RECLAMATION

Managing Water in the West

Concrete Fabric for Concrete Canal Lining Repairs – Scoping Study

Research and Development Office
Science and Technology Program
(Final Report) ST-2019-9227-01 (8530-2019-50)

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

September 2019

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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The primary objective of this project was to learn more about Concrete Cloth ™ and its potential uses as a concrete repair material for Bureau of Reclamation (Reclamation) concrete canal linings. Several locations where Concrete Cloth ™ had been used were visited locally to see how it was performing in a freeze-thaw prone environment. The manufacturer was also contacted for further background information. This report will present the findings of the site visit, background literature review, and recommendations for future studies.

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Science and Technology Program

Concrete and Structural Laboratory, 86-68530

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Concrete Fabric for Concrete Canal Lining Repairs- Scoping Study

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Acronyms and Abbreviations

ft	feet
o.c	on center
PPE	Personal Protective Equipment
m	meters
Reclamation	Bureau of Reclamation

Executive Summary

Concrete Cloth ™ is a geosynthetic cementitious composite mat. The geosynthetic membrane consists of a bottom PVC membrane and a top fabric which is impregnated with a cementitious material that hardens once it has been hydrated. This product is relatively new to the concrete industry and there is little known about the longevity of the product in some of the harsh climates Reclamation structures are subject. This study reviewed examples where the product had been used in similar conditions to what Reclamation might use it. A firsthand look at the product was achieved by conducting a local site visit.

The local site visit established that the product is performing well in a freeze-thaw environment. The site visit also provided insight to a sealing detail that doesn't work in cold freezing conditions. The local government provided feedback on the ease of installation in which a small maintenance crew could install a repair to a corrugated steel pipe using Concrete Cloth in just one day. The site visit was very beneficial to get a first-hand point of view of the pros, cons, and lessons learned from their use of the product.

Many of the case studies that were reviewed for this study and the local repairs were all from installations in recent years. Therefore, there is not much documentation about the long-term performance of the Concrete Cloth ™. This project found that the product appears to be a viable product, but further laboratory and field studies should be conducted prior to specifying it on a large project.

Laboratory studies should be conducted to compare it to other typical repair techniques. In addition, one of the biggest benefits of Concrete Cloth ™ is the ease of installation. The construction costs should be reviewed to consider if the potential cost savings in installation would outweigh the potential performance benefits of traditional methods. Field studies should be conducted to account for real world conditions that may not be replicated in a lab test.

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Abstract

The primary objective of this project was to learn more about Concrete Cloth ™ and its potential uses as a concrete repair material for Bureau of Reclamation (Reclamation) concrete canal linings. Several locations where Concrete Cloth ™ had been used were visited locally to see how it was performing in a freeze-thaw prone environment. The manufacturer was also contacted for further background information. This report will present the findings of the site visit, background literature review, and recommendations for future studies.

Background

Traditionally, concrete lined canals at Reclamation are repaired by cementitious repair products that require skilled labor and extensive surface preparation. Some canals are completely replaced due to the extensive deterioration of the canal. However, there are numerous propriety concrete products on the market that have the potential to be effective concrete repair materials for concrete lined canals. A recent innovation is “concrete fabric” or “concrete cloth” which is a geosynthetic cementitious composite mat which can be rolled out, cut to size, and secured in place. Once hydrated, it will become a rigid barrier and has the potential to serve as a rapid repair method for damaged concrete in concrete canals. There has been some limited use of this product for canal repairs.

Reclamation has hundreds of concrete lined and unlined canals in their aging inventory that need repair. Short outage time to perform repairs becomes critical to the farmers and municipalities that rely on the water provided by Reclamation. Even a short-term repair until a complete replacement can be performed can have significant benefits to the end users.

Conclusions

1. Concrete Cloth ™ has been used successfully in a freeze-thaw environment to repair corrugated metal pipe with little to no signs of deterioration to the fabric after approximately a 5-year period.
2. A polyurethane joint sealant performs better in a freeze-thaw environment than a grouted joint seal.
3. Concrete Cloth ™ needs a compacted, level surface to apply the cloth. Therefore, some minor repairs using cementitious grout or gravel may be necessary to fill voids prior to cloth installation.
4. Further lab and field studies should be conducted to determine if Concrete Cloth ™ can be a long-term repair option of some Reclamation canals.

Discussion

What is it?

Concrete Cloth ™ is a geosynthetic cementitious composite mat manufactured in North America by Milliken Infrastructure Solutions. Milliken Infrastructure Solutions has a license agreement to manufacture and sell Concrete Cloth ™ from Concrete Canvas. Concrete Canvas and Concrete Cloth are the same product. There are no other products like Concrete Cloth ™ (aka Concrete Canvas) being sold in the U.S. that the principle investigator is aware of.

The geosynthetic membrane consisting of a bottom PVC membrane and a top fabric which is impregnated with a cementitious material that hardens once it has been hydrated. The cloth is flexible enough to contour to any slope. However, once it is hydrated, it hardens to the shape in which it was placed creating a nearly impenetrable surface which can be used as a ditch lining, slope protection, and a wear surface for culverts [1].

Concrete Cloth ™ comes in rolls of varying widths and thicknesses ranging from 0.2 to 0.5 inches thick and 3.375 to 3.625 feet wide. The length of the rolls also varies from man portable sized (up to 30 ft long) to bulk rolls ranging from 240 to 656 ft long [2].

Ease of Installation

Concrete Cloth ™ can be installed by a relatively small crew. Batch rolls are meant to be handled by just 2 workers. Bulk rolls, however, require the use of a spreader bar and lift to handle the material [3]. Discussions with a local government which uses concrete cloth mentioned that a 6-man crew is often used to install Concrete Cloth ™ as a repair for corrugated metal pipes which will be discussed further in the Site Investigation section of this report.

The installation involves first preparing the subsurface. The Concrete Cloth ™ will conform to the surface it is applied to so any imperfections will translate through the cloth. Concrete Cloth is also not meant to bridge over soft spots or crevices in the subgrade. Subgrade needs to be fully compacted and level prior to installation.

After subgrade has been properly prepared, the Concrete Cloth ™ is rolled out and placed to fit. The cloth can be cut to the appropriate size using a utility knife [3]. Several crew members lift and move the individual pieces into place. Appropriate personal protective equipment (PPE) shall be used when handling the cloth. When the cloth is placed in the appropriate locations, some cement can become airborne creating a dusty environment. Gloves and long sleeves are also recommended to prevent cement burn.

Once the Concrete Cloth ™ is in its final location, fasteners are used around the ends and overlapping edges of the product to secure it to the substrate below. Stainless steel #12 screws spaced at 4 to 12 inches o.c. are recommended by the manufacturer to fasten one layer of cloth to another. Concrete or soil anchors or screws may be necessary to anchor the fabric to the substrate below. In some instances, it may be necessary to provide an anchor trench at the top (upstream)

end of the cloth to act as a cutoff wall to keep water from getting below the cloth and undermining the system [3].

After the Concrete Cloth ™ has been fastened and all necessary anchor trenches have been installed, the cloth shall be hydrated by completely saturating the cloth with water. It is recommended that the cloth continue to be saturated or sprayed with water until the cloth refuses any more water. Adding water to the cloth will hydrate the cement in the fabric and the cloth will harden [3].

One of the benefits of Concrete Cloth ™ is that it can be submerged during installation. However, there is only a 1-2 hour working time after the cloth has been hydrated [2]. This may require a larger crew to install the cloth and get it fastened prior to hardening. Sealing the edges of the cloth is also complicated with an underwater installation since most polyurethane joint sealants require the surface to be dry for a period while the product cures. Different edge seal details may be required.

Site Investigation

Several corrugated metal pipe culverts in the Denver metro area have be repaired using Concrete Cloth ™. The principal investigator traveled to several of these locations to see how the cloth had been performing in the harsh freeze-thaw prone climate. There were two different joint sealant details which will be discussed further.

Figure 1 shows a typical local application for repairing the corroded invert of a corrugated metal pipe. A single wide row of ½ inch thick concrete fabric was rolled out down the length of the culvert. The upstream end was folded down the upstream face of the culvert and concrete was cast against the fabric to create a cutoff trench. The concrete fabric only covered the damaged area of the pipe and did not come up to the top of water surface. The edges of the cloth were sealed using either polyurethane joint sealant or cementitious grout.

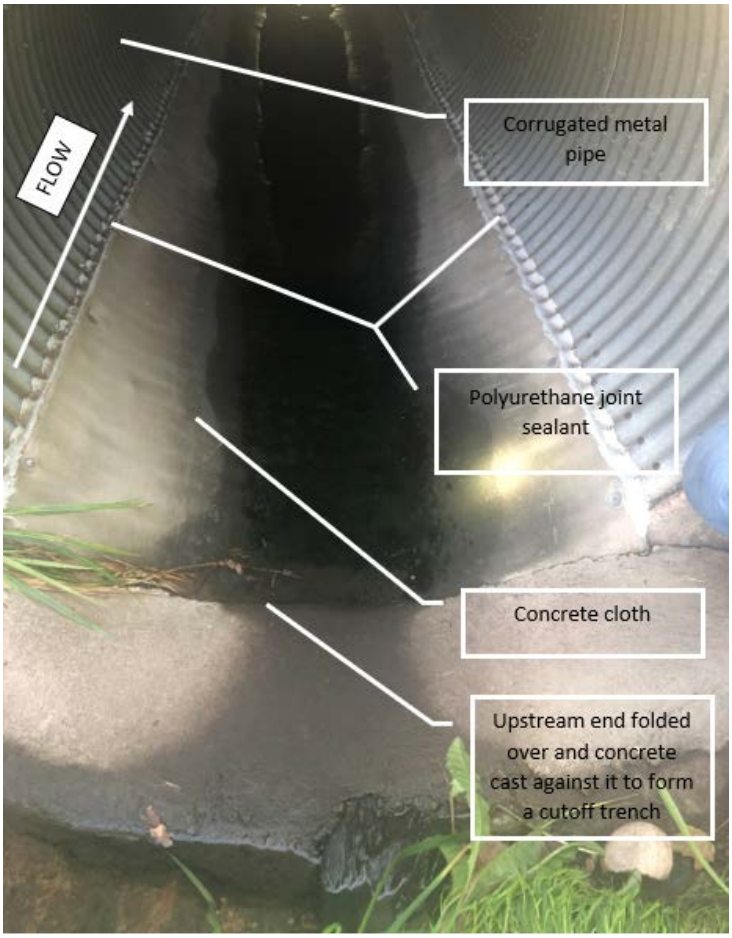

Figure 1. Repair of corrugated metal pipe with concrete fabric

The downstream end of the Concrete Cloth ™ did not receive any special treatment other than cutting the ends off straight. Figure 2 shows the cloth was extend about two to three inches from the end of the corrugated metal pipe. The cloth at the end was hydrated with the rest of the cloth and it hardened to create a stiff end. There did not appear to be any deterioration of the Concrete Cloth ™ at this location.

Figure 2. Downstream end of concrete cloth repair of corrugated metal pipe

Edge Seal

The local government using Concrete Cloth ™ used two different details to seal the edges of the cloth from water getting trapped between the cloth and the metal pipe to prevent possible uplift. The first and most effective can be seen in Figure 3 where polyurethane joint sealant was used. The Concrete cloth was fastened to the corrugated metal pipe with screw fasteners at approximately 12-inches o.c. and the gaps were then sealed with the joint sealant. It was noted that in some cases, the fabric pulled way from the metal leaving a larger gap that was harder to seal. The local government has started placing fasteners closer together to avoid this issue. The

concrete cloth was approximately 4 years old and had no noticeable deterioration or defects that would affect the performance of the repair.

Figure 3. Joint seal detail using polyurethane joint sealant

Figure 4 shows the alternative detail used to seal the edges of the Concrete Cloth ™. The cloth was still fastened to the corrugated metal pipe, but the edges were filled with grout. However, the seal was failing throughout the culvert due to freeze-thaw deterioration and lack of bond of the concrete grout to the metal pipe. The local government plans to strictly use the polyurethane joint sealant for all future repairs and will repair the seal shown in this figure using the polyurethane joint sealant.

Figure 4. Joint seal detail using grouted joint

Discussions were had with the local government about longevity of the product. They said they initially had just planned to use it as a temporary fix, but that the product is performing so well, they are getting much more life expectancy than they thought they would. When asked what they thought the service life was, they said they originally assumed 5 years. However, some of the repairs are at least 5 years old and are still in great condition. Therefore, they think they can get 10 years out of the repairs, saving them time and money to replace the culverts.

Literature Review

Milliken Infrastructure describes many different applications for Concrete Cloth ™ including ditch and channel lining, berm and containment protection, culvert lining, slope protection, canal and irrigation re-lining, and many other uses [4]. The following literature review discusses

several case studies provided by Milliken Infrastructure that highlight the uses of Concrete Cloth ™ and how Reclamation might be able to utilize Concrete Cloth ™ for our aging infrastructure.

Concrete Flume Re-line [5]

Concrete Cloth ™ was used in 2013 to re-line a cast in place concrete flume build in circa 1935. The flume is part of a hydro-electric system operated by Scottish Power. The concrete was deteriorating over time and needed repair. Concrete Cloth ™ was used to line the entire length of the flume (1500 m or 0.93 miles).

The concrete flume was 5-inches thick and had undergone multiple repairs using sprayed concrete and full replacement at some locations over the years. Scottish Power was looking for a different solution so that they didn't have to do so many minor repairs. Concrete Cloth ™ was laid transverse to the flume and placed in a shingled fashion so that the seams were not running parallel with the flow of water. Minor voids were filled with a grout mix prior to Concrete Cloth ™ placement so the cloth did not bridge large defects.

The original cast-in-place flume was subject to a buildup of gravel and debris in some locations. This means that they Concrete Cloth ™ would be subject to potential abrasion erosion. The transverse joints were not sealed to allow water buildup below the cloth to be able to filter into the flume and not create hydrostatic head below the cloth.

Concrete Canal Repair [6]

In 2011, Concrete Cloth ™ was used to repair the leaks in a concrete canal in Huesca, Spain. Like the concrete flume re-lining, concrete cloth was laid transverse across the canal to cut off the cracks in the existing concrete canal. The canal also had erosion damage that was repaired with the Concrete Cloth ™. This canal repair used an automatic thermal welding process to seal all the overlaps of Concrete Cloth ™.

Re-lining of Containment Pond [7]

In 2014 at an undisclosed location, Concrete Cloth ™ was used to re-line an extinguishing lake to provide more impermeability to the existing concrete retention pond. The concrete pond had spalls and cracks that were allowing water to seep out of the lake. Concrete Cloth ™ was laid across the entire length and width of the pond and the layers were overlapped to provide a better seal.

The project selected Concrete Cloth ™ due to the speed of installation. Had they gone with a replacement concrete solution, they would have the lake out of service for approximately a month. The work to re-line the lake was performed by a crew of 5 personnel and was accomplished in just 4 days.

Recommendations for Next Steps

The literature review and the site investigation established that Concrete Cloth ™ is a viable product that should be investigated further by Reclamation. Laboratory studies would be advantageous to narrow down the type of situations or environments where Concrete Cloth could be utilized. Although the documentation from Concrete Cloth ™ states that it can be placed underwater, the principal investigator did not come across any documentation where this has been performed. Underwater installation would be advantageous to Reclamation where taking a canal out of service is not feasible or will have an extreme negative impact. Concrete Cloth ™ could also be used to reline unlined canals or to line an earthen canal to reduce seepage.

Laboratory Research Strategy

Laboratory research is recommended following the plan set forth below.

- Year 1- Mechanical Properties
    - Laboratory testing would be conducted on the Concrete Cloth ™ that will give the principal investigator an idea of the mechanical properties of the cloth. Some of the testing may include abrasion, impact testing, and puncture testing.
    - This same testing should be performed on fiber reinforced concrete, unreinforced concrete, and other composite repair solutions which would be used as a comparison to the performance of the concrete cloth.
- Year 2- Seepage Potential and Constructability
    - Laboratory study will look at seepage potential of the concrete cloth vs seepage of other Reclamation lining systems (shotcrete over membrane and others identified by the geosynthetic specialist).
    - This year will also look at the construction means of each method and discuss items such as ease of construction and required surface preparation. Cost estimators should be utilized to determine the cost difference between each method to establish if there is an advantage to using a product like Concrete Cloth ™.

Field Studies

Field studies are a great way to get a look at how the product will perform in real world situations. Field studies can often provide situations that cannot be replicated in a lab setting. Locations that should be investigated as potential test sites are the following.

- Durango Colorado Area Office project site
    - Freeze-thaw environment
    - Debris buildup in canals
    - Expansive soils
- Yuma Area Office project site
    - High heat
    - High sulfate in soils environment

References

[1] Milliken Infrastructure Solutions LLC, A Milliken Company, *Concrete Cloth (TM) Geosynthetic Cementitious Composite Mat (GCCM),* Milliken Infrastructure Solutions, LLC, 2017.

[2] A. M. C. Milliken Infrastructure Solutions LLC, *Concrete Cloth (TM) Geosynthetic Cementitious Composite Mat - Data Sheet,* Milliken Infrastructure Solutions, LLC.

[3] A. M. C. Milliken Infrastructure Solutions LLC, *Concrete Cloth (TM) Geosythetic Cementitioous Composite Mat (GCCM) - Installation Guide,* Milliken Infrastructure Solutions, LLC, 2015.

[4] K. Chirbas, *Milliken Infrastructure overview,* 2017.

[5] Concrete Canvas, "Remediation," Concrete Canvas Ltd., 2014.

[6] Concrete Canvas, "Canal Repair," Concrete Canvas Ltd., 2012.

[7] Concrete Canvas, "Remediation," Concrete Canvas Ltd., 2014.

Appendix A – Data Sheets

Milliken Infrastructure

Concrete Cloth™

Geosynthetic Cementitious Composite Mat

STORM + SANITARY | BRIDGES + ROADWAYS | OIL, GAS + INDUSTRIAL

The Concrete Cloth™ material is a three-dimensional flexible cement impregnated fabric that hardens after hydration to form a durable concrete layer. Classified as a Geosynthetic Cementitious Composite Mat (GCCM), it is used in a variety of civil infrastructure markets including: transportation, oil & gas, stormwater, landfill, mining, and erosion control. Typical applications for use are ditch lining, slope stabilization, shoreline armor, secondary berm protection, culvert invert protection, and geosynthetic liner protection

	MAN PORTABLE BATCH ROLLS				BULK ROLLS			
Product	**Roll Width ft**	**Roll Length ft**	**Roll Area ft²**	**Unset Roll Weight/lb**	**Roll Width ft**	**Roll Length ft**	**Roll Area ft²**	**Unset Roll Weight/lb**
CC5	3.375	30.0	101.25	141	3.375	656	2214	~3100
CC8	3.625	20.0	72.5	164	3.625	376	1363	3350
CC13	Not Available				3.625	240	870	~3350

Standard production size information is subject to change without notice. Please contact your Milliken representative or distributor on exact roll size quotes (sales based on ft²).
All test data are typical minimum values unless otherwise noted.

Dimensional Parameters

Product	Thickness in (mm)	Dry Weight lb/ft²	Cured Weight lb/ft²
CC5	0.2 (5)	1.3	1.7
CC8	0.3 (8)	2.2	2.8
CC13	0.5 (13)	3.7	5.0

Listed weights are minimum values. Actual product weight may exceed these values.

Tensile Strength: ASTM D-5035

Product	Working Strength lb/inch		Ultimate Strength lb/inch	
	Length	Width	Length	Width
CC5	60	20	140	50
CC8	85	25	190	100
CC13	150	90	190	110

Puncture Resistance: ASTM D-6241

Product	Puncture Strength lb (kg)
CC5	350 (160)
CC8	500 (225)
CC13	720 (325)

CC13 has also passed ASTM G-13 (Impact Resistance of Pipeline Coatings).

Permeability

- Coefficient of Permeability $2x10^{-11}$ m/s (CC8)

Permeability of joints will vary dependent on the jointing method, consult Milliken Infrastructure Solutions or your distributor for more information.

Set Time: ASTM C-807

- Initial Set: 120 min
- Final Set: 240 min

CC will achieve ~70% strength 24 hr after hydration. Working Time 1-2 hrs after hydration.

Flex Strength: ASTM D-8058-17

- 7 Day Minimum: 475 psi (3.3 MPa)
- 7 Day Modulus Minimum: 26,000 psi (180 MPa)

Compressive Strength o f Cement: ASTM C-109

- 3 Day Minimum: 4000 psi (27 MPa)

Taber Abrasion: ASTM C-1353

- Approximately 7.5x Greater than 2500 psi compressive strength OPC

Freeze Thaw: ASTM C-1185

- 200 Cycles - Pass

Flame Resistance: MSHA ASTP-5011

- Vertical and Horizontal Certification

Manning's n Value: ASTM D-6460

- n=0.011

Permissible Shear & Velocity CC5: ASTM D-6460

- Shear <25 lb/ft² (1200 Pa)
- Velocity <35 ft/sec (10.7 m/s)

Product Exceeded Large Scale Testing Capabilities and was not tested to failure. To actually achieve these permissible values, the CC material must be properly anchored with a system designed to meet or exceed these values.

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Milliken Infrastructure

Concrete Cloth™

Geosynthetic Cementitious Composite Mat

STORM + SANITARY

BRIDGES + ROADWAYS

OIL, GAS + INDUSTRIAL

Composition

Concrete Cloth GCCM is a three-dimensional, flexible cement-impregnated fabric that hardens after hydration. The material has a top surface fabric through which water will penetrate during hydration and a bottom surface consisting of a PVC membrane that acts as permeable barrier.

Characteristics

The dry density of the product before hydration is approximately 95 lbs/ft^3 (1500 kg/m^3). Upon complete hydration the density increases between 30-35% to approximately 125 lbs/ft^3 (2000 kg/m^3). The exact density will depend slightly on the thickness of material and the relative proportion of PVC membrane to cement.

Storage & Handling

Concrete Cloth matting is sold in three (3) thicknesses. Standard roll sizes referred to as Bulk or Batch rolls are noted in the product table on the preceding page. Bulk rolls will be shipped a single roll to a pallet, Batch or Custom rolls maybe shipped multiple stacked rolls to a pallet.

It is important to check the wrapping when the Concrete Cloth rolls arrive on the jobsite. Unopened packages can be stored in a dry location, off the ground, and away from moisture for up to one year. Any damage to the packaging should be repaired prior to storage using plastic wrap and tape to protect the Concrete Cloth GCCM from premature hydration.

Batch rolls are designed to be able to lift by two (2) persons. Bulk rolls will require additional handling equipment rated for the weight of the rolls. Use of a load rated spreader bar is recommended.

Subgrade Preparation

Concrete Cloth matting will generally take the shape and structure of the surface to which it is applied and imperfections in the subgrade will be visible. It is necessary that a compact and smooth subgrade be prepared to engineering specifications prior to placement. Subgrade should be prepared to the lines and tolerances of the engineering drawings for the installation. It should be clear of surface vegetation and debris. To the extent possible Concrete Cloth materials should be in direct contact with the subgrade to which it is being applied.

Installation

Concrete Cloth matting is often overlapped to create joints so installation will typically begin at the lowest point of the project and proceed up the grade. A shingled installation overlapping the rolls is used to reduce any water seepage between the overlapped rolls.

The Concrete Cloth material is designed such that the PVC back of the material will be against the subgrade in most applications. This side is water resistant and will not allow subsequent hydration if the material is installed upside down. The PVC back side is identifiable as the side with a continuous film. It is packaged such that the PVC back will be on the outside of the roll. For this reason it is important when placing Concrete Cloth materials to let the fabric off from the bottom side of the roll.

Temporary anchoring may be used on the leading edge of roll to prevent unrolling. In applications where long lengths will be let off the roll, it is good practice to allow several feet of extra material on the down-slope side of the install to allow for migration of the material in the direction of equipment movement.

After installation of the first roll or cut piece, the leading edge of the second roll or cut piece will typically be shingled over the first. If shingling is not possible, other jointing can be used. Please consult the detailed Concrete Cloth Installation Guide for further details.

Cutting

Concrete Cloth matting is designed to be cut with commonly available cutting tools. A box cutter or razor knife is generally acceptable and rotary cutters are more efficient. Always cut the material from the fabric (top) side down to minimize tearing of the PVC membrane. When possible, use a straight edge. Always wear proper hand PPE when working with cutting tools.

Overlap and Jointing

Four (4) inch overlap is typically recommended for shingling. The most common joint is an overlapped screw joint. A stainless steel #12 screw (coarse threads) is recommended 4-18 inch (typical 6) on center at least 1 inch from the overlap edge. Consult the Installation Guide for additional jointing recommendations.

Anchoring

Along all exterior edges (top, bottom & sides) of the Concrete Cloth installation, it is recommended to install a toe-in trench (minimum of 6 inches in depth) to resist migration of surface water between the Concrete Cloth material and the subgrade. The trench may vary based on the recommendation of a certified design engineer.

Some slopes, soil types and applications may require anchors or nails to stabilize the underling soil mass against internal instability. Concrete Cloth matting may be used as the non-structural facing treatment when internal anchorage conditions are required. Anchors may be installed first or the anchors can be inserted through the cloth.

Hydration

Complete hydration is critical to optimal performance. The Concrete Cloth product cannot be over hydrated and over watering is recommended. Any water source is acceptable in most circumstances.

Saturate the top surface. This will take multiple passes of a moderate spray of water from a garden hose or other source. More water will be needed as the slope of the install increases.

Insure that the material has been saturated by means of the "thumb test," by pressing a thumb to observe water pooling at the indention.

Wait 30-60 minutes and then put a final dose of water on the material to ensure complete hydration.

The material can also be hydrated by submersion for 5-10 minutes but will only have a 1-2 hour working time after hydration.

Do not jet high pressure water directly onto the surface. Do not hydrate if temperature is likely to fall below 25°F (-4°C) within 24 hrs of initial hydration. Do not install on frozen ground. Consult the Installation Guide for additional details and pictures.

Health & Safety

The material contains cement powder, which is alkaline, and may cause skin irritation. Always wear proper PPE and consult the SDS for additional information.

Data Sets that Support the Final Report

If there are any data sets with your research, please note:

- Share Drive folder name and path where data are stored:
  - T:\Jobs\DO_NonFeature\Science and Technology\2019-PRG-Concrete Fabric for Concrete Canal Lining Repairs
- Point of Contact name, email, and phone:
  - Shannon Harrell, P.E.
  - sharrell@usbr.gov
  - 303-445-2370
- Short description of the data: Folder includes documentation from the manufacturer and pictures from the site visit.
- Keywords: concrete repair; concrete fabric; canal repair
- Approximate total size of all files: 108MB (folder size)