SYNTHETIC CANAL LINING EVALUATION PROJECT

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ABSTRACT

Irrigation districts in the Lower Rio Grande Valley of Texas have been experimenting with an assortment of synthetic canal lining materials, looking for more cost-effective methods for rehabilitating old, deteriorating canals. The synthetic canal lining materials are showing promise, but little information exists on the relative performance between different products. In 2005, we initiated a program to track the long-term effectiveness and durability of these lining projects and to document the damage caused by such factors as UV damage, animal traffic, intentional and unintentional vandalism. A summary of our results from the first four years of inspections are presented. Inspections for the linings are currently being updated for 2009-2010. Additionally, this paper provides documentation on canal lining installation and maintenance procedures, along with suggested considerations when planning a lining project. This paper also discusses future collaborative efforts underway for the testing and evaluation of synthetic canal liners.

The best performers were the two types of synthetic liners (PVC and polyester) with a protective barrier of shotcrete, which have shown no problems to-date. The noticeable difference between the two types of liners was the ability of the polyester to hold the shotcrete in place on the canal sidewalls. The PVC liner required an additional support system using a wire mesh overlay serving as the attachment between the material and the shotcrete.

The performance of synthetic liners without a protective barrier varied dramatically. One important factor was the location of the project. Liners located in high traffic areas (people and animals) showed significantly more damage than those installed in remote areas. The PVC alloy is the toughest of the 4 liners installed without a protective barrier, is more difficult to cut and less likely to be damaged by unintentional vandalism. We also observed that liners carelessly or improperly installed were more susceptible to intentional and/or unintentional damage.

INTRODUCTION

Water Losses from irrigation canals can be significant, and water districts are looking for more cost-effective methods for rehabilitating old, deteriorating canals other than relining

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with concrete or replacement with pipelines. Synthetic canal lining materials are showing promise as an alternative to more costly methods, but little information exists on the relative performance between different products, or on installation and maintenance procedures needed to ensure long life.

Since 1999, irrigation districts in the Lower Rio Grande Valley of Texas have been experimenting with an assortment of canal lining materials. In 2005, we initiated a program to track the long-term effectiveness and durability of these materials and to document installation and maintenance procedures which will help ensure good performance. Each lining project was inspected multiple times to document the effects of such factors as UV damage, animal traffic, intentional and unintentional vandalism, and normal irrigation district operational and maintenance activities. A summary of the results from the first four years of inspections are presented in this report.

MATERIALS AND METHODS

Lining Materials

Six different lining materials have been installed in seven irrigation districts of the Lower Rio Grande Valley of Texas. Table 1 provides a list of material types and generic descriptions of each. Unlike the other materials, the polyurethane was manufactured on-site during installation using specialized equipment. The locations of the lining projects are shown in Figure 1. In 1999, Hidalgo County Irrigation District No. 1 initiated a program that included four types of liners installed in 27 segments.

Table 1. Description of each lining material's composition.

Material	Description
Polyester with protective barrier	A geocomposite consisting of two layers (top and bottom) of 8 oz/yd^2 nonwoven polyester bonded to an olefinic copolymer geomembrane, 20 mil thick. The protective barrier consists of 2-3 inches of shotcrete.
PVC with protective barrier	Non-reinforced Poly Vinyl Chloride (PVC). The protective barrier consists of a wire mesh with 2.5 inches of shotcrete.
Polypropylene	A reinforced polyester scrim 16 oz/yd^2 between polypropylene layers, 24 mil thick.
PVC Alloy	A polyvinylchloride blend, reinforced with a polyester scrim, 40 mil thick.
EPDM Rubber	A non-reinforced EPDM (ethylene propylene diene monomer), 45 mil thick.
Polyurethane	Two layers of 3-oz/yd^2, heat-bonded, non-woven geotextile saturated with liquid polyurethane, 40 mil thick.

Evaluations and Site Inspections

During each site inspection, projects were given a condition rating ranging from "excellent" to "serious problems" as defined in Table 2, and photographs and other information were collected to document observed problems. Our original plan was to conduct inspections every six months. However, little change was observed over this time period, and succeeding inspections took place annually as follows:

- February 2005
- September 2005
- September 2006
- December 2007

Conducting inspections during the winter months when water levels tend to be the lowest have proved to be the most effective.

Table 2. General performance ratings for canal liners.

Rating	**Definition**
Excellent	0%: no damage and no maintenance required
Good	0 – 5%: mild damage to top anchor and canal interior 1 to 2 significant repairs needed per year
Fair	5 – 20%: mild damage to top anchor and canal interior 3 to 5 significant repairs needed per year
Poor	20 – 50%: mild damage to top anchor and canal interior 6 to 10 significant repairs needed per year
Serious Problems	50 – 100%: mild damage to top anchor and canal interior 10 > significant repairs needed per year

Note: Percentages are based on the linear length of the lining project

Seepage Loss Tests

Before and after seepage loss tests were conducted for Project #5 in Figure 1 using the ponding test method. In this method, earthen dams are constructed at either end of the test segment. The test segment is then filled with water, and the rate and total water losses are measured over a 24–48 hour period (Leigh and Fipps, 2009). The time-line for these tests was as follows:

- pre-lining test - September 2002
- lining project completed - October 2004

- first post-lining test - November 2004
- second post-lining test - July 2005.

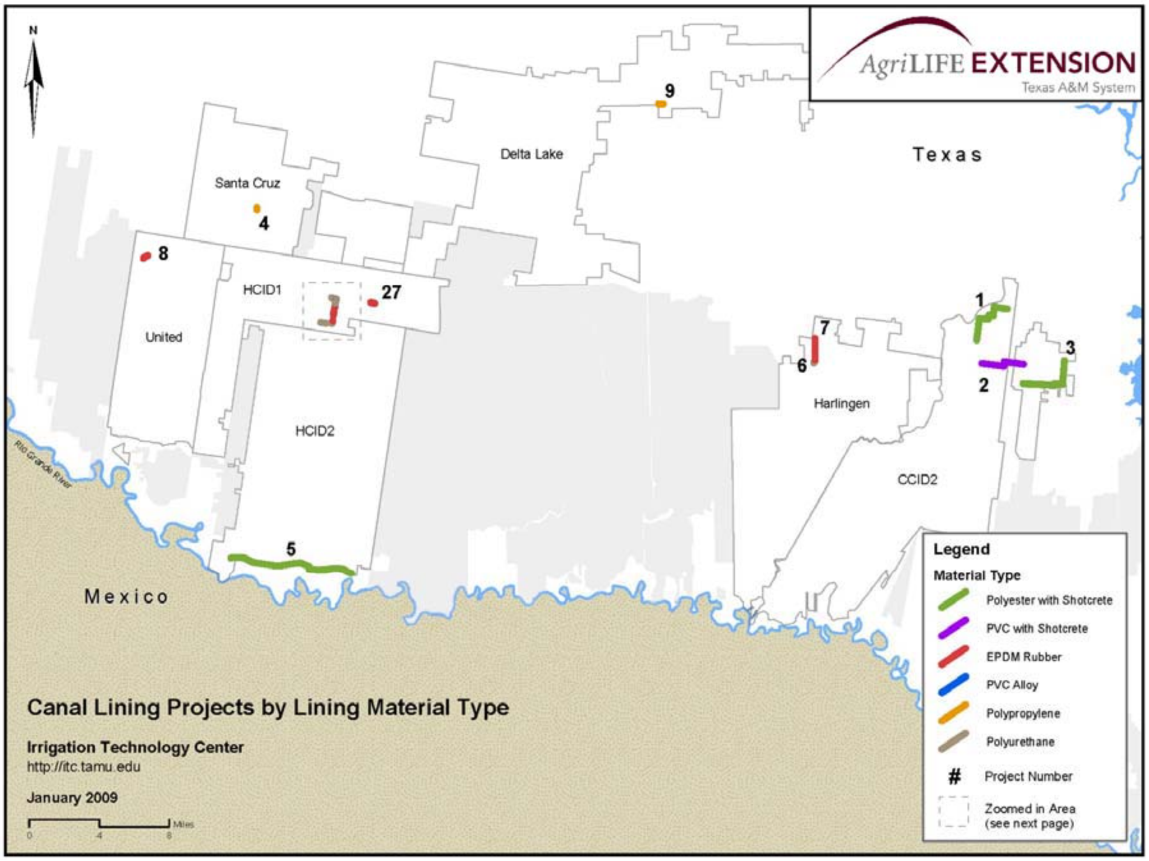

Figure 1. Lining Projects by Material Type

RESULTS AND DISCUSSION

The results of our evaluations are summarized in Table 3. Projects are grouped into lining projects *__with__ a protective barrier* and projects *__without__ a protective barrier*. Without question, liners with a protective barrier performed the best and have required no maintenance, while the performance of the liners without a protective barrier has varied significantly.

Table 3. Range of the performance rating results by lining material			
Material	No. of Projects	Total Miles	Rating
with a protective barrier			
Polyester with	4	14.47	Excellent
PVC with shotcrete	1	2.61	Excellent
without a protective barrier			
Polypropylene	2	0.36	Excellent to Good
PVC Alloy	3	0.05	Excellent to Good
EPDM Rubber	8	2.04	Excellent to Serious
Polyurethane	9	1.42	Excellent to Serious

Liners with a Protective Barrier

The best performers were the synthetic liners with a layer of shotcrete. This system is effective as the liner reduces seepage losses dramatically, while the layer of shotcrete prevents damage to the liner. Five projects extending over about 17 miles were implemented using this system with two different liners: polyester and PVC. The protective barrier consisted of 2 - 3 inches of shotcrete as shown in Figure 2.

To-date, these projects show no evidence of problems and have required no maintenance. No difference in performance was observed between the two types of liners. Hairline cracks developed in the shotcrete on a small stretch of Project #5, but no related problems have been observed.


Figure 2. Polyester canal liner with a 3-inch protective barrier

An important consideration with this system is the ability of the shotcrete to adhere to the liner. The polyester liner has a rough surface to which the shotcrete readily adheres to, while surface of the PVC liner is slick, and a wire mesh must be used.

In seepage loss tests, we found that this lining system reduced seepage losses by 94% after eight months (Leigh and Fipps, 2006). Details are as follows:

- before lining, loss rate = 1.36 gal/ft^2/day (134 ac-ft/mi/yr)
- one (1) month after installation, loss rate = 0.27 gal/ft^2/day (24 ac-ft/mi/yr)
- eight (8) months after installation, loss rate = 0.09 gal/ft^2/day (8 ac-ft/mi/yr)

Liners without a Protective Barrier

The performance of the liners without a protective barrier has varied significantly. Exposed liners are obviously more susceptible to damage caused by UV light, animals, and vandalism, as well as damage caused by the districts' mowers and maintenance activities. However, the amount of damage varied by the location of the project. Liners in remote areas have performed much better than those in urban or high traffic areas.

Installation and maintenance of the liners also appears to explain some of the variation in performance of these projects as discussed below. Another consideration with exposed liners is the potential damage that machinery can cause during normal district mowing operations and while cleaning out aquatic vegetation and sedimentation (Figure 3).

Figure 3. Aquatic vegetation and sedimentation clogging a farm outlet pipe

In general, of the four types of materials, the polypropylene and PVC alloy liners have been more durable and have experienced less damage. The performance of the other two liners, EPDM rubber and polyurethane varied significantly. While some projects are still in excellent condition, others have serious problems or have failed completely. Details are discussed below by type of liner.

Polypropylene In two lining projects, polypropylene was applied on existing concrete canals. To-date, these two lining projects are in excellent condition, with no visual damage. Yet, for one of these projects, we have concerns with the large amount of wrinkles which occurred during installation. Wrinkles can reduce water flow, accelerate sedimentation, and provide loose material that can easily be damaged.

For the project shown in Figure 4, concrete sections approximately 1-foot wide were poured on top of the liner at a spacing of 500 feet. The rational is that the concrete sections will help keep the liner in place and provide access points for sediment removal. Our conclusion is that long-term evaluation is needed to determine if such sections are useful for these purposes.

Figure 4. Concrete sections poured on top of a polypropylene liner

PVC Alloy Three short sections of PVC alloy were installed in 1999, ranging in length from 38 to 148 ft. This material has performed well, requiring little maintenance, with no major damage observed. However, cuts and tears have occurred in the exposed area of the liner (Figure 5) which could develop into larger problems if not taken care of in a timely manner. The overall performances for these small test segments are excellent to good.

Figure 5. PVC Alloy liner damaged on the exposed area

EPDM Rubber The performance of the eight projects using EPDM rubber has varied significantly. Two projects are in good to excellent condition, while the remaining six ranges from fair condition to serious problems, with one totally failing. EPDM rubber is very susceptible to vandalism and punctures caused by animals. It also appears that many cuts and tears initially occurred on the exposed areas where there is the most human and animal traffic (Figure 6). Unless repaired in a timely manner, these tears may lead to increasing amounts of damage (Figure 7).

Figure 6. Cuts/tears in a rubber liner

Figure 7. A rubber liner damaged possibly due to vandalism

Polyurethane During 1999 - 2000, nine short sections were lined with polyurethane, totaling 1.42 miles. The current condition of these projects varies from excellent to serious problems, with one section a total failure. Observed problems include the liner falling off the canal walls which was likely caused by a combination of severe UV damage (Figure 8), material defects, and vandalism. In some segments, the top layer of the material has peeled off, while in others, the entire liner has worn off (Figure 9).

Unlike the other liners, the polyurethane was manufactured on-site by specialized machinery, and requires that the chemicals used to be properly handled. Several problems occurred during its manufacture and installation, including inconsistency in product thickness, which may account for the large variation in performance. In addition, little to no maintenance has occurred since installation.

The location of the section does not appear to be a factor. For example, projects 17, 18, 20, and 21 are all continuing test segments; while projects 17 and 21 are in excellent shape, projects 18 and 20 have serious problems.

Figure 8. Polyurethane liner is shown hanging off the canal wall.

Figure 9. Residue left from a deteriorated polyurethane liner

CONSIDERATION WHEN PLANNING NEW LINING PROJECTS

The installation procedures and equipment requirements vary from material to material, with details available from each manufacturer. Proper installation and maintenance is necessary for avoiding or reducing problems that may contribute to accelerated deterioration of the material.

Lining Installation

Important installation considerations include:

- the methods used to overlap and mend/seam the layers of lining material together
- the methods used for attaching the material to the canal walls, around structures, and to the top of the levee (top anchor)
- the total width of the liner and extension on top of the levee in relation to the normal and maximum operating depth of the canals

Liners need to be properly installed and stretched in order to prevent wrinkles. Wrinkles not only look unprofessional, but make the liner more susceptible to damage. Glues, liquid rubbers resin, tar and types of metal pins are used to secure the material around the structures and at the joints (Figures 10).

Figure 10. Glues being applied to the joints of a polyester liner.

In one of early lining projects, the liner size was not planned properly to overlap and extend onto the top of the levee (Figure 11). As seen in Figure 12, the operating depth of the canal was higher than the top of the liner. The water eventually got underneath this liner and caused it to float.

Figure 11. Canal liner installed too low on the levee

Figure 12. Water level higher than the canal liner installed

Most damage has occurred on the exposed areas of the liner and top side walls of the canal. Figure 13 shows a cut made with a sharp object (probably intentional vandalism) verses Figure 14 could have been a case of unintentional vandalism. In areas where kids are playing, swimming in the canals, or being mischievous, intentional and unintentional vandalism will occur. Vultures have been reported to pick at the seams on the EPDM Rubber; animal hoofs can cut some liners.

Figure 13. Horizontal cuts likely due to vandalism on the canal sidewall

Figure 14. Vertical cut or tear on canal side wall caused unintentionally

Use of a Protective Barrier

While the initial costs of a lining project using a use of a protective barrier such as shotcrete are higher, these costs may be offset by the reduction in costs of maintenance and repairs over the life of the project. An important consideration is the ability shotcrete to adhere to the liner. The polyester material has small fibers (similar to the harden side of Velcro) to which the shotcrete will stick when sprayed on to the liner (Figure 15). On the other hand, the PVC liner has a smooth texture to which the shotcrete will not stick, and a wire mesh needs to be used on the top of the liner to provide grip and added reinforcement. This application also increases labor and cost.

Figure 15. Shotcrete being sprayed onto the fibrous polyester liner

Maintenance

A regular inspection and maintenance program is important so that repairs can be completed on a time basis. Once a tear or cut starts, it will tend to expand or be susceptible to further damage until it is repaired. Districts should consider having their personnel trained to performed the repair and maintenance which sometimes requires specialized equipment, and similar glues and adhesives used during the installation process (Figures 16 and 17). Removing sediment from lined canals may be more difficult due to the limitations of using heavy machinery, and may require increased manual labor (Figure 18).

Figure 16. A district maintenance crew repairing a damage section of lining

Figure 17. Repair of the liner joints around a structure with glue

Figure 18. Sedimentation at the bottom of a lined canal

CONCLUSIONS

The best performers were the two types of synthetic liners (PVC and polyester) with a protective barrier of shotcrete, which have shown no problems to-date. All five projects using a protective barrier were rated with a score of excellent since installation. The use of a protective barrier can extend the life of the lining project by preventing inadvertent damage and discouraging vandalism. The noticeable difference between the two types of liners was the ability of the polyester to hold the shotcrete in place on the canal sidewalls. The PVC liner required an additional support system using a wire mesh overlay serving as the attachment between the material and the shotcrete.

The performance of the synthetic liners without a protective barrier varied dramatically, ranging from excellent to having serious problems. Some were found to be more susceptible to such factors as installation problems, unintentional damage and vandalism.

Most of the damage to the synthetic liners occurred around the exposed areas of the liner near the top anchor attachments and top side walls of the canal. If the damage is not repaired in a timely manner, small tears can grow into larger ones. In general, exposed synthetic liners need more frequent inspections and regular maintenance.

In conclusion, the initial costs of a canal lining project will vary depending on the type of material and whether a protective barrier is used. For that reason, when planning a project, especially in areas of high traffic (animals and pedestrians), the district should consider if the short-term costs of adding a protective barrier will be more cost-effective compared to the long-term costs that will be incurred due to maintenance and repairs from the lining being damaged.

FUTURE COLLABORATIVE EFFORTS

Collaborative efforts are underway to assess more geosynthetic canal lining materials. Texas AgriLife Extension engineers and the Specialty Products division of Firestone are demonstrating three reinforced geomembranes with Adams Garden Irrigation District. The three lining materials included: 300 feet of Green TPO-R 0.060", 110 feet of Black Reinforced EPDM 0.045", and 160 feet of Black Reinforced fpp-R 0.045". During installation, the Extension engineers monitored and evaluated the installation techniques and materials used. The joining methods of the materials and sections were done using the overlap method and TPO QuickPrime tape along with a six inch wide standard unsupported QuickSeam Coverstrip. Further testing methods are being assessed such as tear and puncture testing methods used in the geosynthetic market today.

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