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The Engineering and Science Behind ScourStop Transition Mats: A White Paper

INTRODUCTION

Transition mat technology for scour erosion control has come of age. In less than a decade, an engineered soft armor concept has gained acceptance as a replacement for rock rip rap and other hard armor technologies.

Over the last several years, concern about tightening U.S. Environmental Protection Agency NPDES Phase II requirements has led engineers to consider new solutions to achieve the required minimum control measures in post-construction stormwater treatment. Newer and more stringent stormwater pollutant discharge regulations are dictating accountability on the part of property owners, public or private, through Total Maximum Daily Loading (TMDL) requirements. NPDES permittees must design, install and maintain effective erosion and sediment control to minimize discharge of pollutants.

In response, owners are encouraging civil engineers to design projects that meet legal requirements, during construction and after, and to consider regular and long term maintenance costs of design features. All stakeholders, including contractors, have an incentive to utilize engineered erosion control technologies in meeting today's goals because of encompassing liability.

ROCK AND HARD ARMOR

For many years, erosion control for extreme hydraulic conditions was limited primarily to rock rip rap applications. Some of these have worked well when both properly designed and installed, but they also have several potential drawbacks, any one of which could lead to system failure. These include:

Proper design – A wide variety of rock sizing equations exist. Rock sizing methodologies for channel applications include published equations from the Federal Highway Administration (HEC-11), U.S. Army Corps of Engineers, CALTRANS, ASCE, USGS plus the Ishbash curve. Each delivers different results given the same design inputs, particularly at increased flow velocities. Which is correct? It depends on the application itself. Typically, engineers specify the smallest rock size possible as it is less expensive, easier to acquire and transport to the site, and install. But – if it's the wrong rock size for the application, it can lead to a failure.

Proper excavation and installation – Even appropriately sized rock applications can fail if the site is not properly excavated and graded. A poor installation can be as simple as the contractor installing the wrong size of rock, improper filter layer design, thickness layer consistency or even rock quality. In many instances, the length of protection installed is too short, leading to head cutting that compromises the entire system. In short: a poor installation negates the best design.

Maintenance and continued inspection – Hard armor erosion control systems must be properly maintained to remain effective. Design criteria call for inspections after major storm events to ensure system integrity. NPDES Phase II, Rule #5 requires annual inspection of all post-construction control systems. Ongoing inspections and repairs for rock rip rap often strain municipalities' budgets with significant and recurring costs. But as transportation and maintenance budgets have declined, maintenance and inspection often are delayed or do not occur at all, leading to potential system failures.

ENGINEERED SOLUTIONS

Transition mat technology became available over a decade ago. The first system introduced, ScourStop, has gained acceptance among state departments of transportation and civil engineers as a proven replacement to hard armor in applications that include (but are not limited to) culvert outlets, bridge drains, channels, stream bank stabilization, overflow structures, parking lot outfalls and intermittent check slots in soft-armored drainage ways.

The ScourStop transition mat system is comprised of three components and serves as a biotechnical replacement for hard armor, providing high energy scour protection using (1) a polymer transition mat for mechanical protection, (2) an anchoring system that secures the mat to a depth of 12 to 36 inches depending on soil conditions, and (3) a vegetative soil cover such as sod, turf reinforcement mat (TRM), geotextile or a combination of these, which protect the underlying soil while the transition mat protects the system against hydraulic forces associated with shear stress and flow velocity. The soil cover is typically continued downstream to prevent erosive head cutting, and often on to receiving waters.

Overall, ScourStop has proven – both in the field and at a premier hydraulic testing facility – to be a viable replacement to rock rip rap:

- Multi-year hydraulic testing at the Engineering Research Center's Hydraulics Laboratory at Colorado State University confirms performance results that meet or exceed those of hard armor such as rock rip rap and articulated concrete blocks for scour outlet protection.
- Results have shown to be equal to or more effective than conventional hard armor solutions, with several advantages:
  - System maintenance is minimal compared to traditional solutions, reducing the life cycle costs.
  - Eliminating over-excavation for the hard armor lining reduces the overall application footprint required, saving real excavation costs, optimizing usable land and saving potential costs for right-of-way acquisition.
  - ScourStop offers 50% open area, supporting dense vegetative establishment in applications of high hydraulic stresses, where vegetation alone traditionally hasn't been an option. The EPA recognizes vegetation as a construction and post-construction Best Management Practice (BMP) for stormwater management. Maximizing the amount of potential vegetation in a stormwater conveyance system increases EPA compliance and reduces pollutant contamination of the stormwater runoff.

RESEARCH BEHIND THE TECHNOLOGY

To determine viability under "worst case" scour erosion control conditions, ScourStop has been evaluated by CSU's Hydraulics Laboratory and Engineering Research Center over a five-year period (2005-2010). The extensive test and research program was designed to quantify the performance of ScourStop under numerous design conditions. Recommended design values for both Day One protection as well as under fully vegetated conditions have been appropriately documented under full-scale test conditions. Tests performed include:

The Reality Test (2005)

Objective: Examine the use of the transition mat system at the culvert outlet under extreme conditions to determine the system's maximum performance and its viability as a replacement for rip rap used downstream of a culvert outlet.

Method Synopsis: A high energy, turbulent flow from a 33" diameter pipe served as the flow source.

Results: ScourStop (with both non-rooted sod and un-vegetated high-performance TRM) outperformed 12-inch diameter rip rap, sod alone, and stand-alone TRM. In fact, flow velocities more than twice the typically recommended value for designing culvert outlets were achieved.

Results (Note: product did not fail. Test reached ASTM standards of 0.5" soil loss, the point at which it is believed the seed bed is lost.)	
Erosion Control Mechanism	**Maximum velocity**
ScourStop + non-rooted sod	16 ft./sec.
ScourStop + un-vegetated HP TRM	11.7 ft./sec.
Baseline Comparison	
6" rip rap	8.45 ft./sec.
12" rip rap	10.65 ft./sec.
Sod	5 - 6 ft./sec.
TRM	5 – 6 ft./sec.

Day One Performance Test (2007)

Objective: Quantify the performance of the system in a worst-case scenario (i.e. design event occurs immediately following installation).

Method Synopsis: Test with non-rooted sod and unvegetated TRM/geotextile combination in a channel with extreme hydraulic flows on 4:1 and 2:1 slopes.

Results: The product provided protection under extreme conditions across a range of channel slopes and system components. Performance values obtained were limited by the capabilities of the test facility. No loss of soil was recorded during the tests.

Results: Indoor 4:1 Slope (Note: The limits of the testing facility were reached before maximum performance was reached.)	
Erosion Control Mechanism	**Maximum Velocity and Shear Stress**
Non-rooted sod	19.3 ft/sec. velocity, 7.1 lbs./sq. ft. stress
TRM/geotextile combination	19.5 ft/sec. velocity, 8.1 lbs./sq. ft. stress
Outdoor 2:1 Slope (tested to 0.5" of soil loss)	12 ft/sec. velocity, 13 lbs./sq. ft. stress

Established Vegetation Test (2009)

Objective: Determine the product's performance threshold for a fully vegetated system in a channel application.

Method Synopsis: In an outdoor facility, a 2:1 slope was used with rooted sod established for one year; ScourStop was anchored in accordance with typical field installations.

Results: Levels reached in the fully vegetated state outperformed any other available option in the erosion control industry. Performance values obtained were limited by the capabilities of the test facility. No loss of soil was recorded during the tests.

Results: Rooted sod, 2:1 slope (Note: The limits of the testing facility were reached before maximum performance was reached.)		
Unit Discharge	**Maximum Velocity**	**Shear Stress**
q = 16.3 ft.^{3}/second	23.8 ft./second	16. 1 lbs./square foot
q = 27.7 ft.^{3}/second (max. q)	31.6 ft./second	12.7 lbs./square foot

Design Guidance Test (2010)

Objective: Using an undistorted 1:4 Froude scale model, the test was designed to determine how far downstream of a culvert outlet ScourStop protection is needed to protect the native soil and ensure site stability.

Method Synopsis: In an indoor facility, tests were conducted using three pipe diameters (6", 12" and 17") in three channel widths (8', 6' and 4') and two roughness variations (Day One vs. fully vegetated), which scientifically scale up to real world applications.

Results: A wide channel with a small outlet pipe dissipates energy quickly, with a roller wave on the side but without much turbulence. A narrow channel with a wide outlet pipe generates more of a longitudinal roller wave due to the influence of the channel sides, which leads to a defined hydraulic jump downstream of the culvert where the velocities converge. Using the data from these tests, a design tool was developed to provide engineers with a mechanism to determine the width and length of ScourStop required for a given site based on input parameters such as discharge rate, velocity at the pipe outlet, channel width and pipe diameter.

IN CONCLUSION

The industry practice of specifying products with performance ratings based on fully vegetated applications instead of Day One performance levels carries with it an inherent risk. If erosion occurs before vegetation can establish, regular sediment discharges will result and with that, NPDES non-compliance. Up until now, there has been no green alternative that can deliver Day One performance at higher hydraulic velocities and shear stresses.

ScourStop transition mats offer a permanent, no-maintenance, vegetated, NPDES-compliant replacement for rock rip rap and other hard armor solutions. Independent, defensible and reproducible research at Colorado State University's premier hydraulics laboratory validates its consistent and predictable performance thresholds. The research demonstrates that, in areas of highest velocity and shear stress, ScourStop dissipates hydraulic forces to levels that can be handled by other soil covers downstream. Fully vegetated, ScourStop can withstand hydraulic velocities of 31 ft/sec and 16 pounds of shear; on Day One, those values are 19 ft/sec and 7 pounds of shear on a 4:1 slope and 12 ft/sec and 13 pounds of shear on a 2:1 slope.

We invite engineers to try out our online design tool at www.hanesgeo.com and input their own parameters to see how ScourStop can be used to benefit their projects.