Technical Manual: Overtopping Protection for Dams

Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair

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FEMA

- ***Three-dimensional open***—Woven synthetic meshes having significant thickness (> 20 mm), which are placed in an unfilled condition and then filled with topsoil after seed has been sown.

- ***Three-dimensional filled***—Synthetic mats filled at the time of manufacture with bitumen-bound gravel chips that are still loose enough to permit natural growth of vegetation through the mat.

Some of the specific products tested for CIRIA and FHWA are still commercially available while others have disappeared from use, and many new products have become available. However, the categories described by Hewlett et al. (1987) still encompass most of the available materials. The summary result from the work of Hewlett et al. (1987), confirmed by USDOT (1988), was that in general, three-dimensional filled products and the more tightly woven two-dimensional products offer some immediate protection to the soil surface during the period of grass establishment, but three-dimensional open products provide the best performance after grass is fully established. This may be due to the fact that the infilling of three-dimensional open materials eliminates voids below the geotextile, and the resulting protective layer is relatively permeable compared to more tightly woven materials and the pre-filled mats, which allows for uplift pressure relief.

6.1.3 *Synthetic Turf Revetment*

An innovative erosion protection technology was developed in 2010 for embankment dams and levees that uses artificial or synthetic turf instead of natural grass or hard armor (i.e., RCC, ACBs, and rock riprap) to eliminate the long-term maintenance requirements and potential weaknesses of traditional vegetative and hard armor systems. HydroTurf™[5] combines a durable, engineered synthetic turf underlain by a high-friction impermeable geomembrane with an integrated drainage layer:

- The synthetic turf is infilled in place with a special blend of cementitious materials for ballast, having a compressive strength of 5,000 lb/in^2.

- The cementitious infill is placed dry to a thickness of approximately 1 inch and then hydrated with a light spray of water to produce an erosion-resistant surface. Its high strength is capable of resisting potential damage from vehicles, debris, and burrowing animals.

This system thereby offers the environmental and aesthetic benefits of natural vegetation (i.e., low-turbidity surface runoff and natural appearance) as well as the performance and maintenance benefits of hard armor. A typical installation is shown in Figure 6-1.

[5] Patented product of Watershed Geosynthetics LLC.

Figure 6.1.—HydroTurf™ Outfall Structure with St. Johns River Water Management District in Florida (Courtesy of Watershed Geo, all rights reserved).

6.2 *Design and Analysis*

Plain Vegetative Protection

The design and analysis of a plain grass protective layer on an embankment dam can be accomplished using the erosionally effective stress method described in detail by Temple et al. (1987), updated by Temple et al. (2003), and summarized for application to the allowable overtopping of earthen dams by Temple and Irwin (2006). This method considers the hydraulic attack in the form of shear stress and separate erosion-resistive characteristics of the vegetation and underlying soil.

Application of the erosionally effective stress method begins with consideration of the flow conditions over the dam crest. To accommodate the largest possible overtopping discharge, the crest should be level throughout its length to minimize flow concentrations. Since most embankment dams have some degree of nonuniformity of the crest profile due to camber, the hydraulic attack of the flow should be evaluated at the location of minimum crest elevation and maximum unit discharge.

Flow conditions down the slope are generally represented by uniform flow calculated from Manning's equation (Equation 6-1), as follows.

6.2.3 *Synthetic Turf Systems*

The HydroTurf™ system (Figure 6-3) has been extensively tested at CSU (2013) and has shown good performance under a wide variety of flow conditions, including both sustained flows and wave overtopping. CSU reported stable performance on a silty sand subgrade at a 2:1 slope for steady-state overtopping depths up to 5 feet for a total of 12 hours, with a maximum flow velocity of 29 ft/s and a maximum shear stress of 8.8 lb/ft^2, with a Manning's "n" value of 0.020. Testing was performed in accordance with ASTM D7277 and analyzed in accordance with ASTM D7276; however, testing data are proprietary. Hydraulic jump testing was also performed in the steady-state flume at overtopping depths up to 5 feet with no system instability or underlying soil erosion.

Full-scale wave overtopping testing for levee landward-side slope protection and stability was performed by CSU (2013) on HydroTurf™ in accordance with a methodology developed for USACE. It was tested for 13 hours, with a cumulative water volume of 165,600 ft^3/ft, up to the limits of their wave overtopping simulator, with an average unit discharge of 4 ft^3/s/ft. This flow rate represents a 500-year generic hurricane (or 0.2 percent annual exceedance probability) in New Orleans, Louisiana. On both intact and intentionally damaged installations, the performance of HydroTurf™ was described as good on a highly-erodible silty sand subgrade.

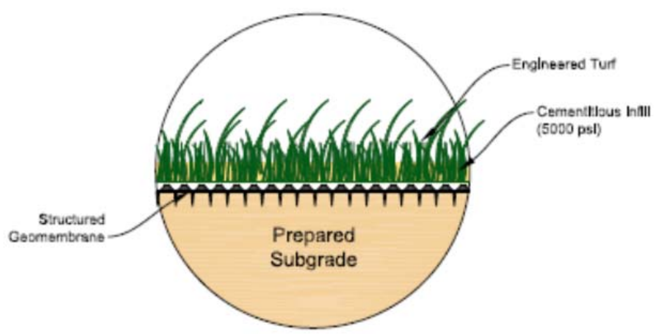

Figure 6-3.—Synthetic turf revetment system (Courtesy of Watershed Geosynthetics LLC, 2013, all rights reserved)

There is currently insufficient information to support further discussion of the design and analysis of synthetic turf systems. There is only one product in this category and it has not been tested to failure, so the mechanisms by which it will fail are unknown. The only design approach would be strictly empirical on the basis of limited laboratory tests and experience. The manufacturer of the HydroTurf™ system should be contacted for further information and guidance in the use of this product.