IMPERVIOUS SYNTHETIC LINING OF DETERIORATED CONCRETE CANALS — WHAT ARE THE REAL COST AND BENEFITS TO IRRIGATION DISTRICTS?

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ABSTRACT

The water crisis in arid and semi-arid agriculturally developed areas in the United States has been the focus of increasing concern and numerous studies over the past 10 years. Due to the increased public awareness and seriousness of the water crisis in South Texas along the Rio Grande during the mid to late 1990's, the U.S. Congress enacted Public Law 106-576 entitled "The Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000". In general terms, the U.S. Congress authorized water conservation projects for Texas irrigation districts relying on Rio Grande water. One of the conservation measures was the implementation of exposed impervious synthetic linings in the reline of old deteriorating concrete delivery canals that were known to experience significant water seepage loss. The cost effectiveness of "relining" these canals was evaluated based on actual reline costs, water saved and expected O & M costs. This paper will evaluate the design, selection, effectiveness and installation of synthetic lining systems installed in various irrigation districts in Texas. Focus will not only be on water and energy savings but overall effectiveness for impervious synthetics that are designed and manufactured for installation and maintenance by the irrigation districts themselves using their own available personnel and resources.

INTRODUCTION

Historical Background of the HID, Cameron County, Texas

The District provides agricultural drainage, flood control and water supply functions to 88.3 square miles of Cameron County. The total irrigated area within the District boundaries is approximately 38,025 acres. The District outer boundary includes portions of the cities of Harlingen, Palm,

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Valley, Rangerville as well as parts of Primera, Combs and Los Indios. The District supplies municipal water to the Harlingen Water Works Service (HWWS) through HWWS's two reservoirs, Dixieland Reservoir and Lake Harlingen. HWWS services the cities of Harlingen, Combes, Primera, Palm Valley and rural water companies, Military Highway Water Supply and East Rio Hondo Water Supply.

The Rio Grande is the only water source for the District. All of the water diverted by the District, from the Rio Grande, originates as surface water released by the International Boundary and Water Commission from Falcon Reservoir. The Harlingen Pump Station draws water from the river and disperses the water into the canal system at a starting elevation of approximately 58 feet above sea level. The terminal downstream end of the system is approximately 24 feet above sea level. The District water supply system consists of 40 miles of earthen canal, 20 miles of lined canal and 155 miles of pipeline. The system also contains 25 check structures and 44 pump sites. The District operates three reservoirs including the CCWC No. 1 Reservoir, located in the south end of the District, and the McLeod-Hood Reservoir and Bogus Lake, located in the north end of the District. The reservoirs are used as a buffer for absorbing changes in daily producer uses as well as equalization mitigating the four-day travel time of water from Falcon Reservoir.

Historically, the irrigation district has faced loss of deliverable water due to high seepage rates in unlined and old concrete lined canals and laterals, approaching over 30 percent. This, in addition to the drought conditions here and in other irrigation districts, has prompted the federal government to intitiate a program for the selection and installation of low-cost lining systems that can be installed and maintained by the irrigation district personnel without the need for specialized installers or contractors. Materials must be capable of being installed in harsh, rough conditions, resist animal traffic and be left exposed in excess of 20 years. Federal Government requests for proposals on the use of impervious linings for canal rehabilitation have traditionally focused on the following areas:

1. Technical Capability
    a. Ease of Installation (Delivery, Placement, Seaming by the ID)
    b. Damage Resistance (During Placement and Operation)
    c. Ease of Repair (Repair by ID over life of the lining)
    d. Expected Life (Manufacturer warranty for exposed conditions)
    e. Seepage control (Effective barrier material)
    f. Descriptive Literature addressing the above
2. Past History and Performance
3. Price

The final selection of a supplier is usually based primarily on technical merit, installation capability by the irrigation district personnel using their equipment, characteristics of the geomembrane material and cost. Thus, the lowest bid price may not be the principal determining factor in the final selection of the system.

HID Canal Rehabilitation Sections

The 2.45 mile irrigation canal section that was lined was an original concrete-lined canal built in 1917 and lined in the late 1950s with significant cracking and some deteriorated reaches and known high seepage loss in excess of 30% . Technical characteristics included the following:

Q (flow rate) = 72 cfs
V (velocity) = 1.32 fps
D (depth) = 4.0 ft
S (bed slope) = .00015

Side slopes were an average of 1H : 1V and base width varied between 4 feet to 8 feet. Total width of the section including anchors at top of slope was approximately 24 feet. Thus, geomembrane panels delivered to the site were required to have a minimum 24 ft. width with no longitudinal seams. Seaming in the field was to be at panel ends only and across the width of the canal section.

EPDM Rubber Geomembrane Chosen for Technical Characteristics and Low Cost

The Harlingen Irrigation District awarded the project to a material supplier of 45 mil thick Ethylene-Propylene-Diene-Monomer (EPDM) rubber geomembrane based on the above design considerations, technical evaluation factors and low cost. EPDM geomembranes have been in use worldwide for over 40 years in a wide variety of containment applications including large and small irrigation canals. Most recently, EPDM was chosen for the Ochoco and Talent Irrigation Districts in Oregon and the Tulelake Irrigation District in California, Maverick County Water Control and Improvement District, Harlingen Irrigation District and El Paso County Water Improvement District in Texas to line canal sections with significant water seepage. All of these projects utilized the irrigation district crews for canal section preparation, EPDM installation, seaming and connections to structures.

EPDM rubber geomembranes are a superior choice for use in the rehabilitation of old concrete and earth lined canals and laterals for the following reasons:

- Minimal preparation of the channel section using district equipment and personnel
- Ease of panel installation with district equipment and personnel
- Ease of seaming and repair methods by district personnel with no requirements for special equipment

- Mechanical properties to resist installation and operation stress in an exposed environment
- Attachment to concrete and steel structures (gates, turnouts, pipes, etc.) using special waterproof adhesive systems
- Lay flat (rubber friction and unit weight) characteristics to resist wind uplift/displacement
- High UV and weathering resistance backed by decades of exposed installations
- Repair and maintenance by irrigation district using simple low tech seaming techniques and repair kits
- Custom panel sizes for differing channel sections
- Installation and seaming in wet conditions
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EPDM Geomembrane Impervious Lining Installation by the HID

EPDM factory panels were manufactured by the Firestone Building Products Company, Carmel, Indiana. The panels were custom-sized for the HID to 30 ft. in width by 200 ft. in length, folded along the length and then rolled for delivery and handling on site. Once the rolls of panels were delivered to the site, the HID deployed the panels using their own equipment and 8 person crew. District personnel fabricated a custom lifting bar which was suspended by cable from the bucket of a backhoe. The rolls of EPDM were lifted, positioned in the channel bottom and unrolled along the channel by advancing the backhoe along the channel access road.

Once the panels were unrolled and unfolded up the side slopes, they were positioned and placed into the anchor benches on both sides of the channel section. The ends of the panels were then overlapped a minimum of 6 in. and the overlap area was cleaned and primed with Firestone QuickPrime Plus. The overlap area was then tacked without wrinkles and Firestone QuickSeam tape, an adhesive tape seam system, was applied by the HID crew. The field fabricated seams were composed of prefabricated 6 in. wide rolls of partially vulcanized Firestone cover strips with adhesive backing. Once the strip was placed and centered on the overlap, it was pressed down onto the two adjacent panels with constant hand roller pressure to ensure complete adhesion.

Advantages of using the patented tape seam system include:

- Designed for remote areas and can be installed in cold and hot temperatures
- No specialized welding equipment, hot air guns or supporting electric generator equipment is required
- Components are simple and can be stored at irrigation district shops for future use
- Seaming requires no specialized training (HID crew received on-site instruction)

- Resultant seam is a continuous 3 in. bond to panel edge with high peel and shear strength. Seam area will resist movement under load of over 100 percent without affecting the waterproof integrity
- The same seam methods are used for repair patches by HID maintenance crews.

During the placement of panels, it was noted that the EPDM sheet material was not susceptible to wind uplift even by high winds which are a frequent occurrence at this site. The EPDM rubber sheet conforms readily to the rough concrete, lays flat and adheres to the concrete due to surface friction, unit weight and flexibility (conformance to substrates).

Once the panels were in place and seamed, the HID crew placed soil in the anchor trenches and compacted the material at top of slope with motor grader wheel loading. Cross anchorage was provided by saw cutting into the concrete, placing the EPDM in the cut trench and backfilling with low slump concrete to provide a smooth transition.

Although the EPDM lining is performing very well, the lined sections of the canal need to be inspected periodically so that any cuts or breaks in the panels caused by mechanical impacts or animals can be patched prior to any water flowing under the panel. A tear in an EPDM panel has limited resistance to propagation in flowing water and should be repaired quickly. Repairs are easily accomplished by district crews using Firestone QuickPrime Plus and the adhesive tape seam system.

Cost-Benefit Analysis in the use of an Impervious Lining over Concrete

Table 1 lists the economic information regarding the canal lining project described previously. The capital investment included all costs associated with the project including engineering and project administration. The expected useful life of the EPDM liner was assumed to be 20 years and that there would be a net reduction in maintenance cost of approximately $500 per mile of canal lining. The annual water savings were estimated based on the seepage rate measured using hydrostatic or ponded water tests. All water used by Harlingen Irrigation District is pumped from the Rio Grande into the Harlingen Main Canal and then conveyed by gravity to approximately 38 secondary lift stations. The energy savings were estimated based on the energy used per acre-foot to pump water from the Rio Grande into the Main Canal.
The minimum value of the conserved water was estimated on the average spot market rates for irrigation water in the Lower Rio Grande Valley. The spot market rates are based on single-time purchases of the use of irrigation water as compared to long term contract rates for the lease or purchase contracts for the permanent sale of the water right. Spot market rates for irrigation water are typically have a lower cost per acre-foot than raw water for municipal use.

The minimum value to cost ratio for the lining project was 1.35 and the annual net revenue of the project that would have resulted if the conserved water was sold on the spot market was $3,363.00

Table 1. Canal Lining Economic Information

Description	
Initial Capital Investment ($)	$ 141,744.00
Expected Useful Life (yrs)	20
Net Change in Annual O & M Cost ($/yr)	$ (1,225.00)
Net Changes in Annual Energy Cost ($/yr) @ $0.10 $/kwhr	$ (1,476.00)
Annual Cost of Capital Investment @ 6.0% ($/yr)	$12,357.89
Net Annual Cost ($/yr)	$ 9,656.89
Estimated Water Savings (ac-ft/yr)	434
Annual Cost (ac-ft/yr)	$ 22.25
Estimated Minimum Value of Conserved Water (Spot Market Irrigation, $/ac-ft)	$ 30.00
Annual Gross Revenue that would result from Marketing Conserved Water	$ 13,020.00
Minimum Value to Cost Ratio	1.35
Annual Net Revenue that would result from Marketing Conserved Water	$ 3,363.11

SUMMARY

The HID successfully installed an exposed EPDM geomembrane system using custom manufactured panels, HID personnel for installation and seaming and HID equipment for placement of panels and the concrete preparation and anchor trench backfilling. The combination of low cost and user friendly materials that can be installed by irrigation district personnel with minimal training and no specialized equipment is an outstanding alternative to other systems.

The HID is typical of many irrigation districts in the South West and Western United States where conveyance channels are unlined or concrete lined but in very poor conditions with many losing between 10 and 50 percent of the deliverable water due to seepage during the irrigation season. With water costs increasing and available water in short supply (especially during dry years or federally mandated allocation restrictions), irrigation canals and laterals are being evaluated for lining with exposed geomembrane systems. There are over 16,100 miles of main canals and over 27,000 miles of laterals in the western United States alone. Of these, only approximately 15 percent are lined with concrete, compacted earth or geomembranes. Although all reaches of earth lined or concrete lined canals or laterals do not need an impervious lining, the potential of those that will need rehabilitation to save valuable irrigation water is indeed very large. The water crisis is real and is here to stay and we must address water conservation with a variety of technologies including the implementation impervious lining systems that have a track record of proven effectiveness, longevity and are economically advantageous to irrigation districts.

Photo 1. Typical Condition of Deteriorated Concrete Canal Section

Photo 2. Example of Seepage Adjacent to Cracked Concrete Irrigation Canal

Photo 3. Placement of EPDM Panels by the Irrigation District

Photo 4. Typical Lined and Seamed Section