Finding the Right Erosion Control Solution

Performance Based Classification System for Hydraulically Applied Erosion Control Materials

By Marc S. Theisen, M.S., CPESC, CPSWQ,
Michael D. Robeson, M.S., P.E., CPESC, CPSWQ
and Frank Lauro, P.E., CPESC, CPSWQ

Hydraulic seeding and mulching techniques have come a long way since the introduction of the first hydraulic seeding equipment in 1953. Over the past 50 years, hydraulic seeding/planting equipment, hydraulic mulches and performance enhancing additives have shown continuous evolution and improvement, resulting in equipment and materials that offer enhanced performance and greater productivity over traditional methods of controlling erosion and establishing vegetation.

Despite the documented advantages and widespread use of these newly evolving technologies, the understanding of Hydraulically applied Erosion Control Products (HECPs) and their cost-effective benefits remains enigmatic. Much of this stems from a lack of direction and material categorization by the hydraulic erosion control industry. Traditionally, green-colored slurries have been applied on areas such as steep slopes, commercial and residential properties, golf courses and athletic facilities. To an untrained eye, the materials exiting the hydraulic mulching equipment appear nondescript. However, contained within these slurries are a growing family of refined wood matrices, tackifiers, naturally derived biopolymers, super-absorbents, flocculating agents, man-made fibers, plant biostimulants and other performance enhancing additives. How can one identify one system from another and, more importantly, where and how does one select and use a technique or system over another?

The purpose of this article is to offer a basic categorization of hydraulically applied materials based upon the attributes described above. This system will offer owners, agencies, designers and contractors a simplified process for product selection and help ensure cost-effective applications while increasing awareness and utility for hydraulically applied erosion control techniques.

Relevant Properties for Design

Index and performance properties are used to differentiate between different classes of hydraulic mulches. Index properties are a measurement of a property that is indicative of a performance characteristic while a performance property is a direct measurement of that characteristic. As the hydraulic erosion control industry evolves in its adoption testing protocols and procedures, several testing procedures have been adopted from the Rolled Erosion Control Product (RECP) industry.

The two primary goals when using hydraulically applied materials are erosion control and vegetative establishment. The hydraulically applied matrix provides immediate erosion protection while creating an environment that assists in accelerating vegetative establishment. Vegetation then provides the long term erosion protection while improving site aesthetics and acting as a filter to remove sediment and other undesirable storm water constituents from entering receiving water bodies. The following properties are most relevant when attempting to achieve these goals:

- *Functional Longevity*
- *Erosion Control Effectiveness*
- *Vegetative Establishment*
- *Wet Bond Strength*

These properties are described further below and on following pages.

Functional Longevity

Functional longevity is a measure of how long the hydraulically applied matrix can be expected to adequately protect the seed and soil from splash and overland flow erosion caused by rainfall. Varying from region to region, functional longevity depends on climatic conditions such as the intensity, duration and frequency of rainfall events, incoming solar radiation and temperature. Other parameters affecting functional longevity include slope aspect, slope inclination, slope length, soil

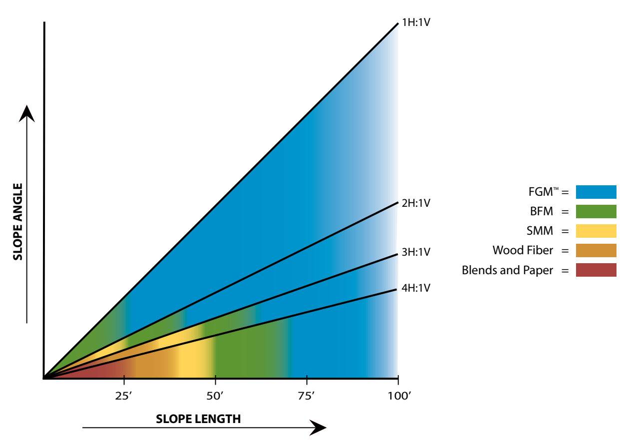


FIGURE 1: Hydraulically applied erosion control materials selection guideline

type and vegetation characteristics. It can be correlated with percent effectiveness but the best method of determination is the use of field experience and judgment by a qualified professional in conjunction with ASTM D5338. The use of this test and field observations allows for a proper basis for functional longevity claims. Functional longevity is an important consideration on challenging slopes and other sites with high erosion potential and the possibility of slow vegetation establishment.

Percent Effectiveness

Percent effectiveness (PE) is a measure of the ability of a hydraulically applied matrix to protect the soil from splash erosion and overland flow caused by rainfall impact. Percent effectiveness is directly related to the cover (C) factor from the Revised Universal Soil Loss Equation and can be calculated by the following relationship:

$$PE = (1-C) \times 100\%$$

The C factor is commonly evaluated using large scale testing with rainfall simulators at universities and test labs. Typical rainfall intensities range from 2-6 inches/hour while testing durations range from 20-60 minutes. The following laboratories have the appropriate facilities, kinetic energy and setup to evaluate this property for hydraulically applied erosion control products:

- *Utah State University - Utah Water Research Laboratory – Logan, Utah*
- *Texas Transportation Institute – College Station, Texas*

This property can be highly variable and depends on rain event duration and intensity, soil type, slope inclination, slope length and hydraulic matrix application rate. Unless field conditions match those evaluated in the laboratory, the use of this property to quantify actual field performance can be difficult. However, this property does provide a means of comparative performance between different erosion control materials when tested under the identical conditions. Percent effectiveness is a key property in the development of a performance-based classification system.

Vegetative Establishment

Vegetative establishment is a measure of ability of an erosion control material to encourage seed germination and plant growth and can be evaluated using ASTM D7322. The larger the value for vegetative establishment, the faster the desired level of vegetation may be achieved. This property is highly dependent on the water-holding capacity of the medium. Typically, the more moisture a medium can retain, the faster vegetation will be established. This property is also dependent on the flexibility of the matrix. The more flexible the matrix, the better it conforms to the subgrade and the more uniform contact the matrix has with the seed and soil. Hydraulically applied materials are very flexible when compared to rolled erosion control materials that must have a smooth seedbed to maintain intimate soil contact.

Wet Bond Strength

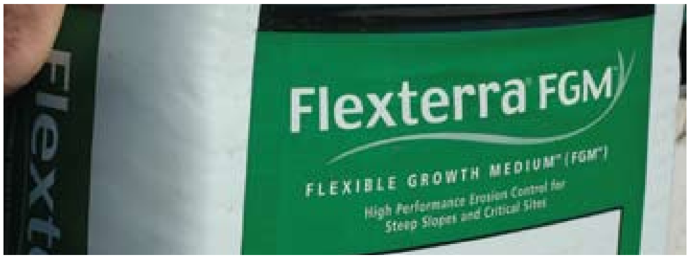
Hydraulically applied materials are typically used in areas that only receive rainfall impact and sheet flow (i.e., slopes). Unexpected rainfall events on unprotected slopes can cause rills and gullies to develop. For constructed slopes that are steeper than 2H:1V, it can be difficult – if not impossible – for heavy equipment to access these slopes to grade them smooth. Within the pre-existing rills and gullies are areas of potentially concentrated flow, and therefore areas where shear stresses can develop. Under these conditions, wet bond strength of the hydraulic matrix is an important property and can be evaluated using a modified version of ASTM D6818.

It is important to recognize the value of hydraulically applied matrices when used synergistically with erosion control products such as Turf Reinforcement Mats (TRMs) designed to accommodate shear stresses developed in channels and on steep slopes. The immediate erosion control and growth establishment properties previously described for hydraulically applied matrices are highly complementary when placed into a three-dimensional TRM structure. The resulting acceleration of growth and maximization of root entanglement and reinforcement will greatly contribute to both short- and long-term performance.

Classification Systems

With a general understanding of the properties that determine hydraulically applied material effectiveness, users can now better understand what type of matrix is right for them. Hydraulically applied materials are combinations of wood and wood cellulose fibers and water, with or without the addition of tackifiers, naturally derived biopolymers, stabilizing emulsions, flocculating agents and man-made fibers. These ingredients are mixed in hydroseeding equipment and sprayed onto disturbed soil surfaces to protect from wind and water erosion. They can be applied without seed for temporary erosion control or with seed, fertilizers and soil amendments for permanent or temporary vegetative establishment.

There are four main types of hydraulically applied materials that are grouped together based on similar performance properties. These



categories of hydraulic mulches are arranged in order of increasing performance and presented in Figure 1.

- *Hydraulic Mulch*
- *Stabilized Mulch Matrix*
- *Bonded Fiber Matrix*
- *Flexible Growth Medium™*

Hydraulic Mulch

Hydraulic mulches (HMs) consist of 100% recycled shredded wood and/or paper fibers, water and/or a stabilizing emulsion (0-3% by weight). Stabilizing emulsions typically consist of an organic tackifier or an inorganic polymer. Common stabilizing emulsions include guar gum, psyllium (plantago) and/or polyacrylamide. Application rates vary from 1,500 to 2,500 lb/ac based on fiber type, slope gradient and slope length. HMs are commonly used to aid in the establishment of vegetation and the temporary stabilization of flat surfaces and moderate slopes (< 4H:1V). HMs typically have a functional longevity of less than three months.

HMs were evaluated for percent effectiveness at Utah Water Research Laboratory (UWRL). This comprehensive testing indicates that, when subjected to larger rain events (5-in/hr for 30 minutes), HMs are less than 70% effective at reducing erosion.[2-4] When the test duration is increased to 60 minutes, percent effectiveness values of < 50% were observed.[2-4] It is important to note that pre-mixed formulations offer proven and more consistent results over field-mixed concoctions that may exhibit wide variability in performance.

Stabilized Mulch Matrix

Stabilized Mulch Matrices (SMM) consist of wood or paper fibers, stabilizing emulsions and water. If paper fiber is used, it should be blended with wood fiber[1]. Common stabilizing emulsions include polyacrylamide flocculants and cross-linked hydro-colloidal tackifiers. These are typically added at a rate of 3-5% by weight.

Cross-linking is an important step in increasing the bond strength and longevity of the hydro-colloidal tackifier. Cross-linking is a chemical process that reduces the water solubility of the tackifier and, therefore, increases the longevity. Cross-linking also keeps the tackifier from rewetting and potentially leaching after the matrix has cured.

Polyacrylamide flocculants function differently than cross-linked, hydro-colloidal tackifiers. Cross-linked, hydro-colloidal tackifiers form a chemical bond that holds the fiber matrix together, thereby protecting the soil from rainfall impact and splash erosion. Polyacrylamide holds soils in place by ionically bonding them together to increase the particle size. Cross-linking results in greater infiltration through the soil pores and increased resistance to erosive forces.

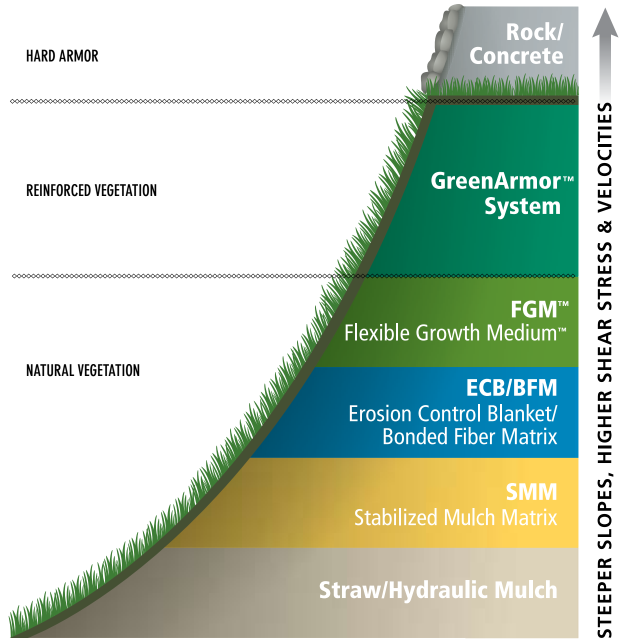


Figure 2: Performance Based on Slope, Shear Stress and Velocity

Regardless of the type of stabilizing emulsion used, the matrix must dry thoroughly after application, which typically takes 12 to 36 hours depending upon weather and antecedent soil moisture conditions. Application rates vary from 2,500-3,500 lb/ac based on slope inclination. SMMs are commonly used to stabilize flat pads and moderate slopes (< 3H:1V) for a period of three to six months. Testing at Utah Water Research Laboratory indicates that SMMs are greater than 90% effective at reducing erosion when subjected to a 5-in/hr rain event for a duration of 60 minutes[2]. As previously mentioned, formulations pre-mixed by the manufacturer offer greater peace of mind and factors of safety over field mixtures where quality control can no longer be assured.

Bonded Fiber Matrix

Bonded Fiber Matrices (BFMs) have been in use for over 15 years and have received acceptance by many state departments of transportation, public agencies and private specifiers. BFMs are pre-blended formulations consisting of Thermally Refined®, 100% recycled wood fibers, naturally derived biopolymers and are 100% biodegradable. BFMs are designed to provide erosion protection for six to 12 months and are commonly used for erosion control and vegetative establishment on steep slopes, long slopes (≤ 2H:1V) and highly erosive soils. Curing

TABLE 1: Summary of Performance Properties

PROPERTY	TEST METHOD	HYDRAULIC MULCH	STABILIZED MULCH MATRIX	BONDED FIBER MATRIX	FLEXIBLE GROWTH MEDIUM
Percent Effectiveness[1,2]	UWRL Protocol	< 50%	> 90%	> 95%	> 99%
Cure Time	Observed	12-24 hours	12-36 hours	24-48 hours	No Curing Period
Wet Bond Strength	ASTM D6818[3]	0	4.5 lb/ft	6 lb/ft	7.5 lb/ft
Vegetative Establishment	ASTM D7322	Not Reported	400%	600%	800%
Functional Longevity	ASTM D5338	< 3 months	3-6 months	6-12 months	> 12 Months

NOTE 1: Intensity of 5 in/hr, duration of 60 minutes
NOTE 2: Percent effectiveness (PE) is related to the cover factor ("C" factor) by PE=(1-C) x 100%
NOTE 3: ASTM test method developed for Rolled Erosion Control Products that have been modified to accommodate hydraulically applied erosion control products

TABLE 2: Summary of Materials for Various Performance Categories

CATEGORY	FIBER	STABILIZING EMULSION	APPLICATION RATE[1]
Hydraulic Mulch	Wood, Paper or Blend	0-3%	1,500-2,500 (lb/ac)
Stabilized Mulch Matrix	Wood or Blend	3-5%	2,500-3,500 (lb/ac)
Bonded Fiber Matrix	Wood	10%	2,500-4,000 (lb/ac)
Flexible Growth Medium	Wood and Man-Made	10%	2,500-4,500 (lb/ac)

1. Increase application rate as slope gradient increases, for soil with few fine soil particles or expansive properties, for roughened surfaces, and in areas of heavy rainfall.

takes approximately 24 to 48 hours and application rates vary from 2,500-4,000 lb/ac based on slope length and inclination. Testing by the Utah Water Research Laboratory indicates that BFMs are greater than 95% effective at reducing erosion when subjected to a 5-in/hr rain event for durations of 60 minutes.

Flexible Growth Medium™

Flexible Growth Media (FGM™) are pre-blended formulations consisting of Thermally Refined®, 100% recycled wood fibers, naturally derived biopolymers, crimped, man-made fibers and are 100% biodegradable. The man-made fibers are crimped to interlock and provide mechanical reinforcement of the matrix. FGM are the highest-performing hydraulically applied technology and provide greater than 99% erosion control effectiveness when subjected to a 5-in/hr rain event for durations of 60 minutes[4], at Utah Water Research Laboratory and three, 30 minute events at 3.5 inches/hr at Texas Transportation Institute (TTI).[4,5] They also require no curing period. The use of man-made fibers increases the loft of the matrix and thereby increases the porosity and water-holding capacity. The increased water-holding capacity has resulted in greater vegetative establishment than any other reported hydraulically applied erosion control material evaluated using ASTM D7322.

FGM have functional longevities of greater than 12 months.[1] FGM are commonly used to stabilize steep slopes (< 1H:1V), long slopes, rough slopes, highly erosive soils and when rainfall is expected within 48 hours.

Table 1 summarizes the performance properties for the different categories of hydraulically applied technologies and Table 2 summarizes the various materials.

Product Selection

When selecting the appropriate hydraulically applied technology, many factors should be evaluated including:

- *Functional longevity*
- *Slope length*
- *Slope gradient*
- *Soil type/texture*
- *Soil preparation*
- *Expected vegetation*
- *Rainfall parameters*
- *Soil fertility*

As the slope length and gradient increase, the water travels at a faster velocity, exerting larger erosive forces on the soil. Therefore, for steeper and longer slopes, a higher performing product is warranted to adequately stabilize the soil and increase factors of safety. Figure 2 presents a simplified design chart that recommends a product category based on slope inclination and length. Combined with the functional longevities presented in Table 1, the appropriate level of performance can be selected based on project requirements. In addition, a free, comprehensive web-based design and product selection program that integrates all of the above parameters and allows for agronomic soil testing to assist users in selecting appropriate erosion and revegetation products is available at www.profileps3.com.

Conclusion

Today's technologically advanced erosion control products offer specifiers and users exceptional advancements to help keep soil and vegetation in place. With this general understanding of available hydraulically applied technologies and the attributes appropriate for specific projects, in conjunction with a design resource such as www.profileps3.com, users can be assured of selecting the technology that's best for them.

1. Caltrans [2003], "Guidance for Temporary Soil Stabilization," July.
2. Utah State University [2004], Profile Internal Testing Report performed by Utah Water Research Laboratory, Report No. 1563, December.
3. Utah State University [1996, 1998, 2001], Profile Flexterra Internal Testing Reports performed by Utah Water Research Laboratory.
4. Utah State University [2001, 2002, 2003], Profile Hydraulic Mulches Internal Testing Reports performed by Utah Water Research Laboratory, 30 and 60 minute test durations.
5. Texas Transportation Institute [2006], Profile Flexterra Internal Testing Report performed by Texas Transportation Institute.

Marc S. Theisen, M.S., CPESC, CPSWQ is vice president-business development and engineered products for PROFILE Products LLC, and is based in Signal Mountain, Tennessee.

Michael D. Robeson, M.S., P.E., CPESC, CPSWQ is technical services manager for PROFILE Products LLC, and is based in Loveland, Colorado.

Frank Lauro, P.E., CPESC, CPSWQ is based in Bakersfield, California.

They can be contacted at mtheisen@profileproducts.com and mrobeson@profileproducts.com respectively.