different erosive properties and reduced permissible shear stress when fully saturated, which normally occurs after exposure to flows lasting two hours or more. With this in mind, it is easy to recognize the importance of long duration testing in order to accurately quantify the ability of Vmax³ reinforced vegetation to control erosion under the most demanding conditions. Long duration testing was accomplished by exposing the Vmax³ test plots to flows of 10 hours at CSU and up to 60 hours at other test facilities. Even under these extreme saturated soil conditions there was less than 0.5 inches (1.27 cm) of soil loss and no physical damage to the Vmax³ reinforced vegetative linings.

Table 3. Permissible Shear Stress for Short Duration Fully Vegetated[1] Vmax³ TRMs

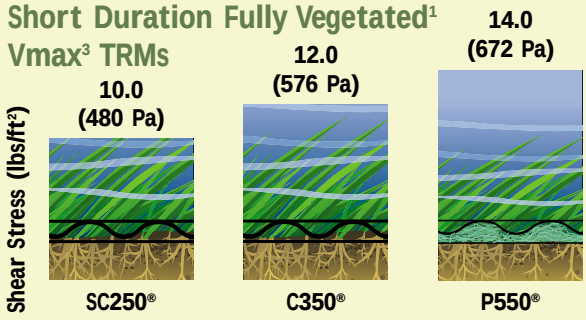
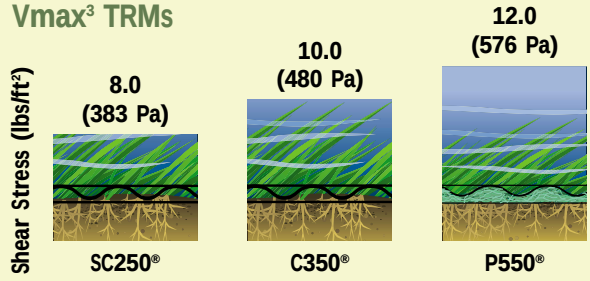


Table 4. Permissible Shear Stress for Long Duration Fully Vegetated[1] Vmax³ TRMs



[1] FHWA Class "C" vegetation at 75-90% density. Design values will vary with vegetative stand height and density. Consult North American Green's ECMDS design software for Class specific design values.

NOTE: Phase 3 vegetation reinforcement research conducted for the SC250 and C350 with only the permanent three-dimensional net structure present.

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Vmax³ PERFORMANCE RESEARCH SUMMARY

The Colorado State University results were unprecedented. Never before has reinforced turf been scientifically proven under such extreme hydraulic conditions. Even in the test flume with a 50% gradient generating shear stresses approaching 20 lbs/ft² (960 Pa), the Vmax³ reinforced vegetation DID NOT FAIL.

This testing, in conjunction with past research, better quantifies the erosion control and vegetation reinforcement capabilities of the SC250, C350 and P550 and provides further substantiation for the design values of all three Vmax³ products as outlined in Tables 1, 2, 3 and 4. Even when exposed to flows generating tremendous levels of shear stress, the vegetated Vmax³ mats experienced nearly no soil loss and incurred no physical damage to their permanent structures while significantly increasing vegetation's resistance to flow. The success of the Vmax³ reinforced vegetation at sustaining these flows was further corroborated by physical observation of the test plots a few weeks after all flow testing was completed. The Vmax³ reinforced vegetation was still in exceptional condition and the vegetation had continued to thrive.

Superior performance of the Vmax³ series of products allows North American Green to offer the Ultimate Assurance Guarantee, which stands as the only comprehensive product performance guarantee in the erosion control industry. Please visit us on the Web at www.nagreen.com for details on the Ultimate Assurance Guarantee.

A free video documenting this research can be requested in DVD or VHS format at www.vmax3.com or by calling North American Green at 1-800-772-2040. The video can also be previewed at www.vmax3.com.

Vmax³ Composite Reinforcement Series

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