7E-11 Turf Reinforcement Mats (TRM)

Source: SI Geosolutions, Pyramat.

BENEFITS

	L	M	H
Flow Control	■		
Erosion Control	■	■	■
Sediment Control			
Runoff Reduction			
Flow Diversion			

Description: Turf reinforcement mats (TRMs) are composed of non-degradable synthetic fibers, filaments, nets, wire meshes, and/or other elements, processed into a permanent, three-dimensional matrix. TRMs are designed to impart immediate erosion protection, enhance vegetation establishment, and permanently reinforce vegetation during and after maturation.

Typical Uses: TRMs are typically used on steep slopes and in hydraulic applications such as high flow ditches and channels, stream banks, shorelines, and inlet/outlet structures. TRMs are used where erosive forces may exceed the limits of natural, unreinforced, vegetation, or in areas where limited vegetation establishment is anticipated.

Advantages:

- Can withstand high hydraulic shear stresses and velocities.
- Provides permanent, long-term reinforcement of vegetation. Does not degrade over time like RECPs.
- Ability to be vegetated creates a more aesthetically pleasing appearance than rip-rap, concrete, or other “hard armor” techniques.
- Can stabilize ground where vegetation is difficult to establish.
- Normally a less expensive alternative to “hard armor” techniques.

Limitations:

- Performance is dependant upon proper product selection and installation
- Can only withstand a limited amount of flow before hard armoring is required.

Longevity: Permanent.

SUDAS Specifications: Refer to Section 9040, 1.08, G, 2.09, and 3.13

A. Description/uses

Turf reinforcement mats (TRMs) are a three dimensional product, constructed of synthetic, non-degradable (though some products are a composite of degradable and non-degradable materials) materials. The non-degradable matting creates a permanent reinforcing system for vegetation. The resulting reinforced vegetation is able to withstand significantly greater erosive forces than normal vegetation.

Traditionally, hard-armor erosion control techniques, such as riprap and reinforced paving systems, have been employed to prevent soil erosion in highly erosive areas. Although these permanent measures can withstand substantial hydraulic forces, they are costly, and they do not provide the pollutant removal capabilities of vegetated systems.

TRMs enhance the natural ability of vegetation to permanently protect soil from erosion. In addition to providing scour protection, TRMs are designed to encourage vegetative root and stem development. By protecting the soil from scouring forces and enhancing vegetative growth, TRMs can raise the threshold of natural vegetation to withstand higher hydraulic forces on slopes, in streambanks and channels, and at inlet/outlet structures.

TRMs, unlike temporary erosion control products, are designed to remain in place permanently to protect seeds and soils, improve germination, and reinforce established vegetation. Some TRMs incorporate natural, degradable fiber material to assist in the initial establishment of vegetation; however, the permanent reinforcement structure of TRMs is composed entirely of non-degradable materials.

In addition to providing permanent reinforcement of vegetation, TRMs also protect disturbed surfaces immediately after installation (prior to establishment of vegetation). This benefit is important for preventing soil loss and protecting newly seeded areas.

B. Design considerations

TRMs are produced by a number of manufacturers, and are available in a wide variety of configurations. The following steps should be considered when designing and specifying an appropriate TRM.

1. Hydraulic stresses:

TRMs in channels should be designed based upon the calculated shear stress. The shear stress imposed on the TRM in the channel should be evaluated under two conditions: temporary (unvegetated) and permanent (vegetated). The temporary condition represents the unvegetated conditions immediately after installation of the TRM. The permanent condition represents the long-term protection provided by the TRM in its fully vegetated state.

A TRM in a permanent vegetated state should be designed to withstand a 10-year storm event. In a fully vegetated channel, the TRM is located well below the top of the exposed vegetation. As a result, its has little impact on the level of shear created by the flow and its presence can be ignored. In doing this, the shear stress in the fully vegetated channel is determined in the same manner as described in Section 7E-4 (Grass Channel).

The TRM should also be analyzed for unvegetated state. Since this condition is temporary, the unvegetated TRM can be evaluated for a 2-year storm (rather than the 10-year). This analysis also follows the method described in Section 7E-4, but since there is no vegetation, the Manning coefficient is constant. The Manning coefficient of a TRM is normally provided in the manufacturer's literature.

Many TRM manufacturers have software available to aid in the calculation of shear stress. This software may be available through the manufacturer's website or local product representative.

Once the anticipated shear stresses are known, a TRM can be selected. Most TRM manufacturers report the permissible shear stresses that their products can withstand in both the vegetated and unvegetated conditions. These values are typically determined from full-scale, third party hydraulic flume testing. Commonly accepted facilities for conducting these tests include the Texas Transportation Institute (TTI), Colorado State University, and Utah State University. The designer should select a product with a greater permissible shear stress than the actual calculated hydraulic shear stress of the system. Note: for TRMs containing degradable components, the reported permissible values must represent only the permanent, synthetic portions of the TRM to satisfy the long-term design and performance requirements.

2. Non-hydraulic stresses:

In addition to the hydraulic stress (shear), consideration must also be given to non-hydraulic stresses. Examples of non-hydraulic stresses include heavy mowing equipment, occasional vehicular traffic, and heavy debris in the channel, or on a slope.

The materials that most TRMs are constructed from are not intended to withstand these non-hydraulic stresses. This type of loading can cause the material to tear, creating the potential for failure of the entire system.

For installations that will be exposed to these types of stresses, a high tensile strength material should be specified. These high tensile strength materials are commonly called high survivability or high performance TRMs. These high strength TRMs will provide long-term structural integrity, even when exposed to potentially damaging non-hydraulic stresses.

Table 1: TRM material requirements and acceptable applications

	Property[1]	Test Method	Type 1	Type 2	Type 3
Material	Thickness	ASTM D6525	0.25 in	0.25 in	0.25 in
	Tensile Strength[2]	ASTM D6818	125 lb/ft	1,500 lb/ft	3,000 lb/ft
	UV Resistance[3]	ASTM D4355	80% @ 500 hrs	80% @ 1,000 hrs	90% @ 3,000 hrs
Performance	Maximum Shear Stress (Channel Applications)	ASTM D4640	8 lb/ft^2	10 lb/ft^2	12 lb/ft^2
	Maximum Slope Gradient (Slope Applications)	N/A	1:1 (H:V) or flatter	1:1 (H:V) or flatter	1:1 (H:V) or greater

1. For TRMs containing degradable components, all values must be obtained on the non-degradable portion of the matting.
2. Minimum Average Roll Values, machine direction only. Tensile strength from ASTM D5035 may be substituted upon approval.
3. Tensile strength of structural components retained after exposure.
4. Minimum shear stress that fully-vegetated TRM can sustain without physical damage or excess erosion (0.5 in soil loss) during a 30 minute flow event in large scale testing. Acceptable large scale testing protocol includes ASTM D6460 or independent testing conducted by the Texas Transportation Institute, Colorado State University, Utah State University, or other approved testing facility.

C. Application

Turf reinforcement mats should be selected and used in locations where vegetation alone cannot withstand the anticipated flow velocities and shear stresses, and where hard armor (concrete and riprap) is not necessary or is visually unappealing, or where stormwater quality and sediment/pollutant removal is desirable.

D. Maintenance

Once installed, there is little maintenance that needs to be done to TRMs. If the TRM is to be vegetated, the vegetation should be watered as needed (refer to Section 7E-6). Until the vegetation is fully established, the ground surface should be inspected for signs of rill or gully erosion below the matting. Any signs of erosion, tearing of the matting, or areas where the matting is no longer anchored firmly to the ground should be repaired.

E. Design example

Assume a channel with a 4-foot bottom, 3:1 side slopes, and a slope of 3% is designed to carry 265 cfs. Lining the channel with a TRM is being proposed. Determine if a selected vegetated TRM, with Class C vegetation is adequate. Also analyze the TRM for the unvegetated condition to ensure that it will provide sufficient protection until vegetation is established. The manufacturer of the TRMs provided the following information on the TRM's properties:

Permissible shear stress, vegetated – 8 lbs/ft^2
Permissible shear stress, unvegetated – 4.55 lbs/ft^2
Manning's n Coefficient – 0.026

Solution:

First determine the shear stress for the vegetated condition. Using Manning's equation, find the depth of flow. This can be done through a trial and error process, or by using various tables and charts.

Trial 1 – Assume a depth of 2 feet.

Area of Flow, $A = (b + Z \times d) \times d = (4 + 3 \times 2) \times 2 = 20\ \text{ft}^2$

Wetted Perimeter, $P = b + 2 \times \sqrt{d^2 + (Zd)^2} = 4 + 2 \times \sqrt{2^2 + (2 \times 3)^2} = 16.6\ \text{ft}$

Hydraulic Radius, $R = A/P = 20/16.6 = 1.2$

Manning coefficient (from Equation 1, Section 7E-4):

$$n = \frac{0.1.2^{1/6}}{19.97\left(\log\left(44.8 \times 0.66^{0.6} \times 1.2^{-0.4}\right) + \log\left(0.1.2^{1.4} \times .03^{0.4}\right)\right)} = 0.051$$

Solving Manning's yields: $Q = {1.49}/{n}\, AR^{2/3} S^{1/2} = \left({1.49}/{0.051}\right)(20)(1.2)^{2/3}(0.03)^{1/2} = 114\ \text{cfs}$

Since 114 cfs is less than the design value of 265 cfs, a larger depth should be assumed.

Trial 2 – Assume a depth of 3 feet.

Following the procedure for Trial 1 – A = 39; P=23; R=1.7; n=0.045; Q= 318 cfs. Q is too large.

Trial 3 – Assume a depth of 2.8 feet

A=34.7; P=21.7; R=1.6; n=.046; Q=266 – Say 265 cfs OK.

Now that the depth is known for the vegetated condition, the shear stress can be determined by Equation 2 from Section 7E-4.

$$\tau_{max} = \gamma \times d \times S = 62.4 \times 2.8 \times 0.03 = 5.2 \text{ lbs/ft}^2$$

Since the maximum shear stress of 5.2 lbs/ft^2 is less than the capacity of the vegetated TRM (8.0 lbs/ft^2), the design is acceptable.

Now analyze for the unvegetated condition to ensure that an adequate level of protection will be provided until the vegetation is established.

Following the same procedure as the previous example, the channel properties are calculated. Note that for the unvegetated condition, a constant Manning coefficient (in this case 0.026) can be assumed.

Assuming a depth of 2.1
A=21.6; P=17.3; R=1.25; Q=249. Q is too low. Select a larger depth.

Assuming a depth of 2.16
A=22.6; P=17.7; R=1.28; Q=265. Assume 266 cfs. OK

Calculate Shear stress on the unlined channel.

$$\tau_{max} = \gamma \times d \times S = 62.4 \times 2.16 \times 0.03 = 4.04 \text{ lbs/ft}^2$$

Since the maximum shear stress of 4.04 lbs/ft^2 is less than the capacity of the unvegetated TRM (4.55 lbs/ft^2), the design is acceptable.