RECLAMATION
Managing Water in the West
U.S. Department of the Interior
Bureau of Reclamation

Research Update

Summer 2015
Bulletin 2015-05

Bottom Line

This research project built a laboratory model of cracks and erosion to evaluate the effectiveness of three remote monitoring technologies.

Better, Faster, Cheaper

Continuously and remotely monitoring Reclamation's infrastructure will provide more timely alerts for potential problems, avoiding costly repairs, or even failures later.

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Listening for Internal Erosion

Continuous, remote monitoring to detect problems early

Problem

Internal erosion (often called piping) can occur in embankments, dikes, abutments, foundations, and under spillways and is one of the most significant risks to Reclamation's structures and the people that live downstream from them. Internal erosion has resulted in several near failures of Reclamation facilities and in costly emergency responses and repairs. At the Arthur V. Watkins Dam in Utah, a local farmer happened to notice cloudy discharge near the toe of the dam and alerted the authorities. If this discharge had been noticed even 1 day later, it is possible the dam would not have been saved. At Red Willow Dam in Nebraska, Reclamation geologists and drillers fell into sinkholes on the downstream shell of the dam while looking for survey points.

Reclamation could monitor facilities continuously and remotely. This would augment its periodic comprehensive facility reviews. Continuous, remote monitoring could have alerted personnel to the onset of these internal erosion failure modes months or years in advance and could have saved significant amounts of taxpayer money.

Solution

This Reclamation Science and Technology Program research project investigated three techniques for suitability as long-term, continuous, and remote monitoring techniques for internal erosion and cracking of embankment dams.

This research project laboratory experiment built upon the large-scale embankment filter research that Reclamation and the U.S. Army Corps of Engineers have been conducting for several years. The primary purposes of the filter testing have been to gain a better understanding of cracked filter performance, conditions which cause a crack within a

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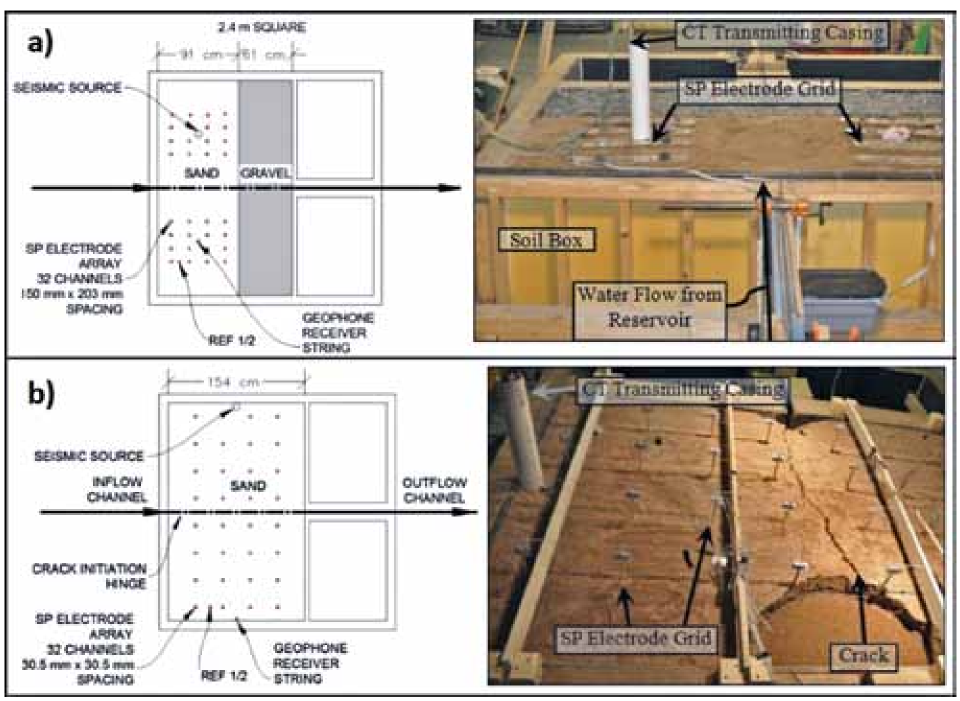

Top: Pre-crack photograph of filter geometry and instrumentation for T11 – two-stage filter.
Bottom: Post-crack photograph of filter geometry and instrumentation for T12 – single-stage filter.

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filter, ability of a filter to heal under flow conditions, and effectiveness of a filter to stop or control flow. The geophysical research presented here served as a complementary addition to the ongoing filter testing and has subsequently led to additional technology development work.

A laboratory model (a soil crack box) was constructed to simulate internal erosion. The box allows for the compaction of filter material in various configurations, subsequent cracking of the filter (i.e., to simulate differential settlement, desiccation, or seismically induced cracking), and impingement of reservoir water upon the cracked filter. As the model was forced to crack, geophysical data from the three monitoring techniques were collected during manually imposed cracking of granular filter materials. Data were collected during both self-healing and during continuing erosion.

Results and Applications

The three techniques tested were:

Passive Acoustic Emission (AE). Using acoustic sensors (e.g., geophones or accelerometers) to listen for noise from the dam. Just as houses creak, eroding infrastructure can make a noise. While many monitoring techniques require an external energy source and personnel onsite, AE relies solely on internal energy sources and is easily accomplished remotely. The only requirements for passive AE monitoring are robust, self-powered electromechanical sensors and a means to transmit the data to a remote monitoring computer. Unique AE signatures of filter collapse and self-healing were observed during these experiments, showing promise for the successful use of the AE method in monitoring applications for full-scale embankment structures.

Cross-Hole Tomography (CT). Tomography techniques (like X-ray) send signals between a transmitter in one borehole and a receiver in another borehole (or along the surface). While seismic tomography data collected between boreholes can offer better resolution of specific targets, one disadvantage is that the CT approach requires boreholes, and subsequent data images are limited to regions between borehole pairs. However, CT results from this research show promise for the applicability of seismic CT techniques for successful detection and imaging of embankment material cracking and self-healing phenomena associated with earthen embankment structure failure mechanisms.

Self Potential (SP). This passive geophysical method measures small variations in electric potential (voltage) that result from naturally occurring electric currents associated with seepage. The observed and expected relationship between SP data and the state of the filter material offers promise in the applicability of the SP technique towards full-scale embankment time-lapse monitoring efforts. Similar to passive seismic techniques, SP can be used to listen for anomalous or alarming changes in geophysical signatures associated with failure mechanisms. It can also be used to detect and image anomalous and concentrated seepage, helping to better characterize problematic seepage and focus remediation efforts at early stages.

Future Plans

This work has helped focus subsequent research for geophysical monitoring of embankment structures during induced failure, including instrumentation of Reclamation's Canal Breach Testing and passive geophysical monitoring of a full-scale embankment failure test that was carried out in the Netherlands during the fall of 2012. Work remains to further understand the link between identifiable cracking, healing, and flow events, as well as the risk of filter failure, in order to provide a complete picture for dam safety decisionmaking. Research in the cracked filter box is ongoing. However, this study serves as a preliminary proof of concept.

For a full-scale earth dam, directly monitoring with buried geophones, surface geophones, or other types of seismic transducers and/or surface SP electrodes can augment conventional instrumentation to enable a higher resolution (in time and space) response that might otherwise go unnoticed by traditional instrumentation and visual methods.

"This research shows that three monitoring technologies hold promise for cost-effective, continuous, and remote monitoring for Reclamation's infrastructure. Reclamation needs to take advantage of these to monitor for many different failure modes on many types of structures."

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More information

www.usbr.gov/research/projects/detail.cfm?id=5500

Redlinger, C., C. Rudkin, D. Hanneman , and W. Engemoen. 2012. "Lessons Learned From Large-Scale Filter Testing." Manuscript submitted March 2012 to the 6th International Conference on Scour and Erosion, Paris, France, August 27-31, 2012.

Reinhart, R., M. Parekh, J. Rittgers, M. Mooney, A. Revil. 2012. "Preliminary Implementation of Geophysical Techniques to Monitor Embankment Dam Filter Cracking at the Laboratory Scale." Manuscript submitted March 2012 to the 6th International Conference on Scour and Erosion, Paris, France, August 27-31, 2012.

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