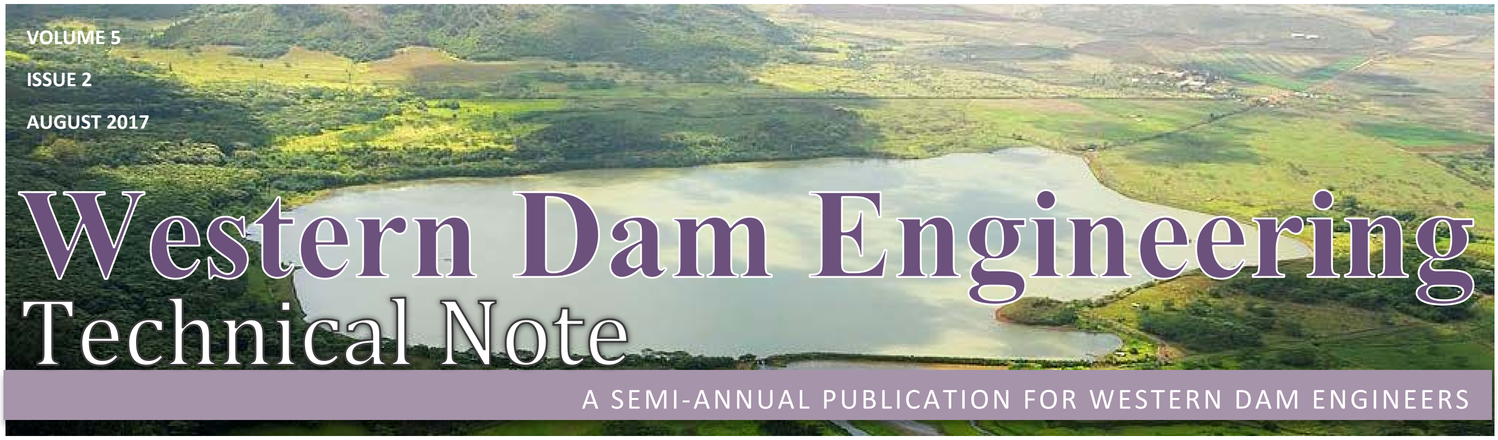

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Western Dam Engineering
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In this issue of the ***Western Dam Engineering Technical Note,*** We present articles on **unmanned drones, overtopping protection methods for embankment dams, cellular grouting for conduit sliplining, and conduit repair with mechanical seals.** This semi-annual newsletter is meant as an educational resource for civil engineers who practice primarily in rural areas of the western United States. This publication focuses on technical articles specific to the design, inspection, safety and construction of small to medium sized dams. It provides general information. The reader is encouraged to use the references cited and engage other technical experts as appropriate.

GOOD TO KNOW

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ASDSO NATIONAL DAM SAFETY CONFERENCE, *Sept 10-14, San Antonio, TX*

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In this Issue

Mechanical Seals for Conduit Repair

Henrik Forsling, PE and Carolyne Bocovich, PhD

Introduction

Outlet conduits provide essential control of the reservoir levels in dams. In embankment dams, leaks due to cracking or joint offsets in the outlet conduit may cause excessive seepage into (infiltration) or out of the conduit (exfiltration), which could lead to internal erosion (i.e., piping of embankment materials), which in turn could threaten the structural integrity of the dam. If an outlet conduit needs rehabilitation due to circumferential cracking, localized longitudinal cracking, localized deterioration, joint offset or joint separation, mechanical seals can provide a simple, relatively low cost rehabilitation option as compared to more comprehensive replacement or rehabilitation options. Mechanical seals have been used for more than 30 years to repair pipe joints, strengthen weak joints, bridge localized cracks or deteriorated sections, seal off abandoned laterals, and seal the ends of a cured-in-place pipe (CIPP) liner.

Mechanical seals comprise a sleeve that is adhered to the interior of the host pipe by a mechanical interlock, sometimes in combination with a chemical adhesive. Depending on the mechanical seal system, the sleeve is typically of rubber, PVC, or stainless steel over a polyurethane gasket.

Figure 1 shows a rubber sleeve with ribbing along the edges to improve contact with the conduit wall. In this application, the seal is held in place with retaining compression bands, which are locked into place by a hydraulic expander.

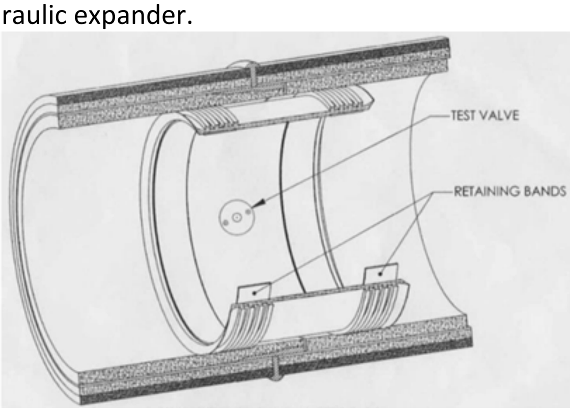

Figure 1. Sketch of a Rubber Sleeve (courtesy of HydraTech)

This particular sleeve includes a test valve in the seal to allow testing for leaks after installation.

Figure 2 shows a stainless steel grouting sleeve with an absorbent gasket. The gasket is placed in the annular space between the sleeve and host pipe, and is filled with an absorbent polyurethane grout that when in contact with moisture, will expand to fill the annulus. The sleeve is locked in place by inflating a plug that expands against the sleeve and engages a mechanical lock.

Figure 2. Stainless Steel Sleeve with Gasket (photo courtesy of Link-Pipe®)

Advantages and Disadvantages

Mechanical seals can provide advantages compared to other conduit rehabilitation options, depending on material, size, shape, and condition of the conduit.

Advantages

Mechanical seals are relatively low cost and can be installed in the dry or in the wet (i.e., with divers), as shown on Figure 3. They can be designed to provide a seal for up to about 300 lb/in^2 in a pressurized pipe or 100 feet of external head pressure.

More importantly, the installation does not require excavation to expose the conduit exterior, and the relatively simple and rapid installation limits the duration the conduit needs to be taken out of service.

Cost of the seals and installation is very dependent on size and shape of the conduit, location of the conduit, and extent of repair.

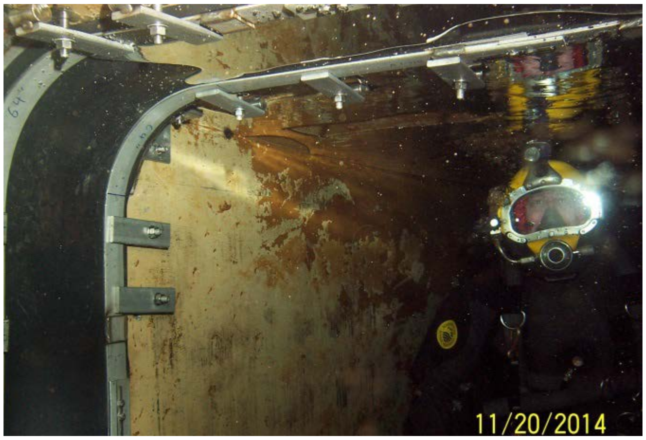

Figure 3. Example of a Mechanical Rubber Seal Installed in the Wet in a Rectangular Conduit (photo courtesy of HydraTech)

Mechanical seals are typically installed in circular conduits (Figure 4); however, these seals can be customized for irregular conduit shapes such as oval, horseshoe, rectangular, and square shapes (Figures 5 and 6).

Figure 4. Example of a Circular Mechanical Rubber Seal in a Concrete Conduit (photo courtesy of HydraTech)

Mechanical seals can be installed in circular conduits greater than 4 inches in diameter depending on the seal design/manufacture, and in host pipes of steel, cast or ductile iron, concrete, masonry, PVC or HDPE. The flexibility of rubber mechanical seals also allows for installation over offset joints, where installation of a conventional liner may be prohibitive, and over joints where some movement is expected due to settlement or vibration. The relatively low profile of the seal typically provides negligible loss of flow capacity through the conduit and reduces the risk of cavitation.

Seal options are available for corrosive environments or to meet potable water requirements, e.g., NSF 61.

Figure 5. Example of a Mechanical PVC Seal in a Horseshoe-Shaped Masonry Conduit (photo courtesy of Link-Pipe®)

Figure 6. Example of a Non-Circular Mechanical Rubber Seal (photo courtesy of HydraTech).

Disadvantages

Most mechanical seal designs require manned entry for installation. This limits their use to conduits greater than approximately 20 inches in diameter and requires training for confined space entry. One example is that irregular conduit shapes or offset joints need a rubber seal that requires manned entry of the conduit for installation. Also, mechanical seals for irregularly shaped conduits require custom fabrication of the retaining bands, which will increase the lead-time and may be prohibitive if urgent repairs are required.

Some manufactures require installation certification for product warrantees. Although certification can be earned, most manufactures offer installation services or recommend certified consultants to install their seals.

If the overall condition of the outlet conduit is poor, long sections of the conduit or numerous joints need repair, or if the host pipe has sustained thickness loss where its capacity to resist external pressure has been significantly compromised, other rehabilitation methods may be better suited and more economical. In such instances, as outlined by FEMA [1], typical rehabilitation methods that do not require excavation of the conduit include lining the existing pipe with a smaller diameter pipe, slip-lining, CIPP lining, or spray-in-place pipe (SIPP) lining. Note that SIPP may not be suitable in applications where the liner needs to be a fully structural liner, as defined by AWWA M28 [2].

Previous Western Dam Tech Note articles have discussed considerations for more comprehensive outlet pipe replacement or rehabilitation with HDPE slip-ling or CIPP liners: Low-Level Conduits – Rehab or Replace? [2] and You Down with CIPP? – Yeah! You Know Me! [3].

Case Studies

A mechanical seal was used to reinforce a repair patch in the 30-inch-diameter pre-stressed steel cylinder outlet pipe at Pike Creek Dam in Lewistown, MT. A routine inspection found an approximately 10-inch-diameter hole in the pipe wall (Figure 7). The hole extended through the concrete liner and steel cylinder, and every other pre-stressed wire was corroded completely through.

Figure 7. Hole through Pipe Wall (photo courtesy of NRCS).

Due to the corroded metal, it was concluded that a concrete patch could not be adequately bonded to the substrate area, and a mechanical seal was installed over the patch repair to provide protection and reinforcement.

Figure 8. Patch repair of pipe wall damage prior to mechanical seal installation (photo courtesy of NRCS).

A 14-inch-wide mechanical rubber seal and five retaining bands were used to reinforce the patch, as shown on Figures 9 and 10.

Figure 9. Retaining Compression Bands Locked into Place by a Hydraulic Expander (photo courtesy of NRCS).

Figure 10. Mechanical Seal and Completely Installed (photo courtesy of NRCS)

At Stillwater Dam in Larkspur, CO, the 30-inch-diameter reinforced concrete pipe (RCP) outlet conduit had a circumferential crack that varied in width from approximately 3/8-inch at the invert to less than 1/16-inch at the top or crown of the pipe. Water flow was observed through the crack and some fine- and coarse-grained soil deposition was observed within the crack and in the invert of the pipe.

The repair, which was installed in 2006 and is still performing well, consisted of injecting the crack and void outside of the pipe with a hydrophobic polyurethane grout. Thereafter, the crack was bridged by an 18-inch-long stainless steel sleeve with an absorbent gasket saturated with polyurethane grout in the annulus between the sleeve and host pipe (similar to the sleeve shown on Figure 2).

A schematic of the relatively simple and inexpensive repair is shown on Figure 11. The cost of this project was approximately $12,500 including all engineering construction oversight and construction. Although not "cheap" the cost was considerably less than other methods considered.

Conclusions

Mechanical seals can be a good alternative to more extensive (and expensive) pipe rehabilitation options for conduits with localized areas needing repair. These internal seals offer a simple, low cost rehabilitation option that does not require excavation, and the rapid installation does not require the conduit to be taken out of service for an extended period of time.

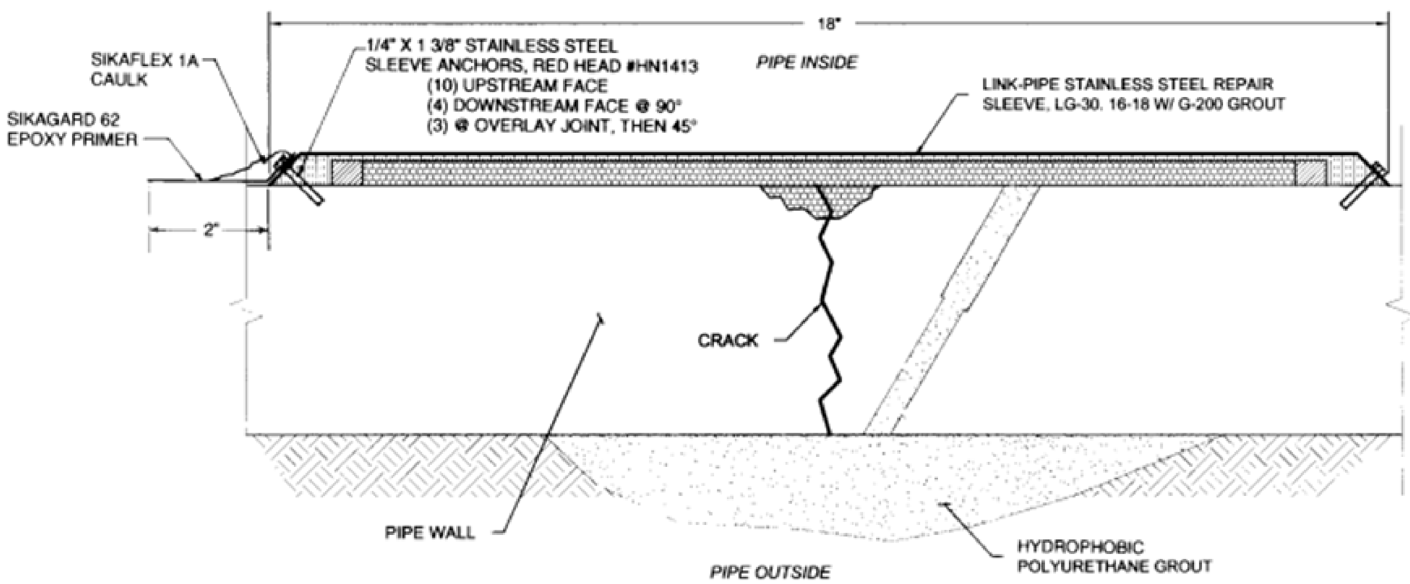

Figure 11. Repair of Cracked 30-Inch-Diameter RCP Outlet.

References

[1] Federal Emergency Management Agency (FEMA), *Technical Manual: Conduits through Embankment Dams.*, FEMA P-484, 2005. https://www.fema.gov/media-library/assets/documents/3875

[2] Western Dam Engineering, *Low-Level Conduits – Rehab or Replace?*, Vol.1 Issue 1, March 2013.

[3] Western Dam Engineering, You Down with CIPP? – Yeah! You Know Me!, Vol.4 Issue 1, May 2016.

[4] American Water Works Association (AWWA), "M28 Rehabilitation of Water Mains." (2014).

[5] HydraTech Engineered Products, Hydra-Tite® joint seal, http://hydratechllc.com/hydratite-internal-pipe-joint-seals/

[6] Link-Pipe Incorporated, http://www.linkpipe.com/