RECLAMATION
Managing Water in the West

Contraction Joint Leak Repair Collaboration

Research and Development Office
Science and Technology Program
Final Report ST-2018-7139-01 (8530-2018-60)

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

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Members of Reclamation and the Corps of Engineers met and collaborated on useful ways to repair leaking waterstops in concrete structures. Starbuck and Maier traveled to Dardanelle in Arkansas to see a rubber sock type waterstop being installed and met with COE to discuss its effectiveness.

14. ABSTRACT *(Maximum 200 words)*

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Science and Technology Program

Concrete, Geotechnical, and Structural Laboratory, 86-68530

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Contraction Joint Leak Repair Collaboration

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Acknowledgements

The principal investigator would like to acknowledge the following people for their contributions to the success of this collaboration. Michael Ellis, Corps of Engineers, and Phillip Orzech, SPS Structural. They were gracious hosts at Dardanelle Lock and dam. They took time to show us the application of the rubber sock waterstop method and answer all of our questions.

Acronyms and Abbreviations

COE	Corps of Engineers
BOR	Bureau of Reclamation
CGSL	Concrete, Geotechnical, and Structural Laboratory

Executive Summary

The main objective of this collaboration was to bring together waterstop repair experts from the Bureau of Reclamation (BOR) and the Corps of Engineers (COE) to discuss different repair methods. There are many techniques for sealing these types of leaking waterstops. Some methods are more successful than others. We had meetings where we discussed the pros and cons of the different types of methods used at our respective facilities.

Patrick Maier and Warren Starbuck traveled to Dardanelle Dam in Arkansas to watch a contractor installation of a rubber sock type waterstop along a contraction joint in a lock dam. BOR personnel met with the COE engineer Michael Ellis and discussed the intricacies of that system. He also provided a tour of the galleries and showed some other types of internal water stop repairs. A travel report can be found in Appendix A.

Conference calls were conducted to bring together people who worked with this type of repair. During these calls participants discussed different types of repairs including their benefits and drawbacks. A Google shared drive was created so these participants could share information. This information consisted of documents such as estimates, reports, and drawings.

The participants of this collaboration from different agencies determined that an in-person meeting to discuss this topic was not necessary, and that document sharing and conference calls were sufficient for the transfer of information.

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Background

Reclamation's concrete structures are mainly designed to retain water. These concrete structures are built with contraction joints that utilize embedded waterstops. These waterstops can start to leak for different reasons, such as old age, poor construction, or material failure to name a few. Some of these structures use a copper waterstop. As the concrete expands and contracts due to temperature changes, the copper can fatigue and break over time. Other more recent structures use waterstops composed of plastic polymers. These types work well as long as they are installed properly. During construction, problems can occur for all types of waterstops, such as a lack of adequate concrete vibration around the waterstop. Once the copper waterstop breaks, or problems occur during installation, a leak can occur. These leaks can lead to millions of dollars of increased maintenance costs across numerous facilities because the water can corrode metalwork, increase operation costs through increased pumping to remove excess water, reduce worker productivity as they work around the leaks, etc.

Meetings

This collaboration focused on meeting with COE and BOR personnel that either had experience with waterstop repair or had an interest in learning more about the topic to help with current or future projects. Table 1 below is a list of meetings held, the people in attendance, and the purpose of the meeting. Mark Lewis and Warren Starbuck submitted documents to the shared Google drive.

Table 1. Meeting Schedule, Attendees and Purpose

Meeting Date	Attendees	Primary Purpose
5-Jan-17	Joel Prusi	Kickoff Meeting to determine who should be involved, and discuss repairs.
	Michael Ellis	
	Ross Foster	
	Westin Joy	
	Kurt Von Fay	
	Natalie Richards	
25-Jul-18	Michael Ellis	Discuss waterstop repairs, and try to setup an in person meeting
	Natalie Richards	
	Patrick Maier	
	Edward Roza	
	D. Warren Starbuck	

As the discussion on this topic continued through meetings and emails it was determined that not all parties originally involved had an interest in continuing with this topic, so the group members of this collaboration were narrowed down to active participants. Table 2, and 3 list the collaboration members who either expressed interest or declined interest.

Table 2. List of Potential Collaboration Members Who Expressed Interest

Individual	Contact Information	Company
Michael Ellis	Michael.C.Ellis@usace.army.mil	COE
Ross Foster	Ross.Foster@usace.army.mil	COE
Natalie Richards	Natalie.A.Richards@usace.army.mil	COE
Westin Joy	wjoy@usbr.gov	BOR
Kurt Von Fay	kvonfay@usbr.gov	BOR
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Joel Prusi	Joel.W.Prusi@usace.army.mil	COE
D. Warren Starbuck	dstarbuck@usbr.gov	BOR

Table 3. List of Potential Collaboration Members Whom Declined or Provided no Response

Individual	Contact Information	Company
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Stuart Foltz	Stuart.D.Foltz@usace.army.mil	COE
Michael McInerney	Michael.K.McInerney@usace.army.mil	COE

Previous Work

In 2013, the Concrete, Geotechnical, and Structural Laboratory (CGSL) performed work at Grand Coulee Dam using a material called Cylutions, which is manufactured by Imagineered Solutions. The material is of a rubber consistency that was ground-up to the size of very small gravel. When it comes in contact with water it reacts and swells approximately 300% (figure 1). The material was placed into the reservoir at Grand Coulee and allowed enter the contraction joint via water flow from the reservoir into the leaking joint. This field work was shared with others in this collaboration group.

Figure 1. Ground-up Cylutions waterstop. Left side before water and right side right after water was added. The cups contained the same volume of waterstop prior to contact with water.

Additional research was performed in the lab using this ground-up Cylutions material and grout. This research involved using a laboratory fixture that closely mimicked the conditions of a leaking contraction joint. The fixture can be seen below in figure 2. The ground-up Cylutions material was used in conjunction with chemical grouts that are used for water leak repairs. The results of that testing was summarized in a report (ST-2016-7688). That report was also shared with this collaboration group.

Figure 2. Internal view of teste fixture mimmicking a leaking contraction joint.

The CGSL also performed laboratory testing on the original Cylutions material. The tests performed were: corrosion, wicking, freeze-thaw, swell testing and wet-dry tests. This research was performed in anticipation of using the material at Pueblo Dam. Ultimately this material was not selected for the repair. However, a final report for the material used in this testing will be completed in FY19. The rough data from these tests was shared with the collaboration group.

The CGSL has mainly worked with the Cylutions waterstop material. They have not conducted any testing on other types of waterstop repair systems such as the rubber sock system described in the Dardanelle travel report.

Next Steps

This topic should be re-evaluated periodically, perhaps on a two year cycle. As the industry makes advancements it will be necessary to stay current on the new materials and methods. It is recommended that a conference call be set up with the members of this collaboration group, so that as new people join Reclamation they have the opportunity to learn this information, and experts can transfer their knowledge and learn of advancements.

Conclusions

This collaboration was helpful in connecting government personnel that work on waterstop repair projects. Some of the participants had either former or current waterstop repair projects. There were also some individuals that were new to this type of repair, and they were given useful information to make better decisions at their facilities.

Staff at BOR gained valuable information about the rubber water sock repair method when traveling to Dardanelle dam and observing that system being implemented.

Appendix A – Dardanelle Travel Report

BUREAU OF RECLAMATION
Technical Service Center

TRAVEL REPORT

PRJ-8.10

Code: 86-68130 Date: March 29, 2018

To: Dick Lafond, P.E. (86-68100)
Chief, Civil Engineering Services Division

From: Patrick Maier, P.E. (86-68130)
Technical Service Center

Subject: Travel to Dardanelle Lock and Dam, Arkansas to observe installation of retrofit waterstop through a contraction joint on dam.

1. Travel period (date): March 6-8, 2018.

2. Places or offices visited: Dardanelle Lock and Dam, Arkansas River, Arkansas

3. Persons Contacted: Michael Ellis, Corps of Engineers
Phillip Orzech, SPS Structural

4. Participants: Patrick Maier (Civil Engineer – TSC – 86-68130)
Warren Starbuck (Mechanical Engineer – TSC – 86-68530)

5. Purpose of trip: Dardanelle Dam and Lock is owned and operated by the U.S. Army Corps of Engineers. The purpose of this trip was to examine a contractor installation of a retro-fit waterstop along a contraction joint. There is also a general need to coordinate and share information between organizations regarding the use of retro-fit type waterstops, successes and failures, as well as testing results.

6. Synopsis of trip: We departed Denver International Airport (DIA) on Tuesday morning, March 6, 2018. Once we arrived in Little Rock, Arkansas, we obtained a rental car and drove to Russellville, Arkansas. The following morning, we met with Michael Ellis (Civil Engineer, U.S. Army Corps of Engineers) at the hotel, and then departed Russellville and drove to Dardanelle Dam and Lock. We met with the contractor onsite, and discussed various aspects of the project and recent progress with waterstop installation and testing. When we arrived, the contractor was preparing to install one of several waterstops on the Lock side of the dam (see Figure 3). The waterstops are a retro-fit type of waterstop that consists of a reinforced vulcanized rubber tube, custom made to a length to fit the core drilled hole. These rubber tubes can be fabricated to fit the core hole, but are typically fabricated in 8-inch or 10-inch diameters. The rubber durometer is between 30 and 40. The length can also be customized based on field requirements. Similar to car tires, the waterstop tubes are reinforced with special fiber strands. However, the tubes are only reinforced longitudinally as opposed to circumferentially (car tire). This allows the tube to expand circumferentially, while providing enough strength longitudinally such that the tubes do not tear while being installed. According to the contractor, these tubes have been fabricated up to 200 feet in length. At Dardanelle Dam, the tubes were on average about 110 feet in length, and the drilled holes were 98 feet deep. The tubes weigh about 700 lbs.

Prior to installation the tubes are pressure tested out in the open to ensure there are no leaks. They are pressurized to 8 psi for about 15 minutes, then at 5 psi for 12 hours while the pressure is monitored. The first step in installing these rubber tube waterstops is to core drill a hole, centered along the contraction joint. The core holes at this dam were 10-inch diameter. The waterstop tube was also 10-inch diameter (pre-filled size). To aid in installation, the tube is first evacuated with a shop vacuum (see Figure 3). Afterwards, the contractor installs zip ties and duct tape at specific intervals to hold the shape of the collapsed membrane, and then disconnects the vacuum. The membrane is loaded onto multiple dollies (spread out along the length) and moved to location by hand (see Figure 4). A spindle assembly is installed near the core hole, and the membrane is then manually inserted into the hole (see Figure 5). As the membrane is installed the zip ties are cut and removed. Once installed, the contractor pulls up on a steel wire which cuts the duct tape, and also collects the pieces as the wire is retracted (see Figure 6 and 7). The contractor then slightly lifts up on the membrane to lift the waterstop off the bottom of the hole, and fills the membrane with approximately 5 gallons of water to seat the membrane. After seating, the contractor lets the waterstop rest again on the bottom of the hole, and then fills the remainder of the membrane up with water. The contractor was using tap water for this application. The contractor has indicated that in very cold climates, clear glycol fluid has been used. In this particular location, the concrete cover was sufficient enough that freezing would not be an issue. After filling, the contractor inserts a CCTV camera and inspects the length of membrane to ensure the membrane has opened up completely (sealed), and there are no tears or bulges. The use of clear water is also important for this very purpose. The contractor indicated that in certain climates, if the water is clear enough in the reservoir, tap water is not necessary. In this particular location, the Arkansas River is extremely muddy and would not allow for inspection if used. Prior to installation of this waterstop, the seepage through the contraction joint was visible on the downstream side (see Figure 9). After installation and filling, the seepage appeared to be eliminated effectively. However, the lock was in the closed position during installation (filled with water), and was in the open position after installation (water was approximately 45 feet lower). The lock was filled again after installation, and the seepage was verified to have been significantly reduced (see Figure 10). After installation and inspection, the tube is cut off flush with the surface and sealed at the top. At a later date, the contractor installs an inspection cover (see Figure 8).

The waterstop tubes are located along the contraction joints of the dam and lock, in areas where seepage has been problematic. The seepage through the contraction joints was attributed to the metal waterstop (from original construction) failing. Metal waterstops were commonly installed along contraction joints in many Reclamation facilities from the early 1920's up to the 1970's. Rubber waterstops were introduced in the 1950's, and PVC waterstops in the 1970's. Unfortunately, use of these flexible materials was not readily accepted until years later. In many cases, rubber waterstops were installed in combination with metal waterstops, due to the uncertainty with the rubber waterstops. Pueblo Dam has a similar feature in which a metal waterstop was installed as the first line of defense (upstream most waterstop), followed by a formed drain and then a PVC waterstop. The PVC material was new at the time of construction (1970's), and faith in the material was limited at the time. Metal waterstops have been shown to be effective, if ideal conditions are present. These conditions include proper consolidation of the concrete around the waterstop, and very little movement of the joint (if any at all). Metal waterstops are commonly constructed from copper, or other form of non-deleterious metal. Dardanelle Dam (and Pueblo Dam) continually expands and contract throughout the year, and the metal waterstop has likely failed due the repetitive cyclic movement. During the winter months, when the water in the Arkansas River is coldest, the seepage through the contraction joints at Dardanelle Dam is greatest. During the summer months, the seepage significantly decreases, and in many of the joints, completely stops all together. Pueblo Dam is also located on the Arkansas River, however, the water temperature fluctuations at Pueblo Dam are significantly less than those seen at Dardanelle Dam. The water that is stored at Pueblo Dam is snow runoff water, and is very cold even in the summer months. The seepage at Pueblo Dam also fluctuates from summer to winter due to the temperature changes, although not nearly as much as what is reported at Dardanelle Dam.

The waterstop tubes appear to be a good product overall, based on the testimony provided by Michael Ellis. Michael also mentioned that on a previous project where this waterstop was installed, the contractor had issues with the performance due to the tube not sealing fully within the hole. Seepage water was still bypassing the waterstop. They inspected the tube and determined that water was bypassing the seal at specific locations, and they were able to evacuate the water, remove the waterstop and reinstall. The performance of the waterstop on the second installation was successful. They determined from this incident that the "seating" load was needed prior to filling the tube with water. Previously they had installed and filled it in one step. They found that this could cause the tube to crimp up at the bottom while filling it, and therefore, they have now changed their installation procedure to include the 5 gallon seating load, which has proven to eliminate this issue. The potential to remove the product if deemed necessary is a beneficial feature, although the contractor did mention this was a very tedious and laborious process. The ability to inspect the waterstop with a camera to determine if the installation is working, and if not, where the leaks are occurring is also beneficial. Because this product requires core drilling, the use on projects such as Pueblo would be difficult if not impossible due to the angled geometry. The contractor mentioned the accuracy of the drilling equipment (plus or minus ¼-inch in 200 feet), and also indicated that they are able to constantly check (and if required correct) verticality via an onboard diagnostics computer and ability to steer the drill while drilling. While this sounds promising, the contractor has only dealt with straight vertical holes, and gravity will aid in keeping the drill bit vertical. On an angled hole, or horizontal hole, gravity will constantly want to pull the bit away from the target. Regardless, this product appeared promising, and there are many concrete gravity dams that this system could be employed. Cost for purchasing and installing this material would also be a factor. It was not clear whether or not this product was patented.

Over the previous several years, the U.S. Corps of Engineers has installed several of the rubber tube waterstops at Dardanelle Dam and Lock. Although the performance of these waterstops appears to vary somewhat, in general these waterstops have been successful in reducing the seepage through contraction joints significantly, and in some cases entirely. After watching installation of the waterstop membrane, the team left the installation area and entered the dam inspection gallery to inspect a separate waterstop system that was used in the past. This waterstop system consisted of a rubber membrane sheet, installed across the contraction joint length wise, then held in place via stainless steel plates and bolts (see Figures 11 and 12). The waterstop appeared to be working effectively, yet there were concerns that there may be a blow out in the future. The pressure behind the waterstop was visible due to the bulges in the stainless steel plate, and portions of the rubber membrane had also bulged outward at miter joints in the plate (causing bubbles). This system is somewhat similar to the system that will be employed at Pueblo Dam, however, the major difference is where the waterstop is installed. At Pueblo Dam, the waterstop will be installed on the upstream face, and water pressure will only help to push / or suck the waterstop into place.

After inspecting the dam gallery, we departed Dardanelle Dam and Lock and returned to Little Rock. On Thursday morning, we departed from Little Rock airport and flew to DIA.

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SIGNATURES AND SURNAMES FOR:

Travel to: Dardanelle Dam and Lock, Arkansas

Dates of Travel: March 6, 7 and 8, 2018

Names and Codes of Travelers: Patrick Maier (86-68130),
Warren Starbuck (86-68530)

<u>Traveler:</u> <u>Date</u>

______________________________ __________________

Patrick Maier, P.E., Civil Engineer
Waterways and Concrete Dams Group 2

<u>Noted by:</u> <u>Date</u>

______________________________ __________________

Ernest Hall, P.E., Civil Engineer
Manager, Waterways and Concrete Dams Group 2

Figure 3 – Typical view of Dardanelle Dam and radial gates.

Figure 4 – Typical view of Dardanelle Lock, located between the left abutment and dam.

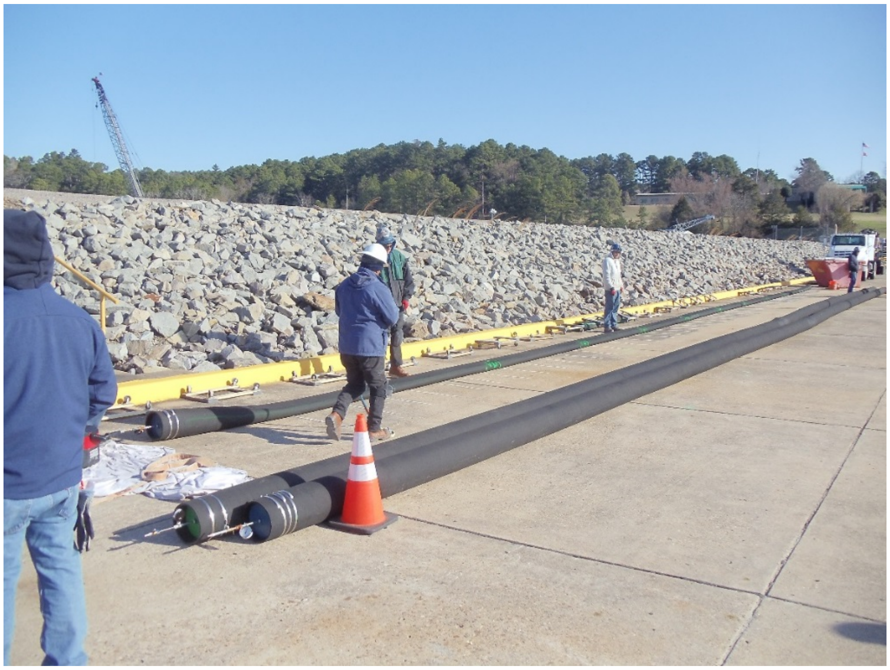

Figure 5 – View showing three waterstop membranes. The two membranes in the foreground are currently being tested with pressure. The membrane in the background is being collapsed with a vacuum.

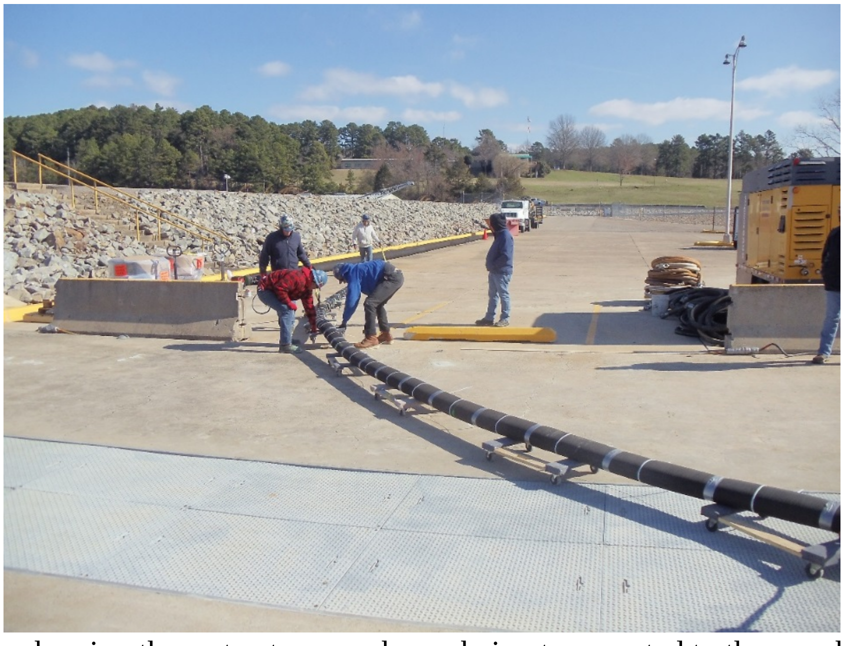

Figure 6 – View showing the waterstop membrane being transported to the core hole via dollies. Note duct tape and zip ties holding the collapsed shape.

Figure 7 – View showing the waterstop membrane just prior to install into the core hole. Note the spindle used to aid in dropping / guiding the membrane into the core hole.

Figure 8 – View showing the manual installation of the membrane into the core hole.

Figure 9 – View of showing the contractor cutting the zip ties as the membrane is inserted. The metal wire is used to cut and remove the duct tape after installation.

Figure 10 – View showing a previously completed installation. The concrete was cut out to allow installation of the inspection cover (to be filled in with repair mortar at later date). The temporary brackets will be removed after the repair mortar has set.

Figure 11 – View showing seepage at the contraction joint prior to insertion of waterstop membrane. Water could be seen exiting face, and percolating upwards from soil.

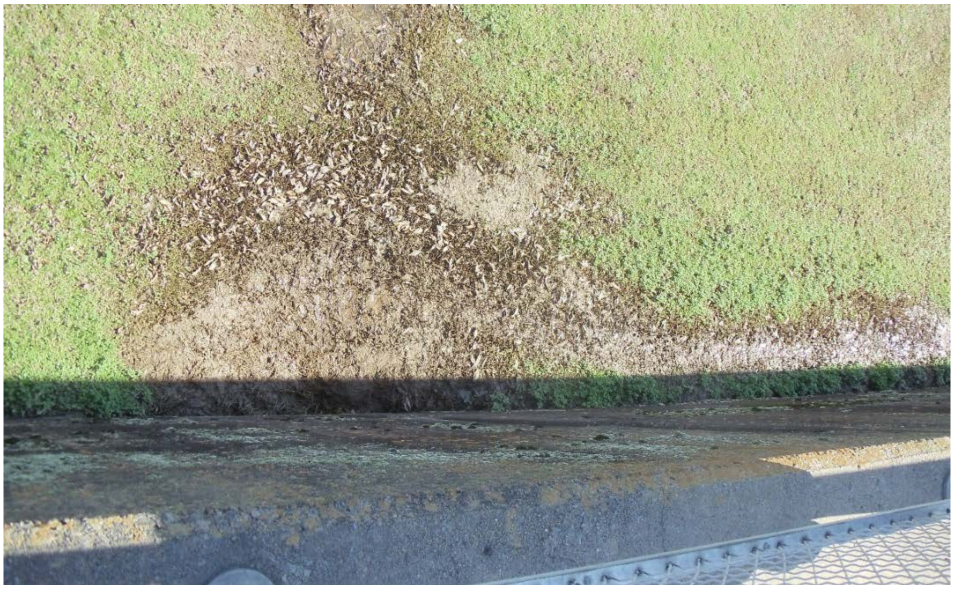

Figure 12 – View showing seepage at the contraction joint after installation and filling of the waterstop membrane.

Figure 13 – View showing a waterstop system installed along a contraction joint within the inspection gallery. Note the waterstop is bulged outwards due to the water pressure.

Figure 14 – View showing the bottom portion of waterstop system shown in Figure 11. Note the waterstop is bulged outwards due to the water pressure.