Methods for Armoring Your Containment and Water Conveyance Systems

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Protecting infrastructure through routine maintenance continues to be an increasingly expensive challenge for asset owners. Higher costs can be for many reasons, apart from the actual construction expense, and can include: **disruptions of daily operations, personnel re-allocations, recurring performance issues, liability exposure and potentially regulatory compliance concerns.** These outlays influence some facility operators to look for alternative repair or design solutions because current standard practices are lacking effectiveness.

Common maintenance concerns include **drainage, water quality runoff, protecting secondary containment systems, erosion protection, soil stabilization, fire protection and facility aesthetics.** The major problems to evaluate for a maintenance project are impacts to daily operations, safety, durability of the solution, regulatory compliance requirements, time restrictions or future infrastructure expansion projects.

There are multiple construction materials available for applications, including Geosynthetic Cementitious Composite Mats (**GCCM**), riprap, shotcrete, asphalt sprays, turf reinforcement mats (**TRMs**), vegetation, poured concrete, revetment mats and articulate concrete blocks for armoring a bund/dike, drainage channels, slopes, shorelines and geosynthetic membranes, but each material has advantages and disadvantages. These materials will be covered in more detail on page 5.

Standards and Requirements

Regulatory standards require terminal storage tanks to have permanent engineered barriers, such as raised earth embankments or concrete containment walls, which are designed to provide secondary containment in case the storage tank fails. There are normal inspection requirements for a dike, berm or other engineered containment systems to make sure the secondary containment is maintained adequately in case a leak occurs.

Required permanent engineered barrier around terminal storage tanks.

The **minimum** inspection requirements are:

1. Verifying capacity of the system to contain the entire tank
2. Identifying the weak areas of the containment system
3. Identifying excessive vegetation that inhibits visual inspection and assessment of berms or large-rooted plants affecting the integrity
4. Fire protection
5. Drainage records for rainwater discharge from a containment area

Facilities are constantly repairing their berms based on the results of the inspection reports and/or new agency requirements for secondary containment. The typical secondary berm protection armoring material is gravel, vegetation or oil emulsion geotextiles. These products have the lowest installation costs and minimum performance capabilities but typically have the highest maintenance costs and usually fall out of compliance because of weather or on-site activities. Hard armoring solutions, such as a GCCM, shotcrete or poured concrete, have higher initial installation costs but lower maintenance costs. These solutions are compliant for a longer period and have better performance under normal and extreme weather conditions.

In addition to the containment itself, terminal storage tanks are typically required to have a permanent drainage system to manage precipitation that accumulates on-site as well as off-site discharge at tank facilities. The drainage ditch must be maintained to ensure stormwater quality is not affected before it is discharged off-site. Maintenance requirements include pH, turbidity (**NTU**) and chemical constitutes that the facility has stored or manufactured on-site.

Example of an out-of-compliance berm.

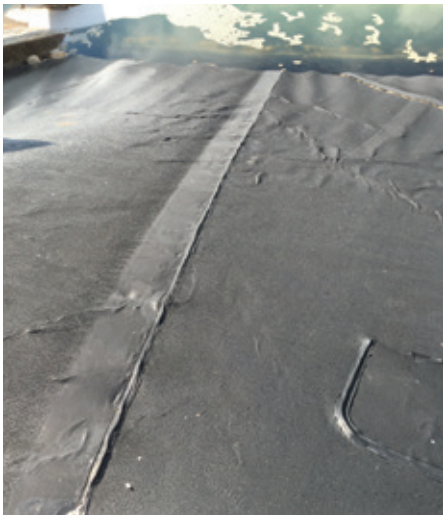
The **normal** inspection requirements for drainage include:

1. Presence of spilled or leaked material
2. Stressed vegetation, erosion or slope stability
3. Cracks (*concrete, liners, earthen materials*)
4. Water sample results

Facilities that do not maintain their drainage systems will most likely be out of compliance for erosion, water quality and saturated soil conditions that can cause geotechnical stability issues and flooding, which accelerates infrastructure corrosion. Just like armor protection for berms, the lower cost solutions (*vegetation, TRMs, asphalt sprays and riprap*) have high maintenance costs with low hydraulic flow capabilities that cause saturated soil conditions and have a higher probability to be out of compliance compared to GCCMs, shotcrete and poured concrete.

Geosynthetic Liners

Geosynthetic liners are also used for containment. They have low permeability rates and excellent chemical compatibility. The liner's capabilities and performance will be compromised, however, if the geosynthetic liners are exposed to excessive UV, abrasion, fire/flame/high temperatures or continuous thermal expansion. Agencies are beginning to suggest that facilities armor geosynthetic liners from exposure to the above issues, especially when the operations are in sensitive ecological areas surrounding the facility and/or protecting the ground water table, waterways or similar structures.



Geosynthetic liner failure.

Typical armoring protection methods for geosynthetic liners include placing riprap, shotcrete, poured concrete or soil over the liner. These methods, however, could potentially damage the liner during the installation and require capacity compensation for volume displacement. Additionally, it would be difficult to verify inspection of the liner and remediation costs for removal if a spill or leak occurred. A relatively new approach is using a material like Concrete Cloth™ GCCM that has a minimum profile (***0.2 – 0.5 inches thick***) with high performance capabilities including abrasion, heat, fire, hydraulic shear and no effect to the secondary volume capacity when installing in existing containment systems.

Concrete Cloth GCCM has a minimum profile of 0.2 – 0.5 inches thick.

Deciding on Armor Protection

Armoring protection for bunds/dikes, drainage and geosynthetic membranes are specific applications, but their performance requirements for the armoring protection are all relatively similar. They need to protect the surface from live and dead load damages that are applied directly or indirectly. Some types of damages include: erosion, punctures, tears, holes, soil stability, melting and fire damage. These damages would cause the facility or unit to be out of compliance. Engineers and asset owners evaluate alternatives to determine which method of armor protection will meet their needs while staying in compliance, minimizing maintenance issues, not interfering with current or future operations and recognizing the functional longevity of the armor. **More specific criteria for evaluating armor selection includes:**

- Ease of installation without affecting surrounding areas or infrastructure
- Total cost *(installation and overall maintenance throughout its functional longevity)*
- Restrictions for maintenance *(such as accessibility, daily operations and safety)*
- Specific performance requirements *(abrasion, flame resistance, compressive strength, permeability, flex strength, coefficient of permeability, frost freeze, chemical compatibility and shear forces)*
- Ease of repairs or modifications
- Minimum labor and equipment for installation
- Seasonal installation capabilities
- Safety issues for installation and maintenance

Other Armoring Materials

Though each material has advantages and disadvantages associated with its use, specific project characteristics and challenges greatly influence the selection of materials. In general, one should not only consider cost, but also weight, life cycle, repairs and other needs of a particular job site. A comprehensive list of armoring materials and their characteristics is detailed below.

	Concrete Cloth™ GCCM	Poured Concrete	Revetment Mats	Shotcrete	Riprap/Gravel	Sprayed Oil Emulsion	Vegetation
Maintenance Requirements	LOW	LOW	LOW	MODERATE	MODERATE/HIGH	HIGH	HIGH
Fire Protection	EXCELLENT	EXCELLENT	MODERATE	EXCELLENT	POOR	POOR	POOR
Installation	MODERATE	DIFFICULT	HARD	DIFFICULT	MODERATE	MODERATE	EASY
Subsurface Access	ACCESSIBLE	NOT ACCESSIBLE	NOT ACCESSIBLE	NOT ACCESSIBLE	ACCESSIBLE	ACCESSIBLE	ACCESSIBLE
Weather Performance	EXCELLENT	EXCELLENT	MODERATE	MODERATE	POOR	POOR	POOR
Hydraulic Performance	GOOD	GOOD	MODERATE	GOOD	POOR	POOR	POOR
Repairs	MODERATE	HARD	HARD	HARD	EASY	HARD	HARD
Life Cycle Cost	LOW	MODERATE	MODERATE	MODERATE	MODERATE	HIGH	HIGH
Permeability	LOW	LOW	MODERATE	LOW	HIGH	HIGH	HIGH
Prevents Desiccation of Subsurface	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT	POOR	POOR	POOR

BETTER — WORSE

Riprap

Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes and channels from erosion. However, Concrete Cloth GCCM performs better than riprap and can be less expensive over the installed life (overall installation and maintenance). The most critical value proposition for using Concrete Cloth GCCM versus riprap is the increased hydraulic performance value characteristics.

The typical manning "n" value for riprap is in the range of 0.05-0.08 versus Concrete Cloth GCCM of 0.01. These values indicate that one can have a larger volume of water for Concrete Cloth GCCM vs. riprap given the same cross-sectional area. The value proportion is that Concrete Cloth GCCM is 0.3 inches thick and riprap is in the range of 1.5 – 3.0 feet thick based on a 1.5:1 slope (a major increase of earth moving and shaping). Additionally, Concrete Cloth GCCM is anchored to the surface, minimizing movement, while riprap tends to move over time.

Other issues are mentioned below:

- Slides down into the channel and changes the hydraulic flow conditions
- Saturates the subsurface, causing slope instability and major water loss
- Increases vegetation, weed, shrubs and tree growth, causing hydraulic flow and increased maintenance costs
- Increase of sediment loading, which decreases the hydraulic flow
- Increase in turbidity (**NTU**) and water quality

Another outstanding performance characteristic of Concrete Cloth GCCM versus riprap is low maintenance costs. It has been believed, and misunderstood, that riprap has a low maintenance cost. As noted above, however, the maintenance cost is high while Concrete Cloth GCCM has a very low to no maintenance cost. The overall installation for Concrete Cloth GCCM will be 3-5 times faster and provide minimal disturbances. The overall system in operation is faster and has minimum weather delays versus the performance of riprap. Also, yearly inspections are easier with Concrete Cloth GCCM compared to riprap.

Revetment Mats/Articulated Block

Revetment mats or articulated block are typically desired for energy dissipation and are used in shoreline protection or heavy erosion control where the use of gabions or riprap is not desired. By design, revetment mats allow the vegetation to grow through such that seeds and nutrients accumulate within the pockets of the mat. This growth can cause additional operational and maintenance costs to the city to remove the vegetation. Concrete Cloth GCCM has a smooth surface, which limits the capacity for seeds and nutrients to accumulate and thus reduces the chance for vegetation to grow on the surface.

In applications where there is a desire to store water, Concrete Cloth GCCM is thinner than a standard 3-inch revetment mat, which provides more water storage capacity.

Concrete Cloth GCCM will be 3-5 times faster to install.

Fabric-Formed Mat

Similar to articulated block, fabric-formed mats are revetment mats created by injecting a "pillow" with ready-mix concrete. The idea is that the fabric sections are sewn together in the field and then pumped with cement, which allows one to form concrete in areas previously considered to be difficult or impossible to use concrete. The system works well for shoreline erosion protection as well as ditches and channels where the grade is less than 2:1. The system does well at eliminating water peculation and vegetation issues and is fairly easy to install given easy site access.

The issues with this system are fabric tears releasing the cement, sloughing of the system down an embankment or UV deterioration of the fabric leading to poor structure integrity and an unsightly area. Additionally, it can require over-excavation and access for the pump truck at the site, which can be significant deterrents.

Turf Reinforcement Mat (TRM)

TRMs are geosynthetic products that create a holding capacity for the vegetation root system to increase its permissible shear force during movement or flow of water and to minimize erosion and water quality. TRMs always require permanent dense vegetation. With the concerns of the constant vegetation maintenance, increased fuel for a fire, saturation of the subsurface soils of the hillside (slope stability issues) and the risk of a TRM entangling with wildlife, maintenance equipment and hikers, this option is sometimes eliminated.

Considering regulations and the advantages of GCCMs for storage tanks, berms, drainage systems and geosynthetic liners over alternative solutions, the use of a material like Concrete Cloth GCCM would be the most cost-effective, accessible and easy option for a repair.

If you would like to consider Concrete Cloth GCCM for your job site, or would like more information on the material, reach out to ClockSpring|NRI with any questions or concerns.

Armor protection using Concrete Cloth GCCM for a drainage ditch.