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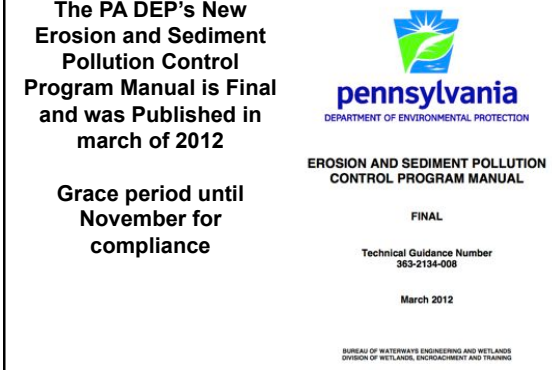
The PA DEP's New Erosion and Sediment Pollution Control Program Manual is Final and was Published in march of 2012

Grace period until November for compliance



The Draft Manual introduces:

"Antidegradation Best Available Combination of Technologies (ABACT) BMPs"

- "Where it is not possible to avoid discharging from disturbed area to a special protection watershed ABACTs should be used to the fullest extent"
- "BMPs with low sediment removal are not ABACTs."
- "BMPs with moderate sediment removal efficiencies are ABACTs for HQ watersheds but not EV watersheds"
- "BMPs with high sediment removal efficiencies are ABACTs for HQ and EV watersheds"

Chapter 3 – SITE ACCESS: ROCK CONSTRUCTION ENTRANCE - Sediment Removal Efficiency: LOW. This device is not an ABACT for special protection watersheds.

Rock construction entrances should be maintained to the specified dimensions and the capacity to remove sediment from the tires by **adding rock when necessary**. For **some sites** this may occur **several times a day**. A **stockpile of rock material should be maintained on site** for this purpose. It should be noted that from time to time the rock construction entrance can become **too clogged** and **may have to be removed and replaced.**

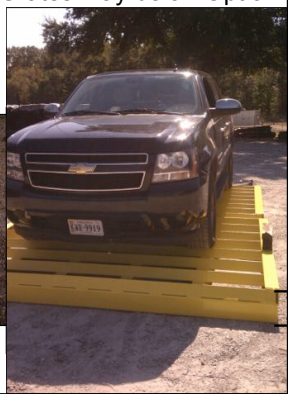
"RUMBLE PAD

Pre-constructed rumble pads may be used in lieu of rock construction entrances provided they are installed according to manufacturer's recommendations and a sufficient number of pads are installed to provide for a minimum of 4 tire revolutions while on the pad."

4 tire revolutions is about 45 feet.

Manufactured Rumble Grates May be an Option*

- Angular cross bars provide excellent tire flex / soil removal.
- Unit height provides storage for reduced maintenance cycles



*Submitted per Chapter 12 New Products and Procedures Process

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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"ROCK CONSTRUCTION ENTRANCE WITH WASH RACK - **Sediment Removal Efficiency: HIGH. This device is an ABACT for HQ and EV watersheds."**

Not pictured: Water Source for Washing Each Individual Tire

WHEEL WASH

Manufactured wheel washes may be used as ABACTS in special protection watersheds (or where special traffic safety issues exist). All such wheel washes should be installed and operated according to manufacturer's specifications. Waste water from the wheel washes should either be recycled or run through an approved sediment removal device prior to discharge to a surface water.

NW Equipment Sales

Portable above grade system provides one full tire revolution cleaning for moderate duty applications.

With the wash platform, access ramp and water management tank all above grade, this system configuration requires no excavation.

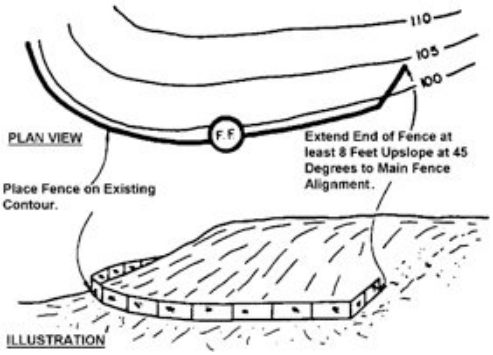
This below grade system provides two full tire revolution cleaning for moderate to heavy duty applications.

This configuration provides a gravity feed to the closed loop water recycling water management tank.

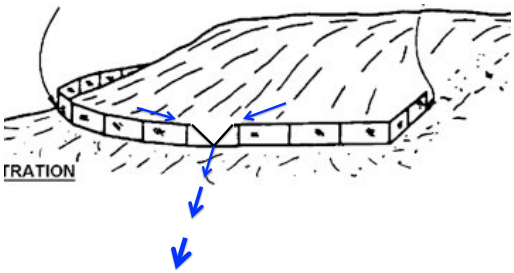
•CHAPTER 4 - SEDIMENT BARRIERS

•Sediment barriers are typically used as perimeter controls for small disturbed areas and as initial protection against sediment pollution during construction of other BMPs such as sediment basins or traps. Each type of sediment barrier has specific advantages and limitations. Care should be exercised in the selection of any sediment barrier to ensure it is suited to the particular site conditions where it is proposed.

FIGURE 4.1



Removal of perimeter controls is an important aspect of construction to post-construction transition. Uneven degradation of the perimeter control can lead to concentrated flow (rills to gullies to channels)



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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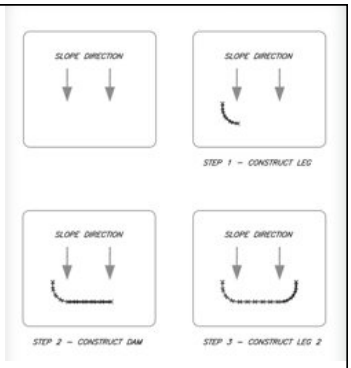
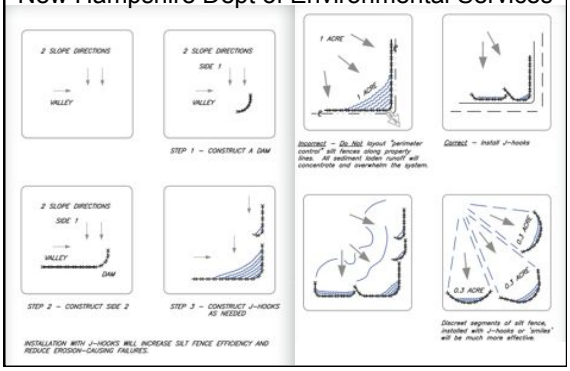
Installation technique with J-Hooks or "Smiles" can increase perimeter control efficiency



Typical Placement – One Slope

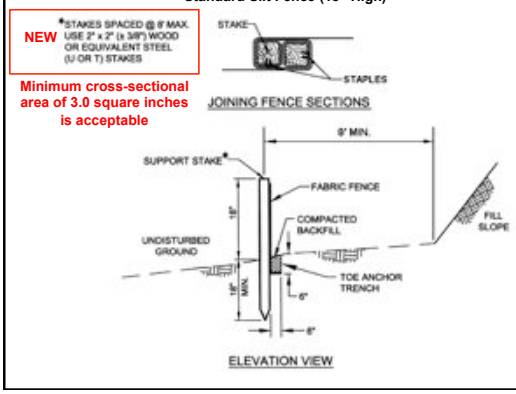
Typical Placement for Two Slopes
New Hampshire Dept of Environmental Services



SILT FENCE (FILTER FABRIC FENCE) - **Sediment Removal Efficiency: LOW. This device is not an ABACT for special protection watersheds. However, it may be used to increase the efficiency of another BMP which is an ABACT**

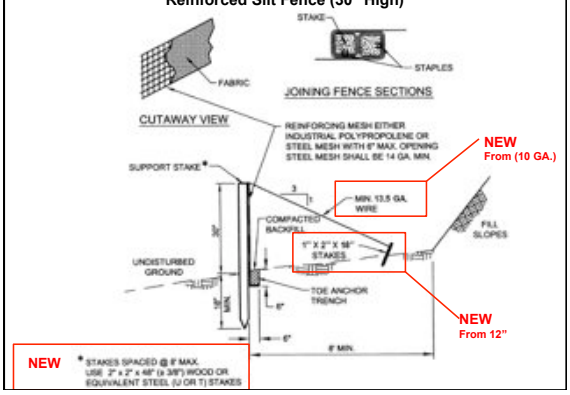
The PA E & S Manual calls out for two standard Silt Fences

STANDARD CONSTRUCTION DETAIL # 4-7
Standard Silt Fence (18" High)



Minimum cross-sectional area of 3.0 square inches is acceptable

STANDARD CONSTRUCTION DETAIL # 4-8
Reinforced Silt Fence (30" High)



The draft manual contains specifications for the silt fence geotextile fabric

TABLE 4.2
Fabric Properties for Silt Fence

Fabric Property	Minimum Acceptable Value	Test Method
Grab Tensile Strength (lb)	120	D1682
Elongation at Failure (%)	20% Max.	D1682
Mullen Burst Strength (psi)	200	D 3786
Trapezoidal Tear Strength (lb)	50	
Puncture Strength (lb)	40	D 751 (modified)
Slurry Flow Rate (gal/min/ sf)	0.3	
Equivalent Opening Size	30	US Std. Sieve CW-02215
Ultraviolet Radiation Stability (%)	80	G-26

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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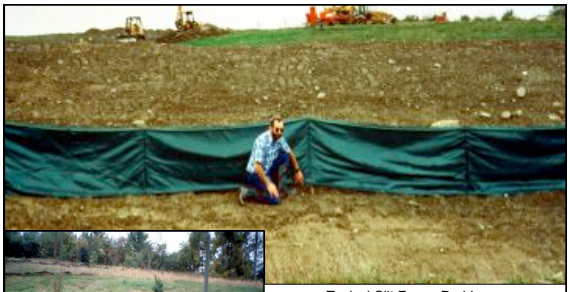
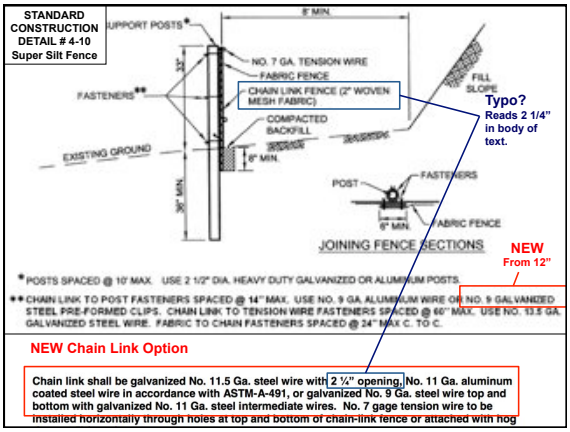


Typical Silt Fence Problems:

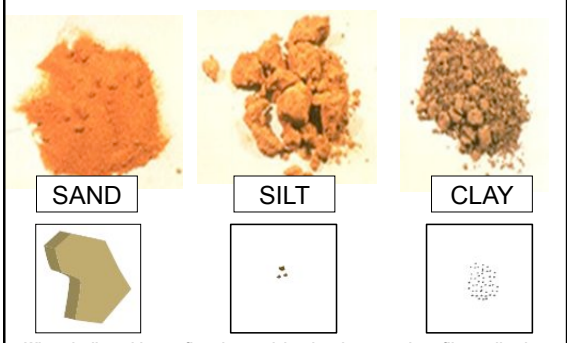
Above: Installed backwards and toe is not buried.

Left: Silt Fence left in place for years after construction

SUPER SILT FENCE - **Sediment Removal Efficiency: LOW. This device is not an ABACT for special protection watersheds. However, it may be used with another BMP that is an ABACT (e.g. vegetated filter strip) to make it more effective.**



It is Silt Fence (not clay fence).



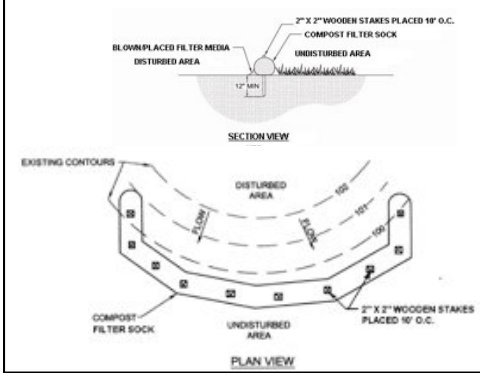
When dealing with very fine clay particles that do not settle or filter well, other treatment options might be needed

COMPOST FILTER SOCK –

Sediment Removal Efficiency: HIGH. This device is an ABACT for HQ and EV watersheds. Compost filter socks are a type of contained compost filter berm.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

STANDARD CONSTRUCTION DETAIL 4-1
COMPOST FILTER SOCK



Survivability was an occasional issue with first generation compost socks.

Palletized compost socks and higher strength sock netting are recent improvements that address some of the issues that developed in the field with compost socks.

The manual contains very specific requirements for mesh component of the compost filter socks:

TABLE 4.1 Compost Sock Fabric Minimum Specifications

Material Type	3 mil HDPE	5 mil HDPE	5 mil HDPE	Multi-Filament Polypropylene (MFPP)	Heavy Duty Multi-Filament Polypropylene (HDMFPP)
Material Characteristics	Photo-degradable	Photo-degradable	Bio-degradable	Photo-degradable	Photo-degradable
Sock Diameters	12" 18"	12" 18" 24" 32"	12" 18" 24" 32"	12" 18" 24" 32"	12" 18" 24" 32"
Mesh Opening	3/8"	3/8"	3/8"	3/8"	1/8"
Tensile Strength		26 psi	26 psi	44 psi	202 psi
Ultraviolet Stability % Original Strength (G-155)	23% at 1000 hr.	23% at 1000 hr.		100% at 1000 hr.	100% at 1000 hr.
Minimum Functional Longevity	6 months	9 months	6 months	1 year	2 years
Two-ply systems					
Inner Containment Netting	HDPE biaxial net Continuously wound Fusion-welded junctures 3/4" X 3/4" Max. aperture size				
Outer Filtration Mesh	Composite Polypropylene Fabric (Woven layer and non-woven fleece mechanically fused via needle punch) 3/16" Max. aperture size				
Sock fabrics composed of burlap may be used on projects lasting 6 months or less.					

The manual contains very specific requirements for mesh component of the compost infill of the socks:

"Compost shall meet the following standards:"

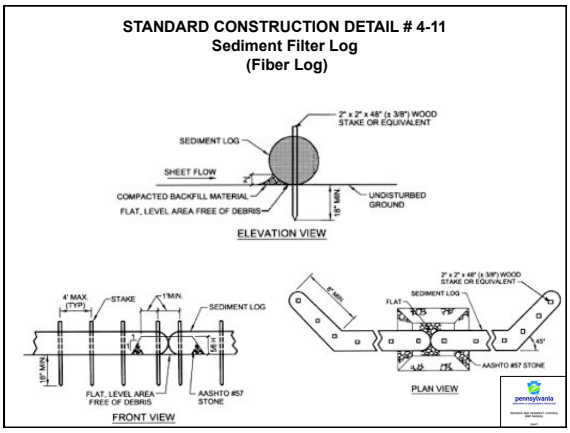
Organic Matter Content	**80% - 100% (dry weight basis)**
Organic Portion	**Fibrous and elongated**
pH	**5.5 - 8.0**
Moisture Content	**35% - 55%**
Particle Size	**98% pass through 1" screen**
Soluble Salt Concentration	**5.0 dS/m (micro mhos/cm) Maximum**

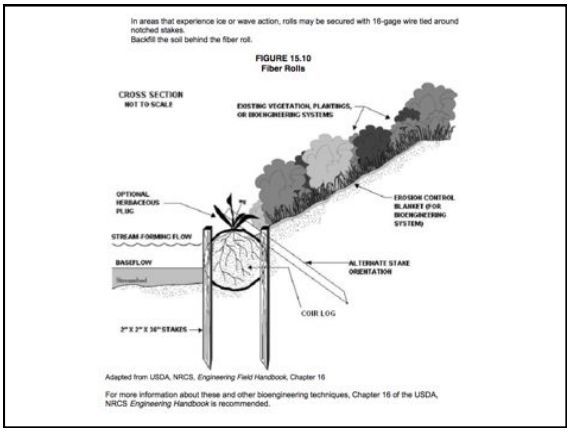
SEDIMENT FILTER LOG (FIBER LOG)

Sediment Removal Efficiency: LOW. This device is not an ABACT for special protection watersheds. However, it may be used with other BMPs that are ABACT to increase their effectiveness.

Sediment filter logs are tube-shaped devices filled with straw, flax, rice, or coconut fiber and wrapped with UV-degradable polypropylene netting, burlap, jute, or coir for longevity.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505





Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Weighted Sediment Tubes: Perimeter Controls

WEIGHTED SEDIMENT FILTER TUBE

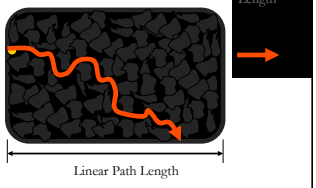
Sediment Removal Efficiency: MODERATE.
This device is an ABACT for HQ but not EV watersheds.

- **They may be used** to control runoff from small disturbed areas where silt fence would normally be used as well as **certain locations** where silt fence is not typically effective (**e.g. above headwalls and endwalls**).
- In general, the maximum slope length for standard silt fence may be used for 12" diameter tubes and slope lengths for reinforced silt fence (see Table 4.3 or Figure 4.3) may be used for 18" to 20" diameter tubes. However, **longer slope lengths** may be considered by the Department on a **case-by-case basis**.
- The tubes can also be used **in lieu of rock filters** or as **filters for storm sewer inlets located in sump areas**.
- **Standard Construction Details # 4-3 through # 4-5** may be used for weighted sediment filter tubes installation and maintenance.
- **When the area tributary to a tube has been stabilized, an undamaged tube may be removed and used at another location.**

Three-Dimensional Filter Under Laminar Flow Conditions

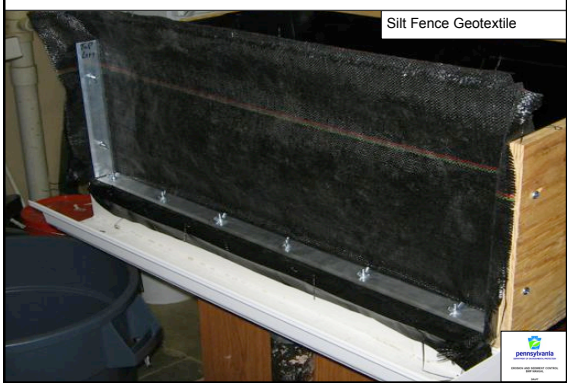
Tortuosity:

$$\frac{\text{Actual Flow Length}}{\text{Linear Path Length}}$$



The greater the tortuosity in the filter media, the greater the attenuation due to settling and adsorption.

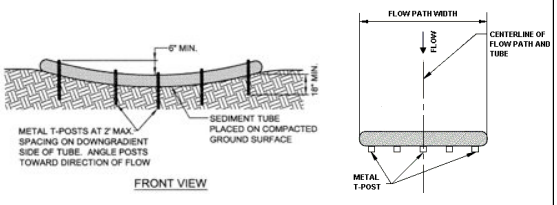
ASTM Flume Test- Silt Fence



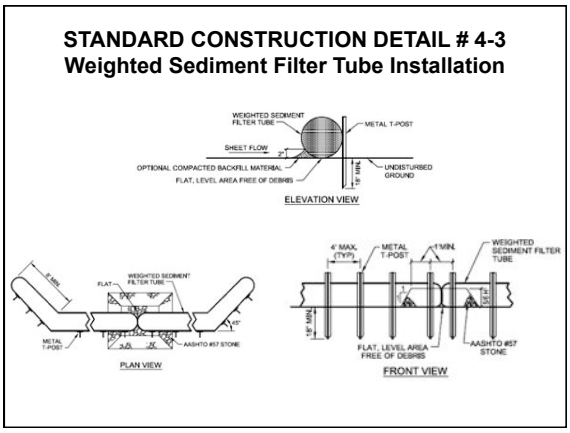
ASTM Flume Test- Weighted Sediment Tubes

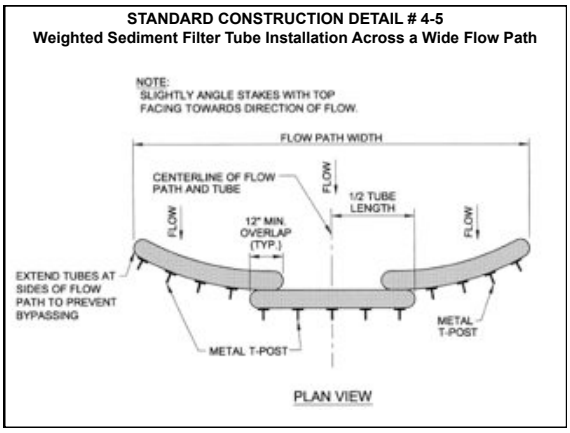
"Weighted Sediment Filter Tubes may be placed in areas of concentrated flow in lieu of rock filters if installed according to manufacturer's recommendations or Standard Construction Detail # 4-4."

STANDARD CONSTRUCTION DETAIL # 4-4
Weighted Sediment Tube Installation in a Concentrated Flow Area



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505





Perimeter Control

Stock Pile Perimeter Control

Designed as perimeter control, weighted sediment tubes provide an alternative to rock filters

Rock Filter

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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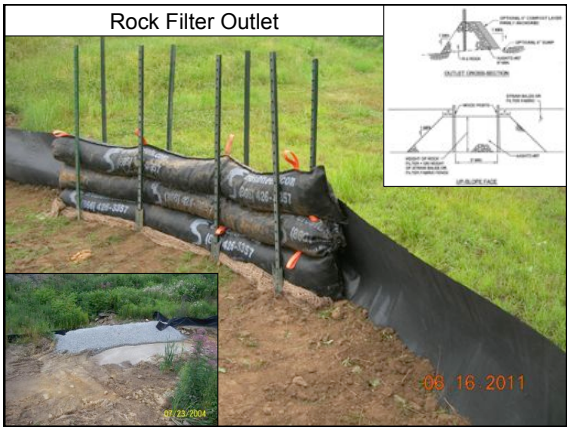
Rock Filter / Check Dam

Rock Filter Outlet

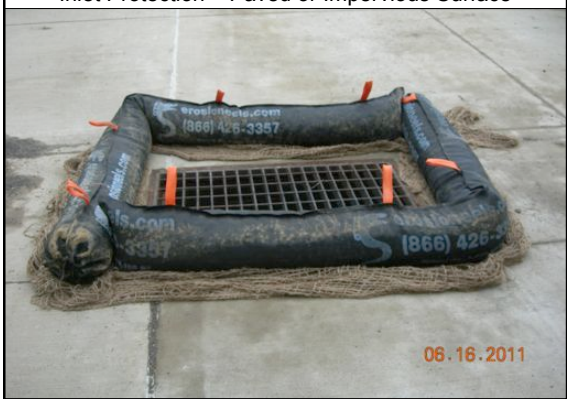


Alternative to Compost Sock Silt Trap

Slope Diversion

Inlet Protection – Grassed or Disturbed Area

Inlet Protection – Paved or Impervious Surface



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

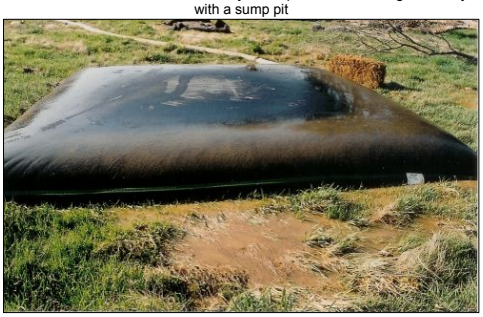
Single WST Diversion – Paved or Impervious Surface

Double WST Diversion – Paved or Impervious Surface

Weighted Sediment Tubes Ready for Re-Use

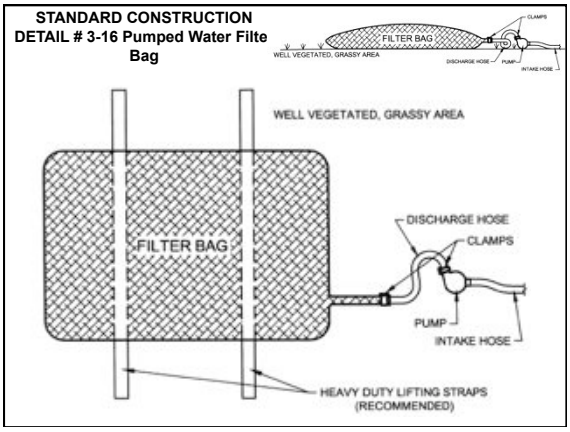
PUMPED WATER FILTER BAG

Sediment Removal Efficiency: LOW. This device is not an ABACT for special protection watersheds unless surrounded by a compost filter sock ring or in conjunction with a sump pit

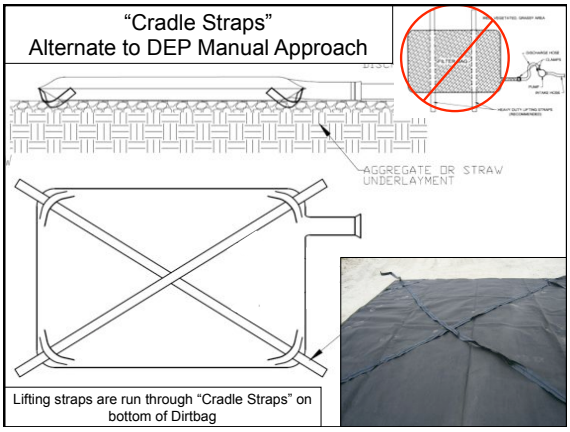


Filter bags may be used to filter water pumped from disturbed areas prior to discharging to surface waters. They may also be used to filter water pumped from the sediment storage areas of sediment basins and sediment traps.

STANDARD CONSTRUCTION DETAIL # 3-16 Pumped Water Filte Bag



"Cradle Straps"
Alternate to DEP Manual Approach



Lifting straps are run through "Cradle Straps" on bottom of Dirtbag

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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Dirtbag being removed by lifting straps run through Cradle Straps

Low Volume Filter bags shall be made from non-woven geotextile material sewn with high strength, double stitched "J" type seams. They shall be capable of trapping particles larger than 150 microns.

•High Volume Filter Bags may be made from woven geotextiles that meet the following standards:

Property	Test Method	Minimum Standard
Avg. Wide Width Strength	D-4884	60 lb/in
Grab Tensile	D-4632	205 lb
Puncture	D-4833	110 lb
Mullen Burst	D-3786	350 psi
UV Resistance	D-4355	70%
% Retained	D-4751	80 Sieve

•The pumping rate shall be no greater than 750 gpm or ½ the maximum specified by the manufacturer, whichever is less. Pump intakes should be floating and screened.

•No downslope sediment barrier is required for most installations. Compost berm or compost filter sock should be installed below bags located within 50 feet of receiving stream or where grassy area is not available. A compost berm or compost filter sock shall be placed below any bag discharging to a special protection surface water.

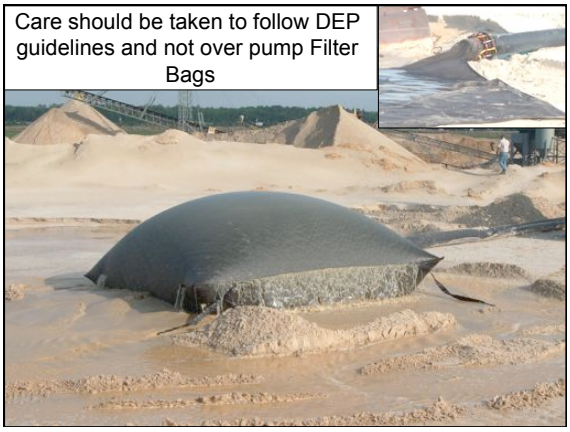
Placing filter bags on a stone or straw bale base will enhance filtration through bottom of bag.

Low Volume Filter bags shall be made from non-woven geotextile material sewn with high strength, double stitched "J" type seams. They shall be capable of trapping particles larger than 150 microns.

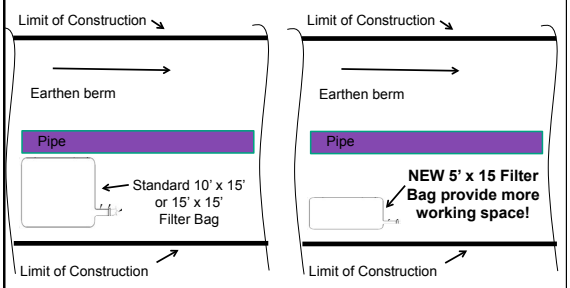

Entry port cut into filter bag fabric will need more detail to create a good seal

Example of non-spec "Prayer" seam more likely to be problematic in the field

Care should be taken to follow DEP guidelines and not over pump Filter Bags



Filter Bag: Example of 5' x 15' Pipeline Special Model



Standard sized Pumped Sediment Filter Bags can take up more space than is practical in a cramped linear application

Standard sized Pumped Sediment Filter Bags can take up more space than is practical in a cramped linear application

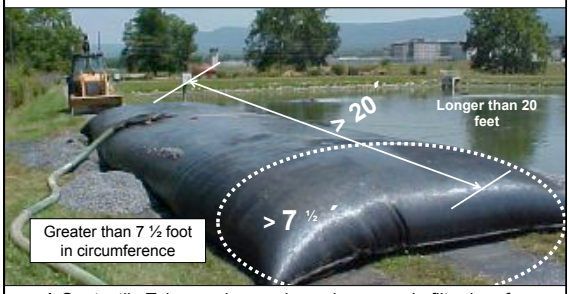
Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

When higher volumes of water are needed to be pumped one option is to use multiple connections from one pump.

High Strength Geotextile Tubes

75

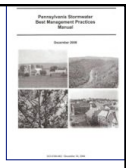
A Geotextile Tube is a permeable high strength woven geotextile fabricated (sewn) into a tube, generally hydraulically filled with a slurry of water and soil, sand or a wide variety of other materials.



A Geotextile Tube can be used as a larger scale filter bag for sediment laden water or as a dewatering device for slurries with a higher percent of solids

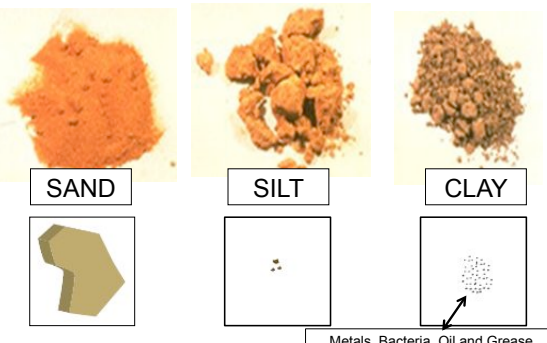
Tube in roll off box

Chapter 2: Making the case for Stormwater Management
2.2.5 Water Quality

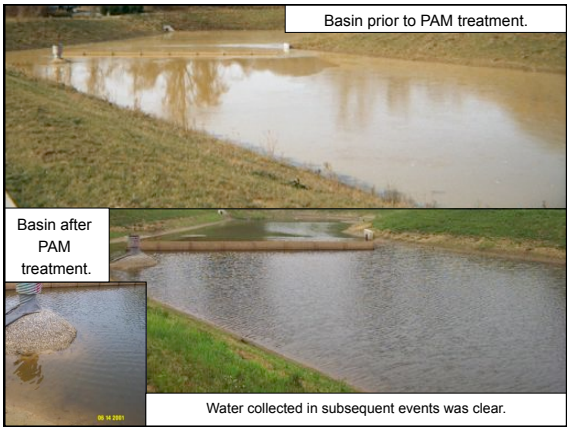


Because a major fraction of particulate associated pollutants is transported with the smallest particles, or colloids, their removal by BMPs is especially difficult.

Filter Bags and many other standard sediment control BMPs work well when soil particles are sand and silt

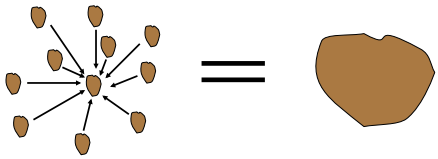


Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505



Soil Stabilization Polymers – Polyacrylamide (PAM)

Polyacrylamide (PAM) is polymer flocculent and is available in environmentally safe, water-soluble products that reduce soil erosion and turbidity in storm water runoff.



SOIL BINDERS

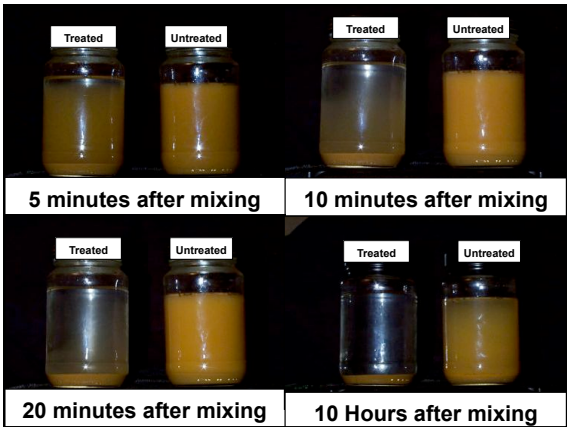
Water-soluble anionic polyacrylamide (PAM) may be applied to a disturbed area as a temporary soil-binding agent to reduce erosion due to wind and water. This practice is recommended for areas where timely establishment of a vegetative cover is not feasible (e.g. non-germinating season), wherever soils have a high clay content, or where the vegetative cover is inadequate to provide protection from erosion. Wherever used, the application should comply with all federal, state and local laws and regulations governing anionic PAM.

PAM Specifications

- Anionic PAM mixtures should be environmentally safe and non-toxic to fish and other aquatic species, wildlife, and plants. It should also be non-combustible.
- Cationic PAM should not be used due to its toxicity to aquatic species.
- Anionic PAM mixtures should have ≤ 0.05% free acrylamide monomer by weight as established by the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA).
- Acute toxicity test data should be provided for each manufacturer or supplier.
- The manufacturer should provide a product expiration date for anionic PAM based upon expiration of PAM in the pure form. e to visually track its application.

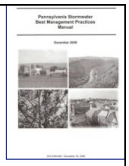
SOIL BINDERS Continued: Application

- Anionic PAM should be applied in accordance with the recommended methods provided by the manufacturer or supplier for the specific site conditions (e.g. slope and soil type). A record of the application (including the date of application, product type, weather conditions, method of application, and the name of the applicator) should be kept on site.
- Application rates should not exceed the manufacturer's recommendations. Repeated applications may be made if necessary to ensure adequate coverage.
- The application method used should provide uniform coverage to the target area while avoiding drift to non-target areas (especially paved areas).
- Manufacturer's recommendations for safe storage, mixing, and use of the product should be followed.
- Use of anionic PAM should be in conjunction with the other BMPs specified in the approved E&S Plan.
- Anionic PAM may not be used in lieu of a protective liner in a channel or in place of mulch on a seeded area. However, seed may be added to the mixture at the time of application.
- Disposal of excess material should be in accordance with manufacturer's recommendations as well as federal, state, and local laws and regulations.
- Anionic PAM should not be applied within the floodway of a receiving stream channel or within 25 feet of other water bodies.
- Anionic PAM may be used to temporarily stabilize Topsoil Stockpiles. However, anionic PAM may lose its effectiveness in as little as two months. Therefore, it might become necessary to reapply the mixture.
- Anionic PAM is not recommended for application on surfaces of pure sand or gravels with no fines or on snow-covered surfaces.
- A visible tracer or colorant may be added to the mixture to visually track its application.



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Chapter 2: Making the case for Stormwater Management
2.2.5 Water Quality



It is possible to add chemicals to a detention basin to coagulate these colloids to promote settling, but this chemical use turns a natural stream channel or pond into a treatment unit, and subsequent removal of sludge is required. A variety of BMPs have been developed that serve as runoff filters, and are designed for installation in storm sewer elements, such as inlets, manholes or boxes. The potential problem with all measures that attempt to filter stormwater is that they quickly become clogged, especially during a major event. Of course, one could argue that if the filter systems become clogged, they are performing efficiently, and removing this particulate material from the runoff. The major problem then with all filtering (and to some extent settling) measures is that they require substantial maintenance. The more numerous and distributed within the built conveyance system that these BMPs are situated, the greater the removal efficiency, but also the greater the cost for operation and maintenance.

General Introduction PAM

One form of PAM powder is specifically tailored for controlling soil erosion.

The powder can be applied in dry form.

http://sand.nwisrl.ars.usda.gov/pampage.shtml

NWISRL
Kimberly, ID

Polyacrylamide (PAM) and Biopolymer Update

An Overview of PAM Technology Developed at or in Cooperation with NWISRL

USDA

NWISRL
Kimberly, ID

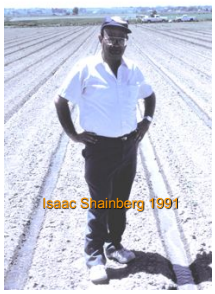
USDA - Agricultural Research Service
Northwest Irrigation & Soils Research Lab, Kimberly, Idaho
http://sand.nwisrl.ars.usda.gov

Research Contributors

NWISRL
Kimberly, ID

USDA

- **ARS**-- Sojka, Lentz, Bjorneberg, Entry, Trout, Robbins, Leytem, Aase, Lehrsch, Westermann, Orts, Glenn & Others
- **Volcani Institute**-- I. Shainberg
- **New Zealand**-- C. Ross, D. Horne
- **U Delaware**– J.J. Fuhrmann
- **Australia**-- A. Surapaneni, S. Phillips & Others
- **U. of ID**-- D. Morishita, M. West, J. Elsworth & R. Spackman
- **ID State U.**-- M. Watwood
- **WSDOT**– Ed Molash & Others
- **Wisconsin**– Aicardo Roa
- **NRCS**-- T. Spofford & Others
- **Industry** -- H. Asbell, F. Barvenik & Others



Massey University | Manaaki Whenua Landcare Research | University of Idaho | University of Delaware | U.S. Department of the Interior Bureau of Reclamation | NRCS

Anionic PAMs: "Off the Shelf " Industrial Flocculents

- **Cosmetics**
- **Paper Manufacture**
- **Potable Water**
- **Dewater Sewage Sludges**
- **Clarify Fruit Juices & Sugar Liquor**
- **Mining & Drilling Applications**
- **Adhesives & Paper in Contact with Food**
- **Washing & Lye-Peeling of Fruits & Veg's**
- **Animal Feed Thickener & Suspending Agent**

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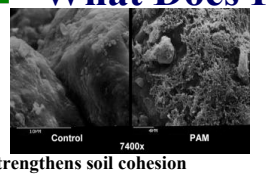
USDA

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

What Does PAM Do?

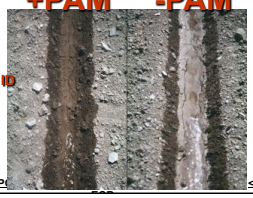


- Strengthens soil cohesion
- Preserves surface roughness
- Increases viscosity slightly
  - *Reduce particle detachment*
- Flocculates suspended solids
  - *Reduces sediment transport*
- All these preserve pore continuity
  - *Maintains higher infiltration*

NWISRL Kimberly, ID

PAM Effects on Infiltration

- Soil dependent (texture)
  - Balances surface seal vs viscosity effects
  - Reduces surface sealing
  - Longer advance time
- Net increases
  - 15 % on silt loams
  - 50 % on clays
  - 0% or slight reduction on sands
- 25 % increase in lateral wetting on shallow furrows



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PCs Inlets Filter Bags & Tubes PAMs P< Home

PAM Persistence in Soil

- PAM N-groups quickly consumed by microorganisms
- PAM carbon backbone more resistant, UV & mechanical shear (degrades at least 10%/yr)
- Monomer (AMD) biodegrades rapidly in soil, 18-48 hours
- PAM *does not* degrade to AMD

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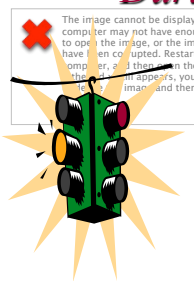
PAM Mobility & Fate *During* Irrigation



- PAM is mobile while in solution
- PAM quickly adsorbs to solid surfaces
- Adsorbed irreversibly upon drying
- Field retention 97-99%

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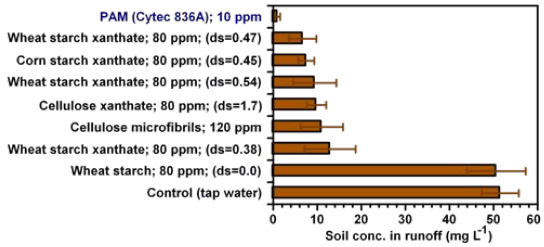
Anionic Erosion PAMs are FAR less toxic than Fungicides, Insecticides, Rodenticides, most Herbicides and even concentrated Fertilizers

NWISRL Kimberly, ID

Runoff sediment conc. from lab mini-furrows for PAM vs polysaccharide derivatives.



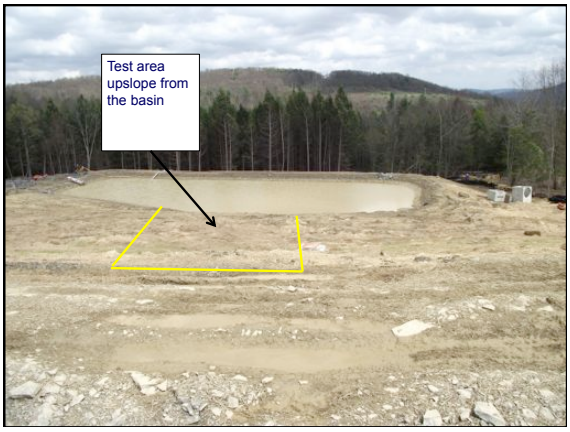
Soil pH 7.5, exchangeable Ca 7%, ~5% organics.
10 ppm $Ca(NO_3)_2$ in water, for ionic bridging.
SD based on 5 reps/sample.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

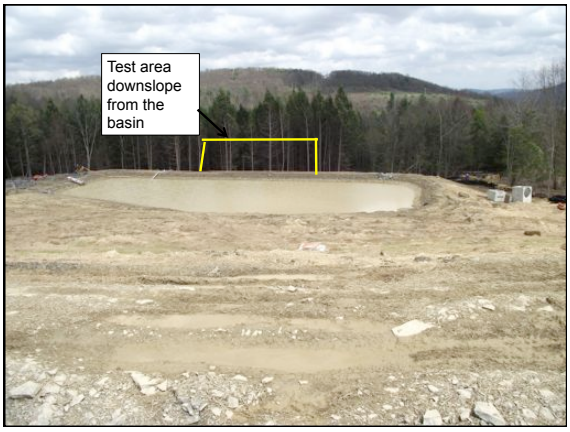
Here is an example of the dry powder Pam treatment in a basin.

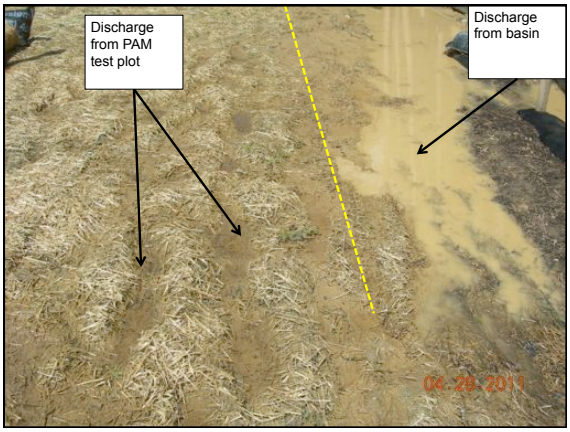
Here is an example of the dry Pam treatment.

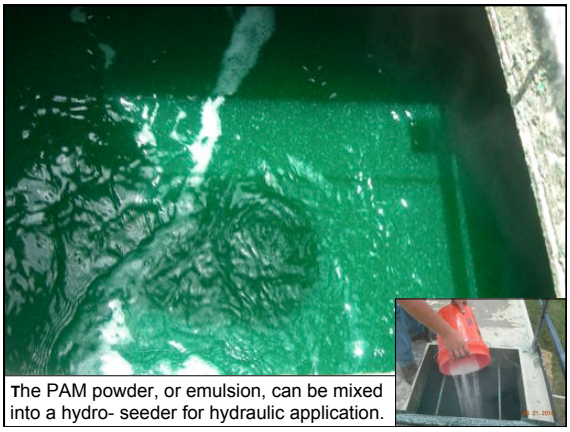
PAM powder can also be mixed with sand for dry applications using basic equipment.



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505







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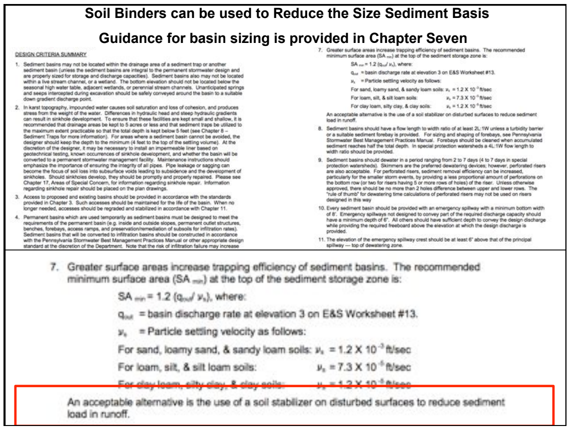
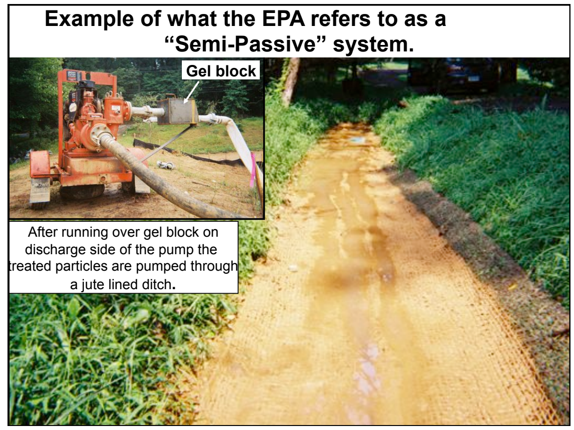
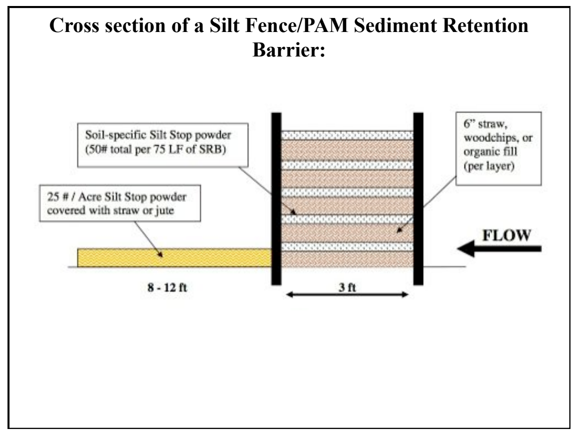
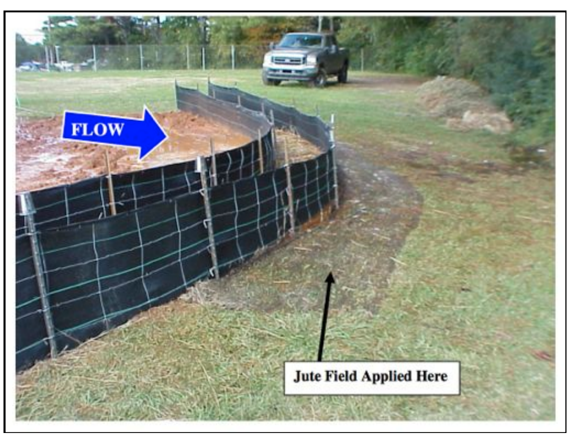
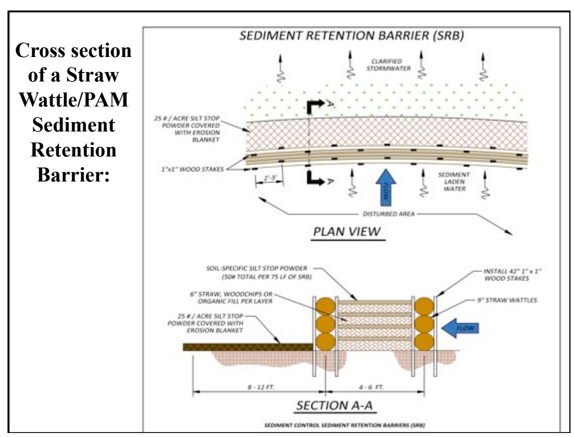
wcohn@acfenvironmental.com, 888-856-4505











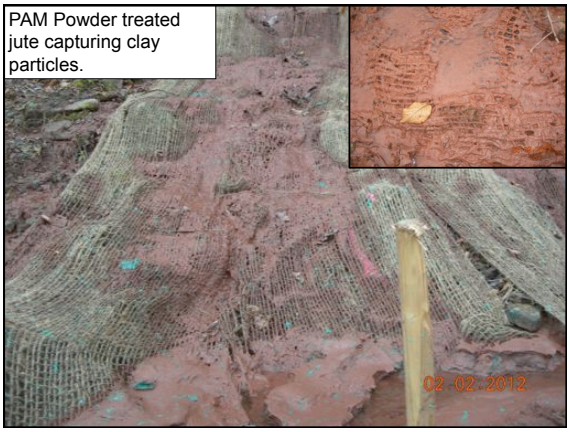
Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

PA DEP Gas & Oil – 2012 Marcellus Shale industry Training

The combination of a large linear area of disturbance, "reddish" soil with colloidal clay particles and a limited footprint for tradition sediment capture and settlement BMPs…

…resulted in the discharge of a cloudy flume that resulted in a visible contrast in the stream running adjacent to the discharge point from the site.

PAM Powder treated jute capturing clay particles.



Further down the flow path straw bales, jute matting and PAM powder were used to create small detention / treatment areas.

Dispersion field of Pam powdered jute catches treated particles.

Looking downstream from, and upstream at, discharge point.

No turbidity released from detention / treatment cells and dispersion field

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

After the site specific soil analysis, a specific emulsion was recommended to treat disturbed soil

The emulsion/water mixture was then applied to the disturbed soil at a predetermined rate.

The collection basin was also treated in this manner.

PAM powder and/or emulsion application may not always be 100% effective in preventing soil particle movement, especially in the case of less frequent, more extreme rain events.

PAM is also available as a gel block that, when placed within storm water or construction site runoff, will remove fine particles and reduce turbidity.

Gel Block Application

- Timing will be a critical factor in Gel Block effectiveness.
- The test report will indicate which Gel Block to use as well as how long of an interaction or mixing time is need for the PAM to work.

Gel blocks were tied to stakes placed in the ditch and also installed in inlet structures.

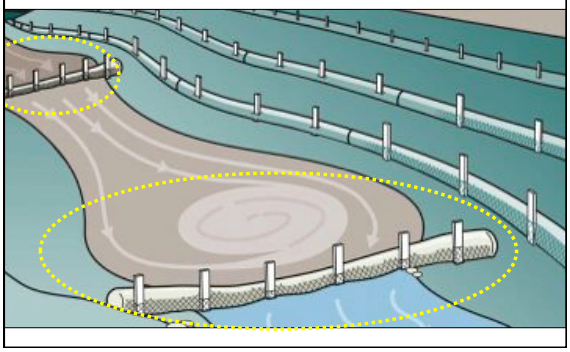
Gypsum / PAM composite treatment. Mixture is applied dry and will settle and then bind particles on bottom of basin.

Dry Application

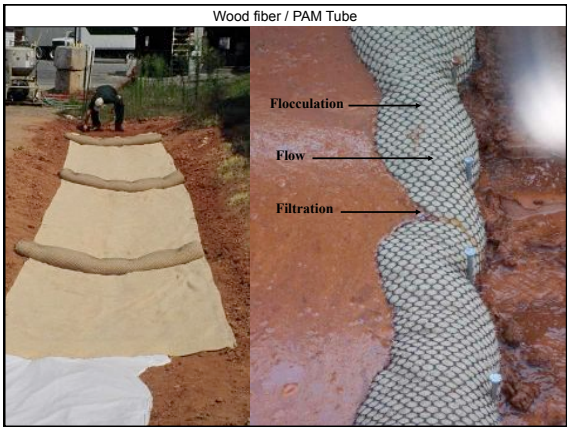
Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Sediment Retention Devices (SRDs)

Composition - An open weave containment netting wood fibers and a PAM blend.



Wood fiber / PAM Tube



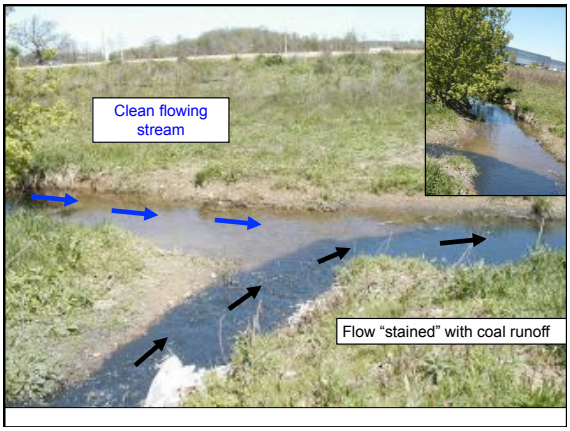
The TerraTube will flocculate and filter the colloids as they flow thru the tube.

Better here than in an impaired waterway!

Example Case Study

SRDs @ Lehigh Valley Business park, Macungie, PA

Storm water basin excavation began to discharge coal polluted water that stained the banks of a downstream trout stream.



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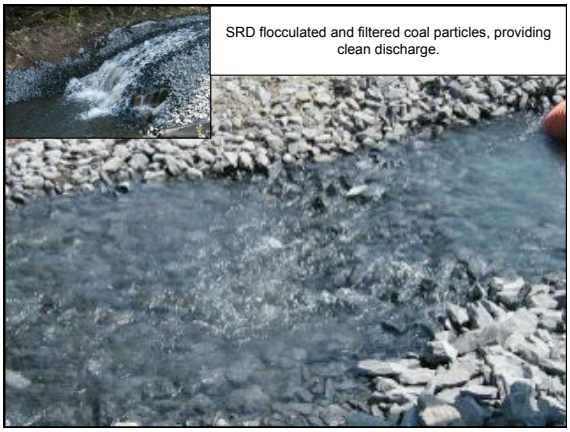
wcohn@acfenvironmental.com, 888-856-4505

A flume was built and lined with plastic and then, Geotextile.

SRDs were placed two high into the flume and the balance of the flume was filled with stone.

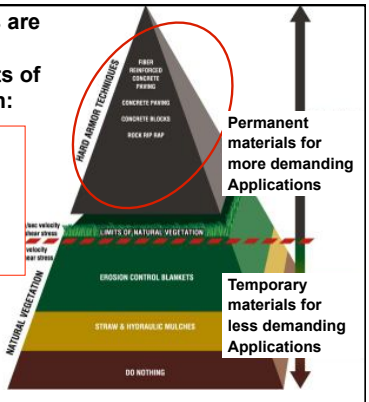
SRD flocculated and filtered coal particles, providing clean discharge.



Degradable ECBs are effective to the performance limits of natural vegetation:

Channels:
- **5-6 fps Velocity**
- **1.55 to 2 lbs/sf Shear Stress**

Slopes = ?



Permanent materials for more demanding Applications

Temporary materials for less demanding Applications

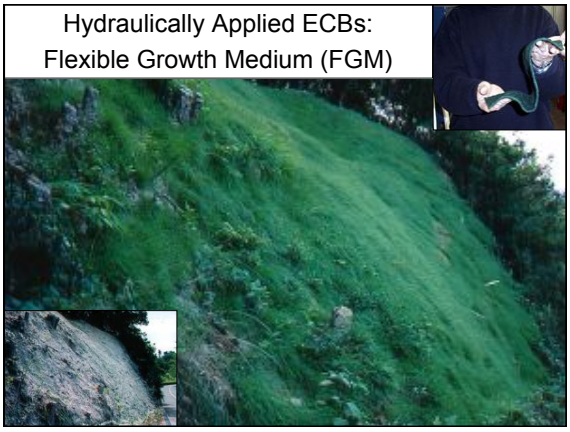
HYDRAULICALLY APPLIED BLANKETS

Hydraulically applied blankets should not be used in areas of concentrated flow (e.g. channels).

A **Flexible Growth Medium (FGM)** has the added component of ½ inch long, crimped manmade fibers which add a mechanical bond to the chemical bond provided by BFMs. This increases the blanket's resistance to both raindrop impact and erosion due to runoff. Unlike BFMs, a flexible growth medium typically does not require a curing time to be effective. Properly applied, an FGM may be as much as 99% effective.

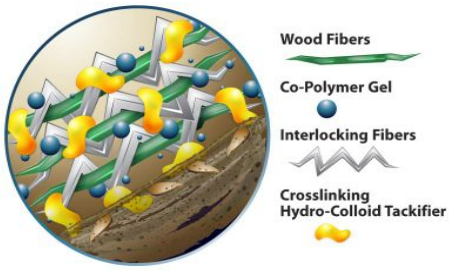
Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Hydraulically Applied ECBs: Flexible Growth Medium (FGM)



Flexible Growth Medium (FGM)

Engineered, Three-Dimensional Composite of Wood Fibers, Interlocking Crimped Man-Made Fibers, Particles of Super-Absorbent Co-polymer and Cross-linked Hydro-Colloid Binders.



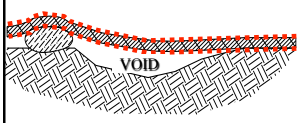
Easy to Install

Mix into hydro-seeder, add seed and fertilizer and other amendments, shoot from hose or cannon.

Better Intimate contact with the Soil

Better

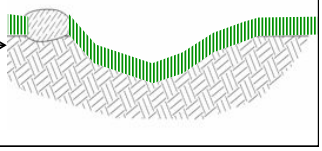
soil and sediment management



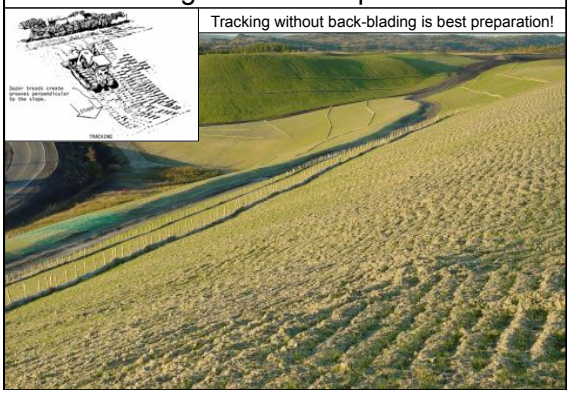
Netting or stitching of blankets can bridge over irregularities in final soil grading

Blankets

Flexterra has no netting or stitching to bridge over irregularities in final soil grading



Savings on Site Preparation

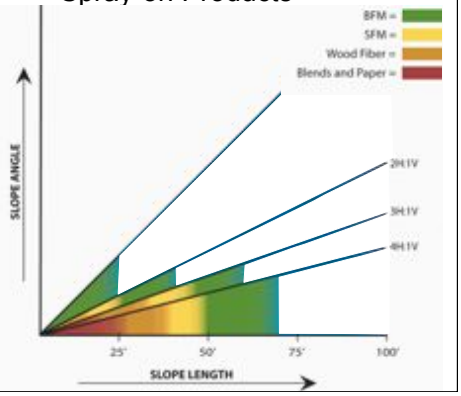


Tracking without back-blading is best preparation!

Spray-on Products

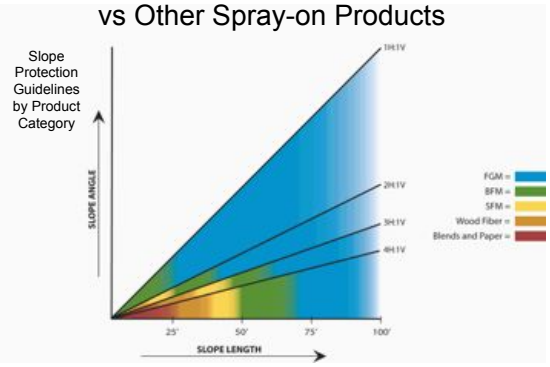
Slope Protection Guidelines by Product Category

Industry standards, not New York State based.



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

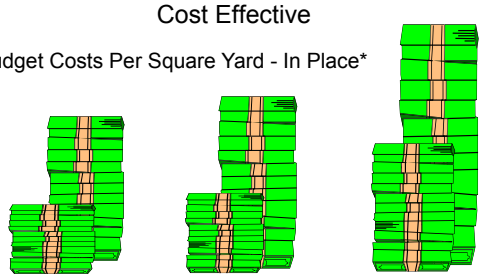
Enhanced Performance vs Other Spray-on Products



Slope interruption devices or water diversion techniques are recommended when slope lengths are in excess of 75 feet.

Cost Effective

Budget Costs Per Square Yard - In Place*



Bonded Fiber Matrix
$0.85 - $1.10

Flexible Growth Medium
$1.10 - $2.00

Erosion Control Blankets**
$1.20 - $2.50 and up

*National averages are listed, local prices may vary but relationship to other methods remains the same.

**Does not include final grading and raking associated with blankets applications.

Better Erosion Prevention Performance

Low "C" Factors and High Percentage of Effectiveness

TESTING FACILITY	UWRL[1]	SDSU/SERL[2]	TTI[3]	TRI[4]
Test Method	Lab Protocol[5]	Lab Protocol[5]	Lab Protocol[5]	ASTM D6459[6]
Application Rate	3,000 lb/ac	3,500 lb/ac	3,500 lb/ac	3,500 lb/ac
Test Conditions[5]: Slope Gradient Soil Type Test Duration	2.5H:1V sandy loam 1 hr	2H:1V clayey sand 3 successive 1.8 hr	2H:1V sandy loam 3 successive 1/2 hr	3H:1V sandy loam 3 successive 1/3 hr
Rainfall Rate	5 in/hr	1.9 in/hr	3.5 in/hr	2, 4, 6 in/hr
Cover or "C" Factor[6]	0.0004	0.0001	0.0026	0.01
% Effectiveness[6]	99.96%	99.99%	99.74%	99%

1. UWRL—**Utah Water Research Laboratory**—Lab protocol developed over 20 years of rainfall simulation testing.
2. SDSU/SERL—**San Diego State University/Soil Erosion Research Laboratory**—Testing simulated three successive 50-year storm events in Los Angeles Basin.
3. TTI—**Texas Transportation Institute**—Hydraulics, Sedimentation and Erosion Control Laboratory under auspices of Texas DOT.
4. TRI—**TRI/Environmental, Inc.**—"Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hill Slopes from Rainfall Erosion"
5. Testing conducted on fully cured matrix.
6. Cover or "C" Factor determined from comparison of treated slope vs. bare slope condition. The "C" Factor is the component of the Modified Universal Soil Loss Equation (MULSE) that measures the erosion control effectiveness of a product. % Effectiveness = One minus "C" Factor times 100%.

FGM Slope Residential Development Slope.

FGM Road Side Slope.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

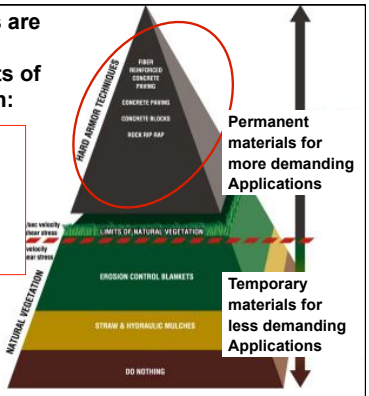
Permanent Erosion Prevention and Site Stabilization for Post Construction SWM

- Turf Reinforcement Mats (TRMs)
- High Performance Turf Reinforcement Mats (HPTRMs)
- Scour Prevention Transition Mats
- Articulating Concrete Blocks (ACBs)
- Cellular Confinement Systems

Degradable ECBs are effective to the performance limits of natural vegetation:

Channels:
- 5-6 fps Velocity
- 1.55 to 2 lbs/sf Shear Stress

Slopes = ?



Riprap

Permanent Erosion Prevention and Site Stabilization for Post Construction SWM

- Turf Reinforcement Mats (TRMs)
- High Performance Turf Reinforcement Mats (HPTRMs)
- Scour Prevention Transition Mats
- Articulating Concrete Blocks (ACBs)
- Cellular Confinement System

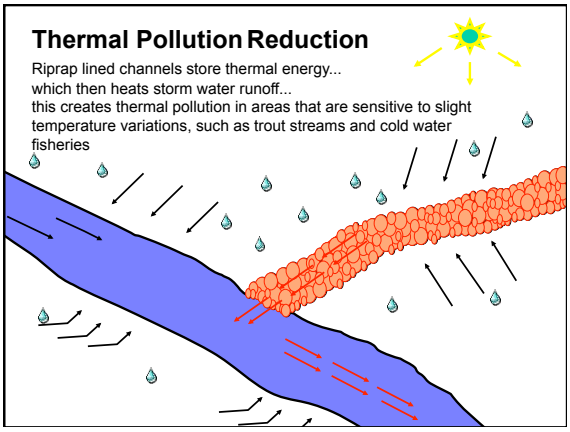
All can replace hard armor applications and have some common characteristics.

Environmentally Friendly

TRMs prevent erosion and enhance water quality through filtration and infiltration

Thermal Pollution Reduction

Riprap lined channels store thermal energy...
which then heats storm water runoff...
this creates thermal pollution in areas that are sensitive to slight temperature variations, such as trout streams and cold water fisheries



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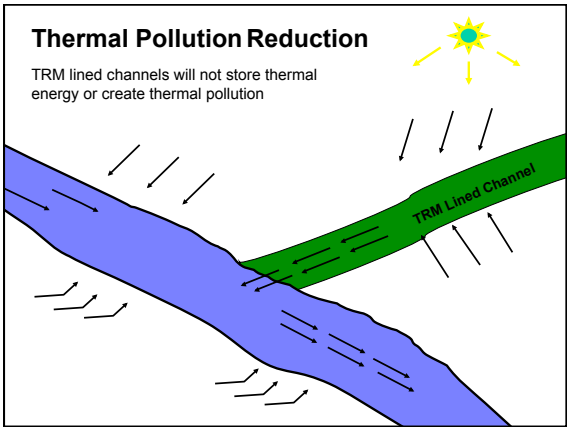
wcohn@acfenvironmental.com, 888-856-4505

Thermal Pollution Reduction

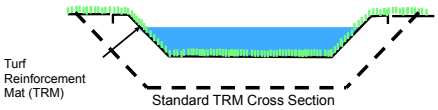
TRM lined channels will not store thermal energy or create thermal pollution



Reduced Cost of Excavation..

Standard Riprap Cross Section
(Requires Undercut Excavation)

For a given volume of water, the required amount of excavation can be reduced by using a TRM



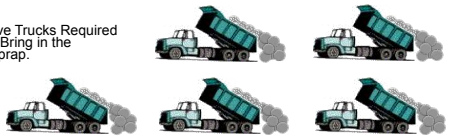
Standard TRM Cross Section
(Reduces Undercut Excavation)

Reduced Site Disturbance

By reducing the undercut excavation, one roll of LANDLOK® or PYRAMAT® can eliminate as many as…

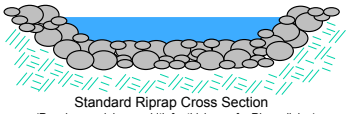
Seven Trucks Required to Remove the Over-Excavated material, and...

Five Trucks Required to Bring in the Riprap.



Subgrade preparation for hydraulically stable HPTRM design

Reduced Right of Way.



Standard Riprap Cross Section
(Requires a minimum width for thickness for Riprap lining)

For the same volume of water, a Turf Reinforcement Mat lined channel will require less Right-of-Way than a Riprap lined channel.

Standard TRM Cross Section
(Requires less Width for TRM lining)

Completed installation, within existing right-of-way, after 6 months.

Traditional rip-rap application would have required a much wider footprint.

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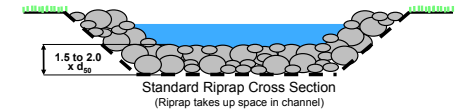
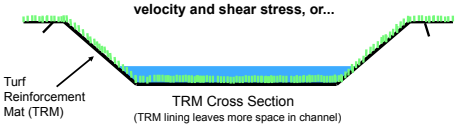
wcohn@acfenvironmental.com, 888-856-4505

Increased Channel Capacity.



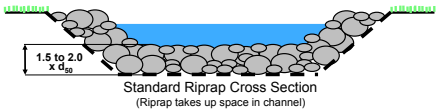
Standard Riprap Cross Section
(Riprap takes up space in channel)

For a given channel cut, a TRM lining will allow the same amount of water to run wider and shallower, reducing velocity and shear stress, or...



TRM Cross Section
(TRM lining leaves more space in channel)

Increased Channel Capacity.



Standard Riprap Cross Section
(Riprap takes up space in channel)

…the same channel cut will provide a greater flow capacity to convey more water.

TRM Cross Section
(TRM lining leaves more space in channel)

Aesthetics, Safety, Vandalism, Maintenance and Pest Control.

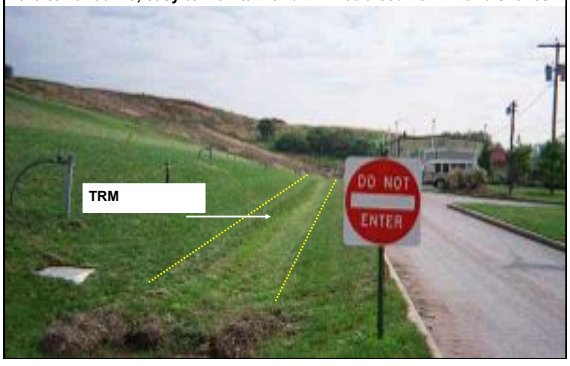
Riprap applications are eyesores that are dangerous, easy to vandalize, difficult to maintain and tend to breed vermin and snakes.

Aesthetics, Safety, Vandalism, Maintenance and Pest Control

TRMs provide a safe, aesthetically pleasing finished application that is hard to vandalize, easy to maintain and will not breed vermin and snakes

Aesthetics, Safety, Vandalism, Maintenance and Pest Control

TRMs provide a safe, aesthetically pleasing finished application that is hard to vandalize, easy to maintain and will not breed vermin and snakes



… and Aesthetically Pleasing

Safe, Clean, Easy to Maintain, Resistant to Vandalism and Not Conducive to Breeding Vermin and Snakes.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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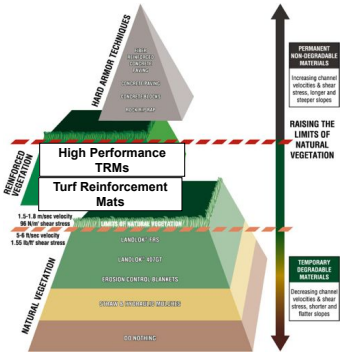
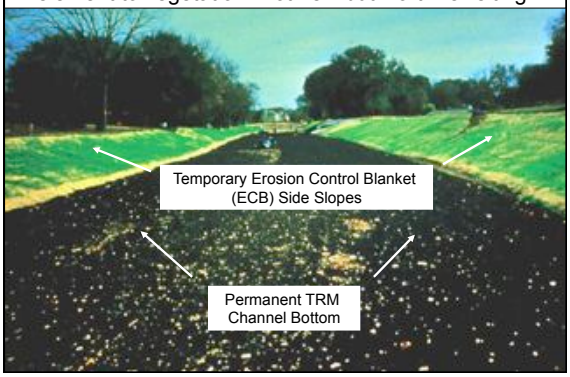
Turf Reinforcement Mats (TRMs) address performance limits that were traditionally addressed with hard armor.

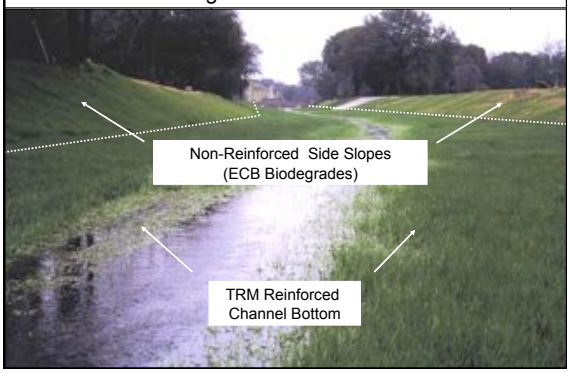


Turf Reinforcement Mats, Scour Prevention Mats, Articulating Concrete Blocks and Cellular Confinement Reinforce Turf to Extend the thresholds of vegetation.

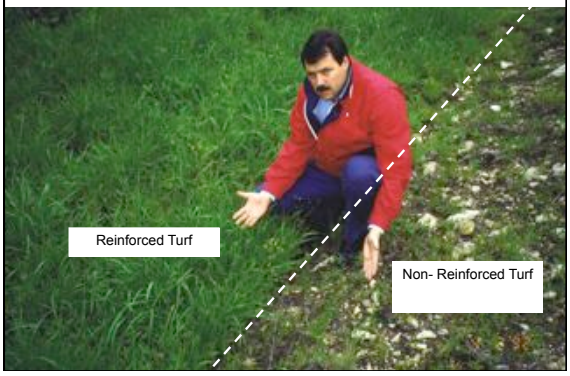
Turf Reinforcement Mat (TRM) provides a structural element to vegetation. Not new but worth revisiting.



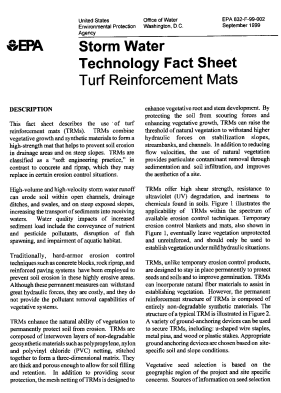
Vegetation establishment provides reinforced turf with higher thresholds...



Reinforced turf clearly prevents erosion better than non-reinforced turf



Turf Reinforcement Mat (TRM) Technology is recognized and accepted as a Best Management Practice (BMP) to improve water quality.



United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-002 September 1999

EPA

Storm Water Technology Fact Sheet
Turf Reinforcement Mats

DESCRIPTION

This fact sheet describes the use of turf reinforcement mats (TRMs). TRMs combine vegetative growth and synthetic materials to form a high-strength mat that helps to prevent soil erosion in drainage areas and on steep slopes. TRMs are classified as a "soft engineering practice," in contrast to concrete and riprap, which they may replace in certain erosion control situations.

High-volume and high-velocity storm water runoff can erode soil within open channels, drainage ditches, and swales, and on steep exposed slopes, increasing the transport of sediments into receiving waters. Water quality impacts of increased sediment load include the conveyance of nutrient and pesticide pollutants, disruption of fish spawning, and impairment of aquatic habitat.

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

TRMs enhance the natural ability of vegetation to permanently protect soil from erosion. TRMs are composed of interwoven layers of non-degradable geosynthetic materials such as polypropylene, nylon and polyvinyl chloride (PVC) netting, stitched together to form a three-dimensional matrix. They are thick and porous enough to allow for soil filling and retention. In addition to providing scour protection, the mesh netting of TRMs is designed to enhance 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 stabilization slopes, streambanks, and channels. In addition to reducing flow velocities, the use of natural vegetation provides particulate contaminant removal through sedimentation and soil infiltration, and improves the aesthetics of a site.

TRMs offer high shear strength, resistance to ultraviolet (UV) degradation, and inertness to chemicals found in soils. Figure 1 illustrates the applicability of TRMs within the spectrum of available erosion control techniques. Temporary erosion control blankets and mats, also shown in Figure 1, eventually leave vegetation unprotected and unreinforced, and should only be used to establish vegetation under mild hydraulic situations.

TRMs, unlike temporary erosion control products, are designed to stay in place permanently to protect seeds and soils and to improve germination. TRMs can incorporate natural fiber materials to assist in establishing vegetation. However, the permanent reinforcement structure of TRMs is composed of entirely non-degradable synthetic materials. The structure of a typical TRM is illustrated in Figure 2. A variety of ground-anchoring devices can be used to secure TRMs, including: u-shaped wire staples, metal pins, and wood or plastic stakes. Appropriate ground anchoring devices are chosen based on site-specific soil and slope conditions.

Vegetative seed selection is based on the geographic region of the project and site specific concerns. Sources of information on seed selection

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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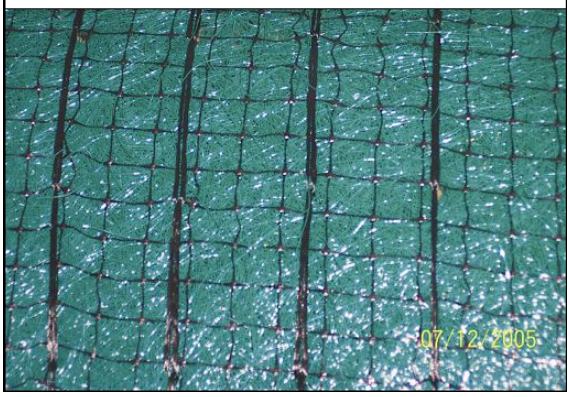
TABLE 6.2
Maximum Permissible Shear Stresses for Various Channel Liners

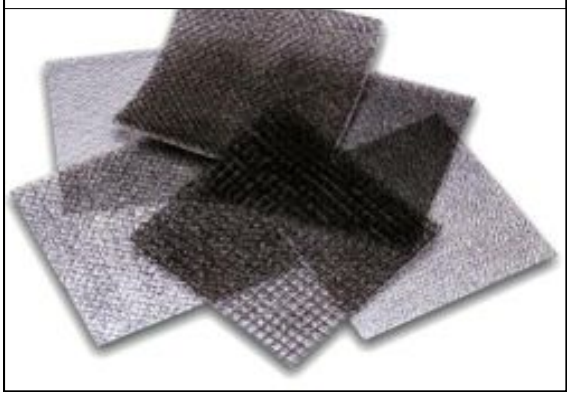
Lining Category	Lining Type	lb/ft²
Unlined[1] - Easily Eroded Soils[2]	Silts, Fine -Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Unlined[1] - Erosion Resistant Soils[3]	Clay Loam	0.25
	Silty Clay Loam	0.18
	Sandy Clay Loam	0.10
	Loam	0.07
	Silt Loam	0.12
	Sandy Loam	0.02
	Gravelly, Stony, Channery Loam	0.05
	Stony or Channery Silt Loam	0.07
Manufactured Liners[4]	Jute	0.45
	Straw with Net	1.45
	Coir - Double Net	2.25
	Coconut Fiber -Double Net	2.25
	Curled Wood Mat	1.55
	Curled Wood-Double Net	1.75
	Curled Wood - Hi Velocity	2.00
	Synthetic Mat	2.00
Non-Reinforced Vegetation	Retardance C- grass mix[5]	2.00
Riprap[6]	R-3	1.00
	R-4	2.00
	R-5	3.00
	R-6	4.00
	R-7	5.00
	R-8	8.00

1. Not permitted in HQ or EV watersheds
2. Soils having an erodibility "K" factor greater than 0.37
3. Soils having an erodibility "K" factor less than or equal to 0.37
4. Manufacturers' recommended maximum shear stresses may be used if supporting documentation is provided showing the higher shear stresses are justified by independent testing results over a time period of at least 20 minutes
5. For description of Vegetative Retardance C, see Federal Highway Administration Publication HEC15
6. Permissible shear stresses based on rock at 165 lb/cu. ft. Adjust shear stresses for other rock weights used. See Table 6.8

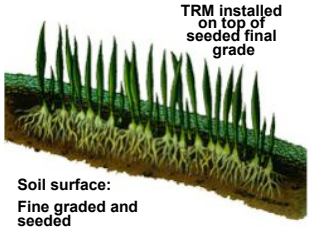
Stitch Bonded Fiber Matrix



Extruded Nylon



Non Soil-filled TRM Application



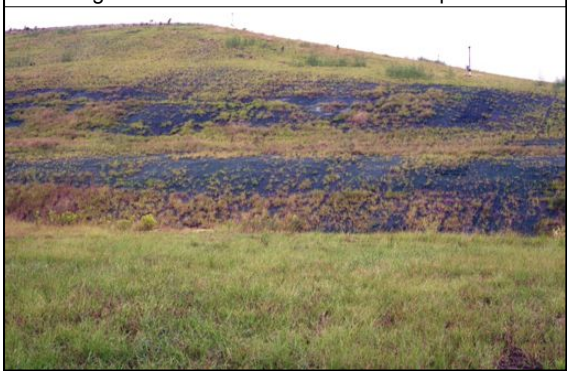
- Protects soil and seed from sun burnout and rain drop, wind, sheet/channel flow erosion during germination
- Provides permanent "Soft Armor" layer of protection
- Green color provides immediate aesthetic benefits
- Engineer's discretion

Channels (Seeded Under Blanket)

For Slopes
(Seeded Under Blanket)

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Permanent TRMs provide a significant benefit if vegetation does not establish as anticipated.



Soil-filled Turf Reinforcement Mat Application (TRM)

- Soil filling enhances intimate contact with soil, performance, and offers protection to seed and TRM
- Protects soil and seed from sun burnout and rain drop, wind, sheet/channel flow erosion during germination
- Provides permanent "Soft Armor" layer of protection
- Engineer's discretion

For slopes, and…

Channels (TRM in place and then vegetated after soil filling)...

Blowing compost has also proven to be a very efficient and effective method of soil filling. Soil or compost filling or "loading" may be useful where smooth final grading be difficult.

Example of turf reinforcement with into roots growing into TRM.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

High Performance Turf Reinforcement Mats

(HPTRMs)

Higher factors of Safety : HPTRM characteristics will provide higher factors of safety than conventional TRMs

More Demanding Applications: HPTRM has expanded the use of geosynthetics into new areas such as pipe outlets, continuous flow channels, wave attack environments, etc.

Survivability: HPTRM unsurpassed strength will provide resistance to physical stresses from installation, rubber tired vehicles, foot traffic, etc.

High Performance Turf Reinforcement Mats

(HPTRMs)

Come also may also differ in their composition.

HPTRM will perform successfully non soil-filled.

(3 weeks)

(6 months)...

Or soil-filled.

High Performance TRMs will provide higher factors of safety than standard TRMs (6 Months after in this shot)

1. TRM Installed
2. TRM Compost Filled
3. Vegetated TRM

1.

2.

3.

Next Section

1. TRM Installed
2. TRM Compost Filled
3. Vegetated TRM

TRMs saved the PTA over $20.00 per square yard or over $100,000.00 on a

5,000 sf project

1.

2.

3.

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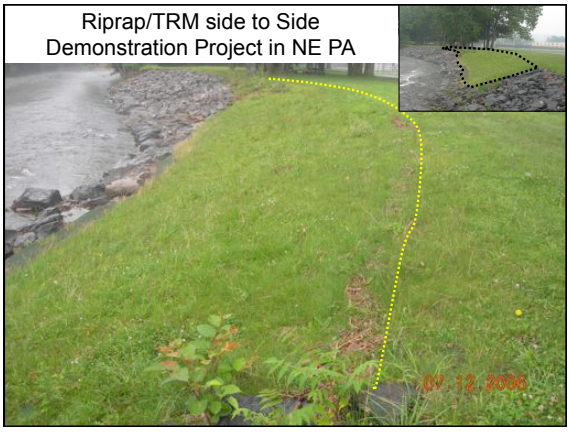
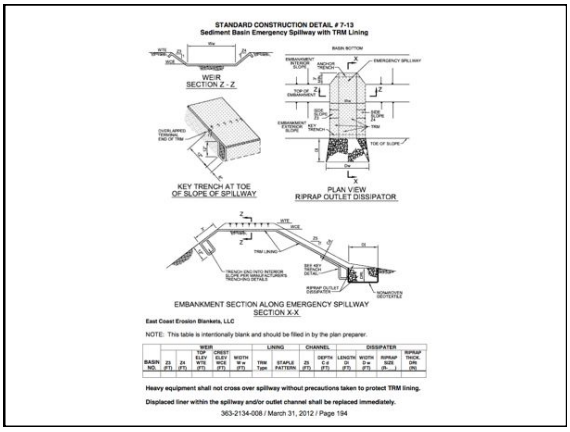
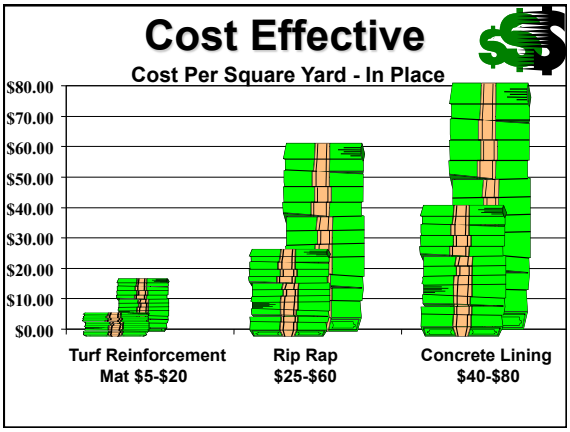
wcohn@acfenvironmental.com, 888-856-4505

Riprap/TRM side to Side Demonstration Project in NE PA







Keys to TRM Success

DESIGN: Comprehensive project evaluation, product selection and specification.

QUALITY CONTROL: Because consistent product is the key to consistent performance.

INSTALLATION: Protect the integrity of your application design by incorporating proper installation techniques into contract documents.

QUALITY CONTROL

Why Quality Control?

CONSISTENT PERFORMANCE: TRM performance characteristics are derived flume testing and used to design for long term project lives.

CONSISTENT PRODUCT: The key to consistent performance is to have uniform, consistent product (the same as product tested).

QUALITY CONTROL: Incorporating QUALITY CONTROL clauses into contract documents is the only way to guarantee consistent performance.

MARVs: Minimum Average Roll Values

Standard deviations determine MARV Values

- **Typical Value - indicates a 50% confidence that any sample taken during quality assurance testing will exceed the value reported.**
- **MARV - indicates a 97.5% confidence that any sample taken during quality assurance testing will exceed the value reported!**
- **The key to evaluating consistent product is to establish and maintain updated MARV values.**

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

Keys to Installation

SOIL CONTACT

ANCHORS

ANCHOR TRENCHES

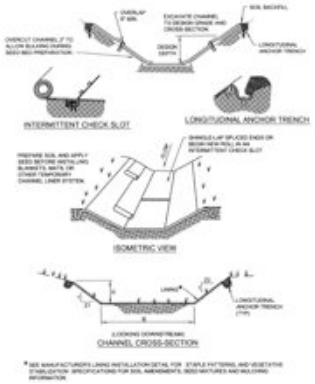
SOIL CONTACT: Establishing intimate contact with the final soil grade is essential for any successful TRM installation.

ANCHORS: Proper anchor selection, frequency and pattern is another essential aspect of successful TRM installation.

ANCHOR TRENCHES: Protecting the integrity of the TRM with proper termination anchor trenches is the final essential issue in successful TRM installation.

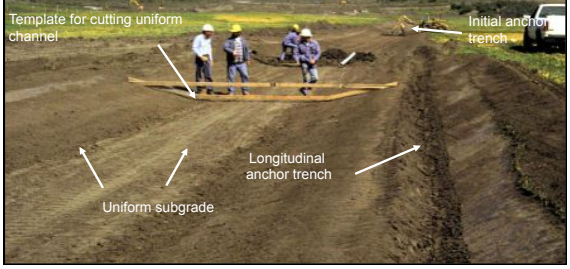
STANDARD CONSTRUCTION DETAIL # 6-1 Vegetated Channel

Page 146

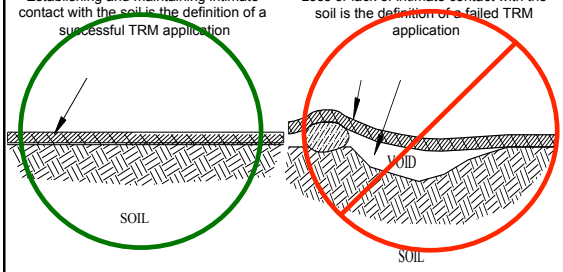


Proper preparation is important

The key to a successful TRM installation is to "Establish and maintain intimate contact with the soil surface" and not let water umdermine the application.



Intimate Contact with Soil Sub-grade



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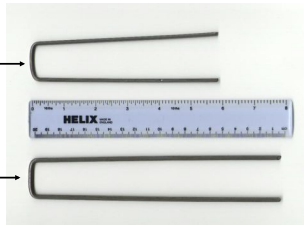
wcohn@acfenvironmental.com, 888-856-4505

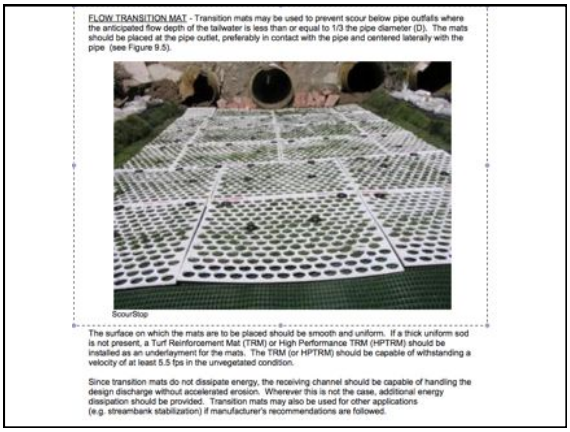
Installation

Anchors

ECBs generally use 6"x 1"x 6" 11 Gauge U shaped Staples



TRMs generally use 8"x 1"x 8" 9 Gauge U shaped Staples



FLOW TRANSITION MAT - Transition mats may be used to prevent scour below pipe outfalls where the anticipated flow depth of the tailwater is less than or equal to 1/3 the pipe diameter (D). The mats should be placed at the pipe outlet, preferably in contact with the pipe and centered laterally with the pipe (see Figure 9.5).

ScourStop

The surface on which the mats are to be placed should be smooth and uniform. If a thick uniform sod is not present, a Turf Reinforcement Mat (TRM) or High Performance TRM (HPTRM) should be installed as an underlayment for the mats. The TRM (or HPTRM) should be capable of withstanding a velocity of at least 5.5 fps in the unvegetated condition.

Since transition mats do not dissipate energy, the receiving channel should be capable of handling the design discharge without accelerated erosion. Wherever this is not the case, additional energy dissipation should be provided. Transition mats may also be used for other applications (e.g. streambank stabilization) if manufacturer's recommendations are followed.

Post Construction Erosion Prevention

FlowTransition Mats

A high value, low environmental impact & economical solution to surface flow protection needs.

Light-weight and portable mats protect surfaces from damage caused by concentrated or sheets flows, vehicles, equipment and pedestrians.

Flow Transition Mats provide resistance to the erosive forces that can be generated at these transition areas.

Example of Flow Transition Mat application.

Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

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Example of Flow Transition Mat application.

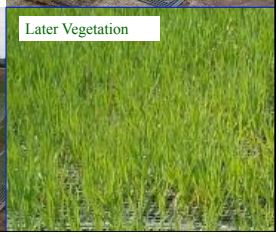
FlowTransition Mats
Surface Flow Protection

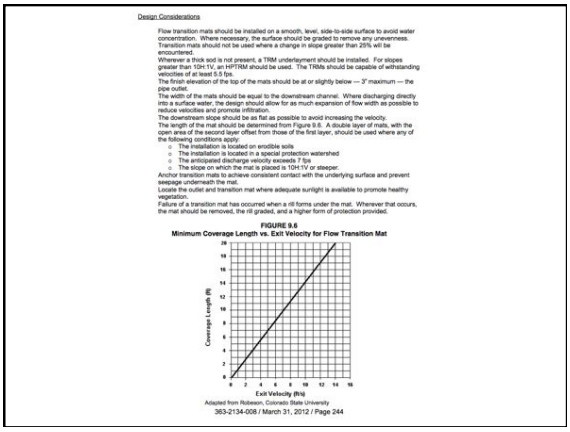
Hardened vegetated system that disappears after full vegetation growth.

Culvert Outfall Areas

Overflow Structure:
6 months later.

Flow Transition Mat Stormwater Channel





Design Considerations

Flow transition mats should be installed on a smooth, level, side-to-side surface to avoid water concentration. Where necessary, the surface should be graded to remove any unevenness. Transition mats should not be used where a change in slope greater than 25% will be encountered.

Wherever a thick sod is not present, a TRM underlayment should be installed. For slopes greater than 10H:1V, an HPTRM should be used. The TRMs should be capable of withstanding velocities of at least 5.5 fps.

The finish elevation of the top of the mats should be at or slightly below — 3" maximum — the pipe outlet.

The width of the mats should be equal to the downstream channel. Where discharging directly into a surface water, the design should allow for as much expansion of flow width as possible to reduce velocities and promote infiltration.

The downstream slope should be as flat as possible to avoid increasing the velocity.

The length of the mat should be determined from Figure 9.6. A double layer of mats, with the open area of the second layer offset from those of the first layer, should be used where any of the following conditions apply:

- The installation is located on erodible soils
- The installation is located in a special protection watershed
- The anticipated discharge velocity exceeds 7 fps
- The slope on which the mat is placed is 10H:1V or steeper.

Anchor transition mats to achieve consistent contact with the underlying surface and prevent seepage underneath the mat.

Locate the outlet and transition mat where adequate sunlight is available to promote healthy vegetation.

Failure of a transition mat has occurred when a rill forms under the mat. Wherever that occurs, the mat should be removed, the rill graded, and a higher form of protection provided.

FIGURE 9.6
Minimum Coverage Length vs. Exit Velocity for Flow Transition Mat

Adapted from Robeson, Colorado State University

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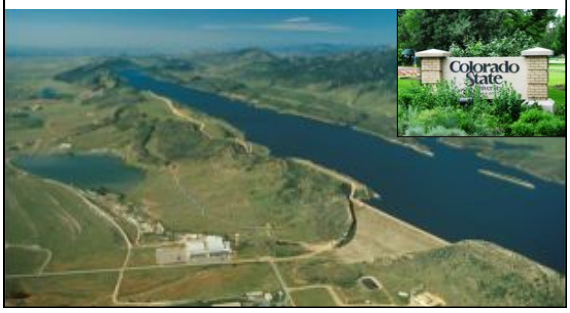
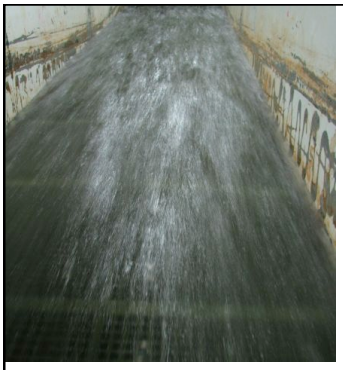
Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505

A system with full scale hydraulic testing should be considered.

Example: Colorado State University Testing Facility





Colorado State University Hydraulics Laboratory

Test in accordance with ASTM D6460, Standard for Erosion Control Products in Earthen Channels

Flow Transition Mats placed over TRM and anchored per MFG recommendations

40 ft long channel

Consecutive 30 min tests until failure

Failure is 0.5 in of soil loss

Impressive Unvegetated Results:

Increased TRM performance 6.1x based on shear stress

Increase TRM performance 2.4x based on velocity

Higher Manning N value

MISCELLANEOUS HARD ARMOR TECHNIQUES

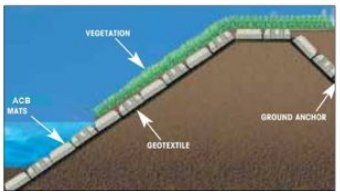
Various other products exist on the market that may be suitable for streambank stabilization. These include but are not necessarily limited to: cable concrete, articulated concrete, and concrete jacks. Where such products are proposed, consideration should be given to specific site conditions such as access by construction equipment, anticipated flows, soil limitations, site dimensions, public use, and aesthetics, which might make some products less desirable than others. The manufacturer's recommendations, product limitations, cost, and project life are other factors that should be taken into account when choosing a suitable stabilization method.

Source Unknown

In each case, product specifications, installation details and sequencing, and maintenance standards should be included in the E&S Plan for each product proposed.

ACB System

- Suitably compacted subgrade
- Site specific geotextile
- ACB Blocks
- Backfill



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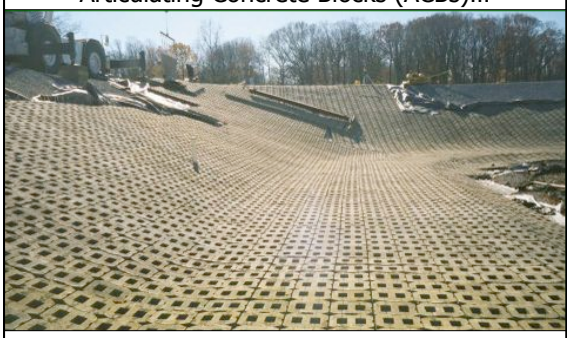
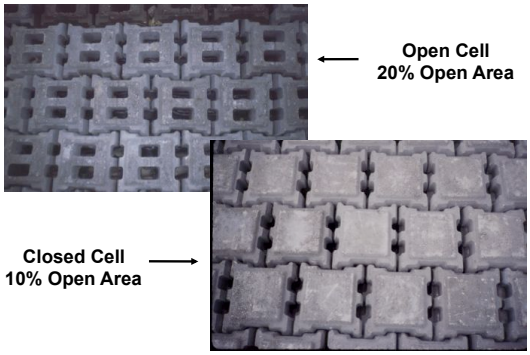
Articulating Concrete Blocks (ACBs)…



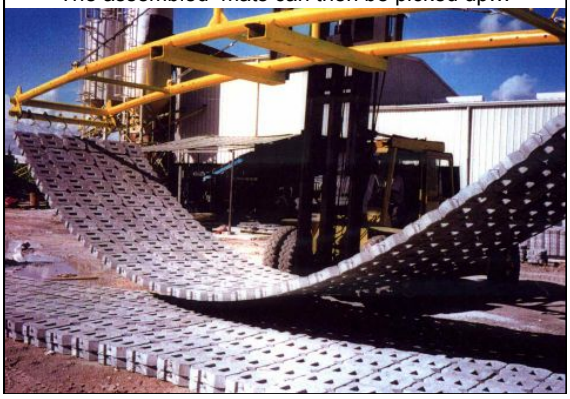
…are individual concrete block units joined together to create revetment mats or systems.

The individual ACB units are generally manufactured at standard block plants…



Cabled systems are assembled at the Block plant.

The assembled mats can then be picked up…



…and transported…

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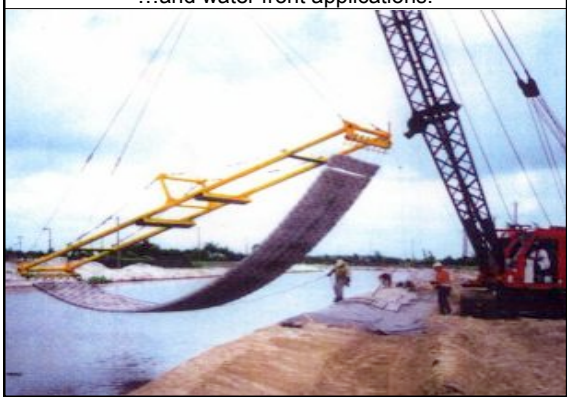
…and then installed one mat at a time.
The large mat installation process may be beneficial for both inland…

…and water front applications.



•Hand placed ACBs are used to provide protection for underlying soil materials system provides protection for underlying soil materials.

•The individual blocks conform to changes while remaining interlocked by virtue of the geometric shape of each block.
•The interlocking properties allow for expansion and contraction.

•ACB is hand placed on top of selected geotextiles or other engineered bases and act as a soil revetment.

Hand placed ACBs delivered and "spotted" on pallets and then placed by hand.

ACBs also offer Unique Construction Flexibility.

Unique Construction Flexibility.

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ACBs provide open area which can be…

…re-vegetated, providing a green solution that will allow filtration and ground water infiltration of channelized flow, acting as both a water quality and water quantity BMP.

Channel Linings

Steep Downchutes.

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Pipe Protrusions

Many systems offer open or closed cell systems

Small Residential Application

The Virginia Department of Transportation needed a cost effective solution for a vehicle crossing on a stocked trout stream located in rural Highland County.

After obtaining the site grades, hydraulic flow data, desired width of the travel lane, expected vehicle frequency and loads a specific supplier was able to design a system of ACBs

The Closed Cell ACBs were delivered to the project site as prefabricated cabled mats.

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ACB Mat Placement Sequence begins as mats are picked up from the flatbed using a Spreader Bar.

The stone base was leveled prior to ACB mat placement.

The ACB System installation sequence continues.

The ACB System installation sequence continues.

Installed ACB System ready for vehicle traffic. The project took four days in total to complete.

The ACB mats were fabricated to meet the specified 14' travel lane width.

Completed stream crossing in use.

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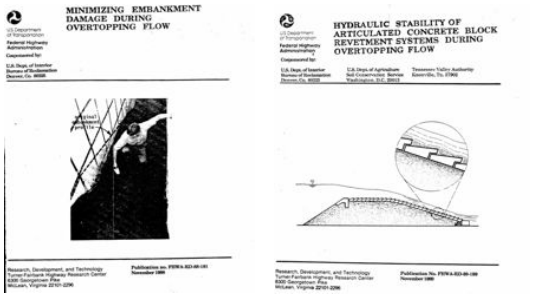
Original Solution

Aesthetics, Safety, Vandalism, Maintenance and Pest Control

ACBs provide a safe, aesthetically pleasing finished application that is hard to vandalize, easy to maintain and will not breed vermin and snakes

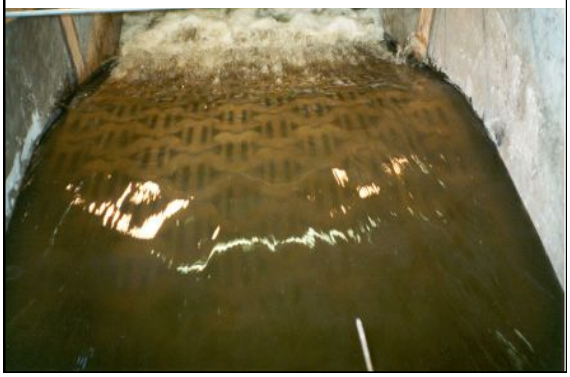
Hydraulic Stability

Significant research has been conducted to establish design and evaluation methodology for ACBs…



…full scale flume testing of ACBs indicate that…

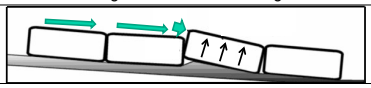
…each ACB system has its own set of hydraulic characteristics, based on the weight and interlock of that particular ACB,



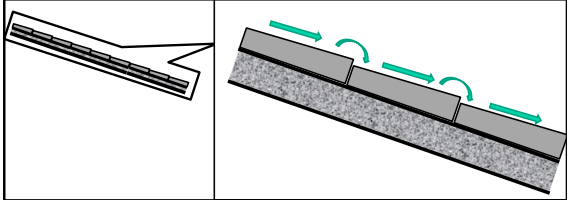
ACB's Tapered Series

New Tapered ACBs for Enhanced Hydraulic Performance

The most common mode of hydraulic failure of standard ACBs is due to the forces on any individual blocks that are protruding above the upstream blocks due to sub-grade or installation irregularities.



The tapered top of the new SD series prevents the protrusions; greatly enhancing the hydraulic performance of the ACBs.



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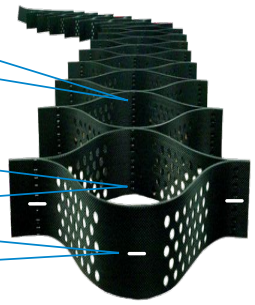
Cellular Confinement Systems

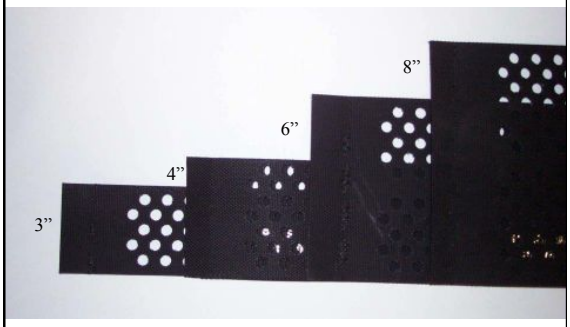
The Container
Comes in different Sizes, Depths and Panel lengths

The Content
Topsoil
Aggregates
Concrete
Engineered Fill

Other Components
Geo-Items
Tendons
Anchors



CCS cells and panels are available various heights.



Infill options for the CCS include free draining soil, sand, stone, concrete or mixtures of soil with sand and/or stone.

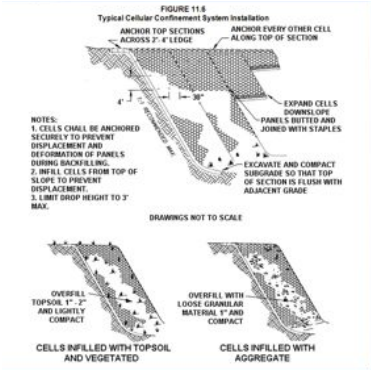
A Cellular Confinement System (CCS) is an engineered, expandable, polyethylene, honeycomb-like cellular structure.

CELLULAR CONFINEMENT SYSTEMS are three-dimensional, honeycombed sheets, mats, or interlocking structures filled with soil, gravel, concrete, or other material. They are used to stabilize the surface of cut and fill slopes, streambanks, or natural slopes. They may also be used to increase the load-bearing capacity of a roadway or to create a permeable pavement system. The honeycomb-shaped cells encapsulate and prevent erosion of the infill material, making it an appropriate method of stabilizing high volume or high velocity channels.

Geosynthetics

Manufacturer's recommendations should be followed regarding application, slope limits, installation procedure and appropriate fill material. It is important that the cells be properly anchored in order to prevent deformation or sliding of the panel. Therefore, cellular confinement systems should not be used where soil or rock conditions prevent installation of the anchoring pins in the required pattern.

When filling the cells, care should be taken to avoid damaging them. Limit drop heights to 3 feet or less.



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Cellular Confinement: Slope Protection

- PA Stormwater BMP Manual Chapters 5 & 6
  - 5.6 Minimize Disturbance and Minimize Maintenance
    - 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species
      BMP 6.6.2 Wet Pond/Retention Basin

Shop 'n Save, Monroeville, PA

Rocks falling from the slope face onto the parking lot was the problem…

…loose rock and soil was removed to prepare the surface…

…palletized, unexpanded CCS was delivered to project site…

…apparatus was created to run tendons through CCS panels…

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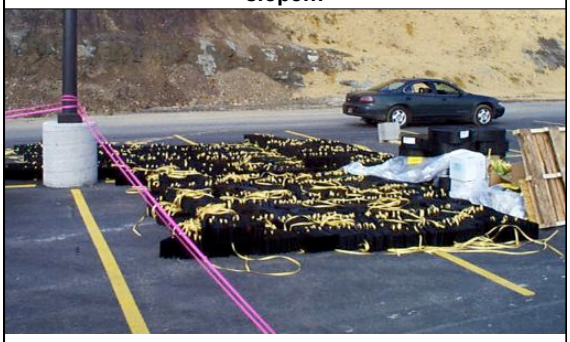
…prepared CCS panels staged for installation on slope…



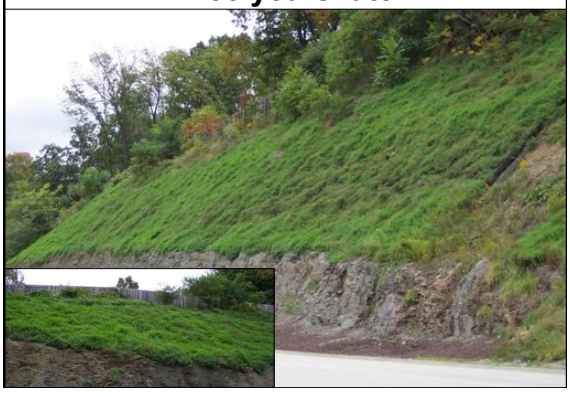
…Geotextile fabric was placed first and then CCS panels with tendons secured to anchor I-Nuts …

…CCS panel installation continues across slope…

…view of partially in-filled CCS on slope…

…one year later slope is stable, secure and vegetated.

Three years later.



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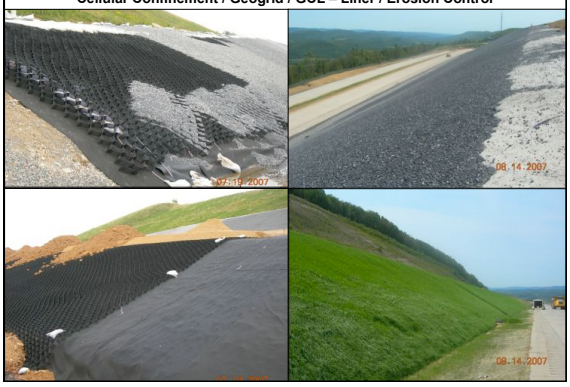
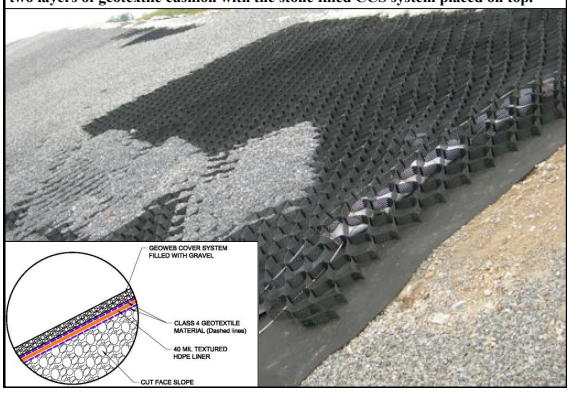
I-99 Pyrite Slope Remediation Project
Cellular Confinement / Geogrid / GCL – Liner / Erosion Control

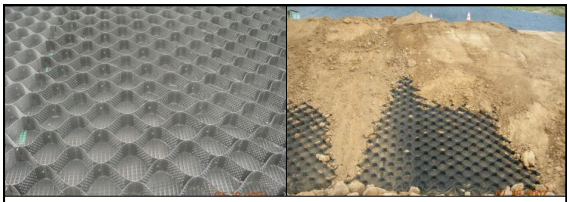


The large cut face slope used a profile of a 40 mil textured HDPE liner between two layers of geotextile cushion with the stone filled CCS system placed on top.



One portion of CCS / Liner / stone fill system slope completed.

Another portion of the remediation project used a profile of GCL with Geogrid and soil-filled CCS on top.



CCS placed on top of the GCL and Geogrid, soil-filled and seeded, covered with an erosion control blanket and vegetated.

Completed section of GCL / Geogrid / CCS Cellular Confinement composite.

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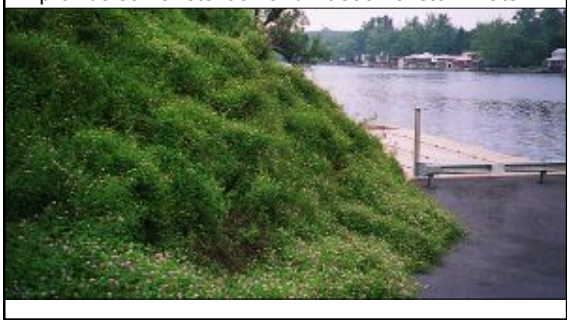
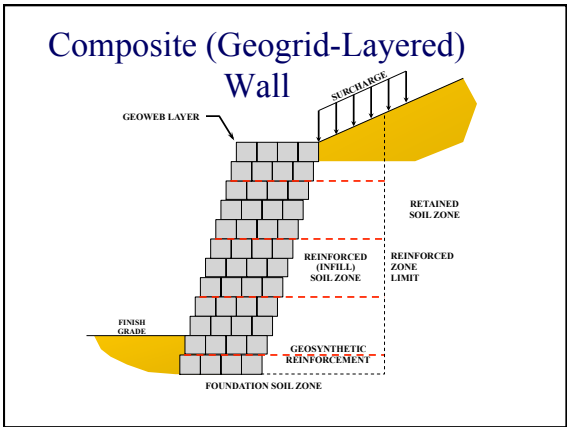
The basic concept for implementing a CCS in these "earth retention" applications is to use a solid outer face on the panels and offset them back as they are stacked.

The resulting exposed outer cell provide the options of a vegetated, living "green" wall which is aesthetically pleasing, provides animal habitat, graffiti proof and will provide some retention and filtration of stormwater.





The CCS construction sequence continues lift by lift to desired height.

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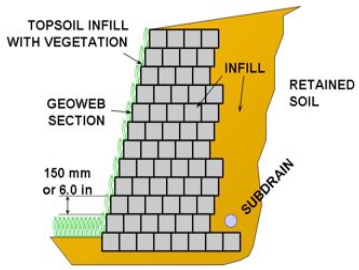
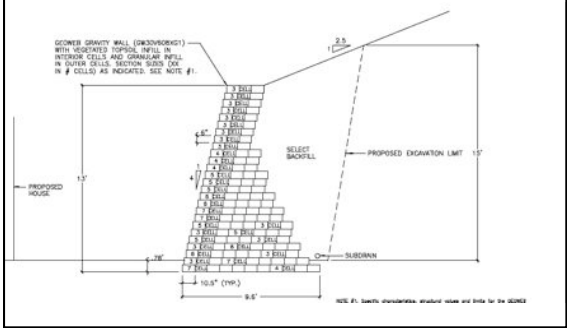
Geoweb Gravity Wall



A stacked CCS can also be used as a gravity structure, eliminating the need for deeper embedment lengths for planer reinforcement.



CCS is spread and placed on frame.

8 inch perforated CCS

Spreader form is turned over during construction sequence to facilitate placement of infill.

Granular infill is placed into CCS

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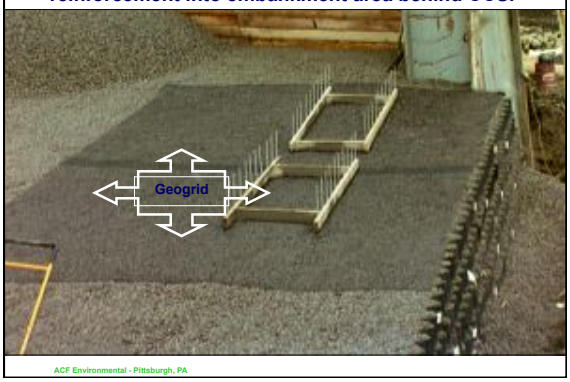
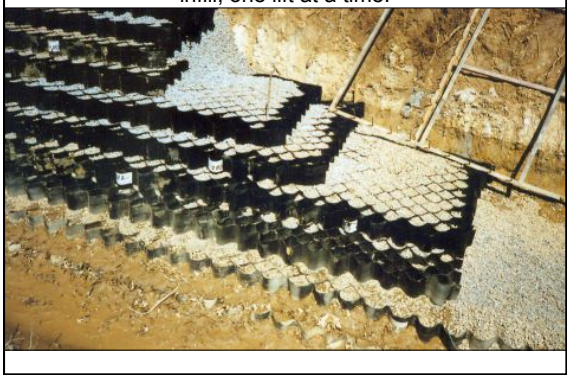
Granular infill is placed into CCS. Note geogrid reinforcement into embankment area behind CCS.



ACF Environmental - Pittsburgh, PA

Entire structure was built in 36 Man-hours

Construction of stacked CCS continues with structural infill, one lift at a time.



Construction of stacked CCS continues on the other side of the waterway.

Completed stacked CCS gravity structures.

Stacked CCS gravity structures vegetated (13 years).

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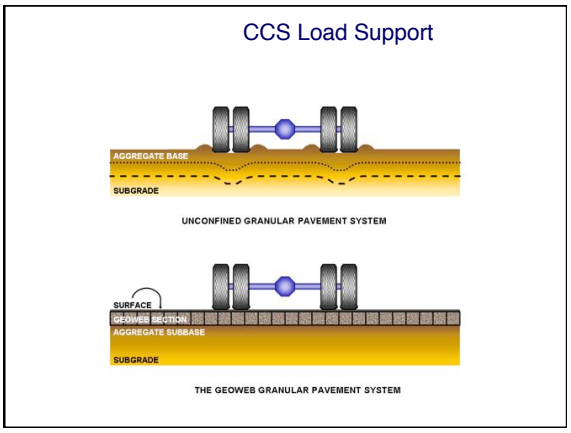
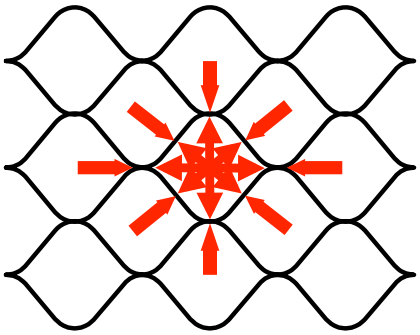
Stacked CCS gravity structures vegetated (13 years).



The CCS structure will enhance the performance of any infill materials.



CCS panels are expanded and stapled.

Infill is placed onto expanded CCS.

Infill is spread and compacted into CCS.

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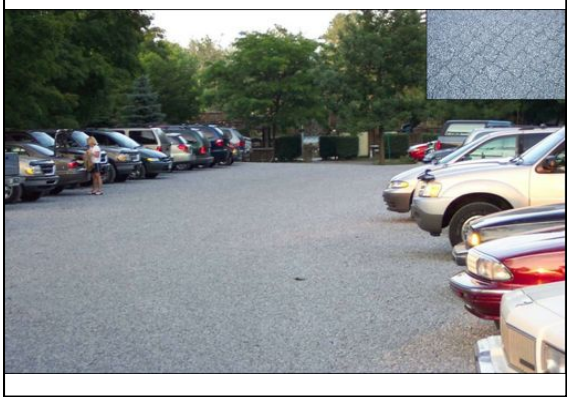
Completed CCS Gravel parking Application.



Comparison of CCS gravel parking area vs conventional gravel lot during a rain event.

Pa. American Water Co. / West Decatur, PA Water Tank
Steep Access Road / Surface Stability Application / April 2003

Expand panels and anchor in place.

Filling cells with a 2A stone w/ 2" wearing surface

Some hand work may be needed to finish-grade surface.

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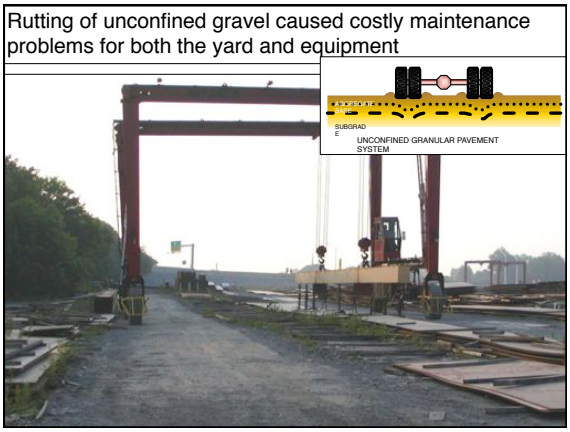
Finished installation

Steel Structures Industrial Yard

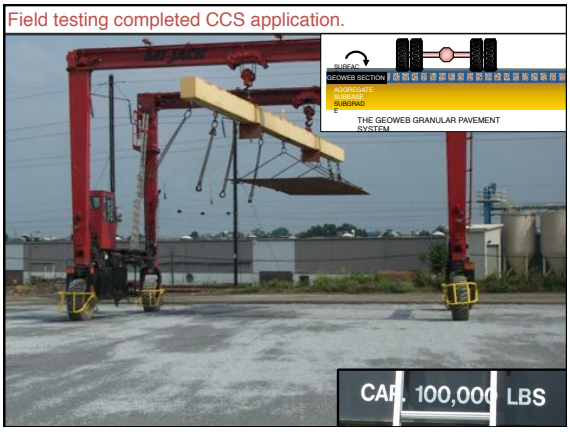
Rutting of unconfined gravel caused costly maintenance problems for both the yard and equipment



Panels are easily fit around protrusions.

Field testing completed CCS application.

Field testing completed CCS application.



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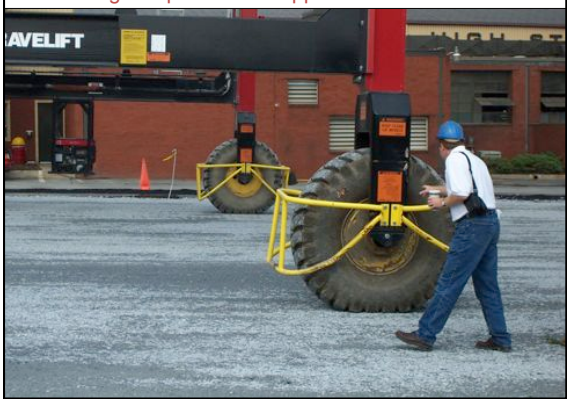
Field testing completed CCS application.



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High Water Bypass Sequence

High Water Bypass Sequence

High Water Bypass Sequence

High Water Bypass Sequence

CCS filled with "Engineered Soil" mixture of soil and stone provides a cost effective and easy to construct pervious roadside treatment.

1. Mixing of "engineered soil"

2. Placement of engineered soil into CCS.

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Completed CCS / Engineered Soil application.

COLORADO STATE UNIVERSITY

Cellular Confinement Testing

Vegetated CCS Testing w/TRM

Unvegetated CCS Testing w/TRM

- Unvegetated Testing
  - Geoweb GW30V6
  - NAG C350 TRM
  - 9 runs
    - 2.2 – 10.2 cfs
    - Slope 2.5 – 10.5%
    - Max velocity: 9.3 fps
    - Max shear: 3.7 psf
    - Max soil loss: 0.27 in
- Test Details
  - Per ASTM D6460 – ECB Standards
  - Performance Threshold is a Soil Loss < 1/2 inch

Vegetated CCS Testing w/TRM

TEST PARAMETERS

- Per ASTM D6460 – ECB Standards
  - Performance Threshold is Soil Loss < 1/2 inch
- Blade density above 300 blades/sqft

Vegetated CCS Testing w/TRM

IMPRESSIVE RESULTS

Slope = 2:1
(26.5 Degrees)

Max Velocity of 29 ft/s

Max Shear Stress of 16 psf

Essentially Zero Soil Loss (0.05") – 1/10 of ASTM D6460 Threshold of 0.5 Inches

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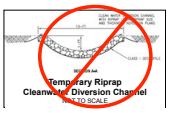
Concrete filled CCS Liner / Pad

Reusable hard armor channel liner as alternative to rock riprap

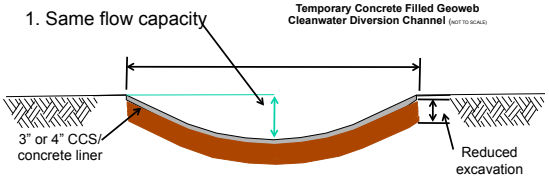
Concrete Filled CCS Pipe Line Applications:

Temporary, reusable diversions as alternative to Riprap Channels



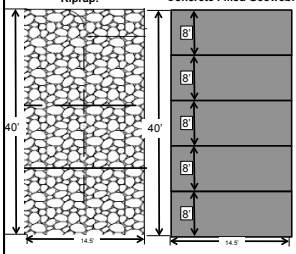
Benefits:

1. Same flow capacity



2. 3" to 4" depth of concrete filled CCS liner will reduce over excavation by up to 15 inches!

Riprap vs. Concrete Filled CCS Diversion Considerations



Riprap vs. Concrete Filled CCS:

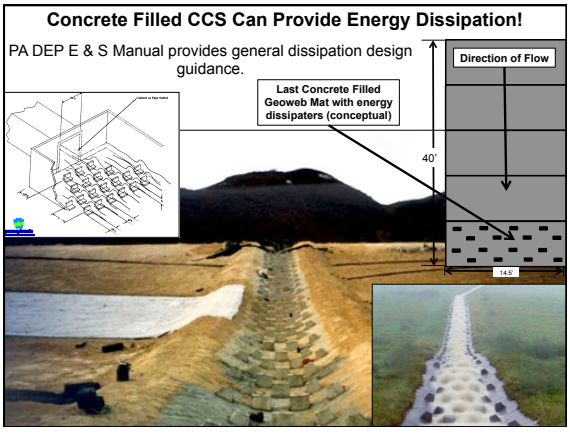
Liner Material	Weight lbs. sq ft	Max Velocity FPS	Max Shear Stress lbs sq ft
R-4 Riprap	165	9	2
R-5 Riprap	250	12	3
3" Concrete Filled CCS	37	37	29
4" Concrete Filled CCS	50	37	29

Typical Diversion Comparison: Riprap vs. Concrete Filled CCS
R-4 Riprap: d^{50} = 6" / 12" layer, 165 lbs sq ft, 14.5' wide x 40' long = 580 sf X 165 lb. sf = **95,700 lbs.**
R-5 Riprap: d^{50} = 9"/ 18" layer, 250 lbs sq ft, 14.5' wide x 40' long = 580 sf X 250 lb. sf = **145,000 lbs.**
3" Concrete Filled CCS: 3" Thick layer, (5 – 8' x 14.5 ft mats) = 580 sf X 37 lb. sf **= 21,460 lbs.**
4" Concrete Filled CCS: 4" Thick layer, (5 – 8' x 14.5 ft mats) = 580 sf X 50 lb. sf **= 29,000 lbs.**

Concrete Filled CCS provides flexibility and many placement equipment options.

Concrete Filled CCS Can Provide Energy Dissipation!

PA DEP E & S Manual provides general dissipation design guidance.



Warren Cohn CPESC, CPSWQ
wcohn@acfenvironmental.com, 888-856-4505