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Research Summary

Landslide Monitoring Methods: Application of Existing Technologies to Long-Term and Real-Time Monitoring of Slope Movements

This research project sought to monitor a slow-moving landslide near Branson, Missouri. Study results provide MoDOT with a better understanding of landslide movement and methods to predict and lessen the deleterious effects of landslides around the state.

This project successfully monitored a previously identified landslide in a cut slope above the Ozark Mountain Highroad using various remote sensing techniques for 28 months (June 2020-October 2022). The goal was to assess the strengths and limitations of various monitoring methods and instrumentation methods so that the department could more confidently select monitoring methods for other slow-moving landslides in the state.

A site reconnaissance of the area was completed in May 2020 and identified a second landslide in the embankment supporting the northbound lanes. This landslide was incorporated into the investigation and monitoring program, testing wireless site communications. Three UAV flights were completed between June 2020 and June 2022 to collect LiDAR for a high-resolution ground surface. Subsurface investigation, instrumentation installation, and installation of the remote monitoring system was completed in September 2020. Instrumentation included slope inclinometers, an in-place-inclinometer (installed June 2021), vibrating wire piezometers, and a weather station. Instrumentation was connected to an automated data acquisition system (ADAS) that used a modem and cellular connection to regularly upload data from the on-site dataloggers to a website for remote monitoring.

The research team's analysis concluded that both cut slope and embankment landslides are impacted by seasonal precipitation patterns, with most measured movement occurring between the beginning of April and the end of June. The cut slope landslide is moving on a shear zone approximately 10 feet below the ground surface at the boring location. The embankment slide is moving approximately 23 feet deep, near the contact between the embankment fill and the original ground.

> *"For this slide, movement is triggered by precipitation events that deliver at least four inches of rainfall to the site between the months of April and June."*

Combining the various on-site data sources, the research team determined that movement in the embankment slide is triggered by precipitation events that deliver at least four inches of rainfall between the months of April and June. This increases background pore water pressures, thus making the slide more susceptible to movement when the larger, more intense storm events occur. Movement was measured at other times of the year, but larger precipitation quantities were necessary for similar displacements.

Figure 1: Overview of cut slope landslide and gabion retaining wall system.

At the conclusion of the monitoring period, the various monitoring methods used during the project were compared in a monitoring methods analysis. This analysis of the various monitoring techniques incorporated sensitivity, approximate cost, and ease of use, including both set-up in the field and processing the data collected.

The research found the in-place inclinometer most sensitive to subsurface deformation, measuring displacements as small as 0.01 inch. Manual slope inclinometer surveys identified shear zone displacement as small as 0.1 inch. LiDAR scans required surface deformation of about 12 inches to reliably capture ground surface changes. The various costs and considerations involved in selecting an instrumentation and monitoring plan are summarized in the report's methods analysis section, serving as a decision support tool for future projects. The research results also support the implementation of multi-year monitoring periods for slow moving slides, improving risk assessments, and making mitigation more cost-effective.

Project Information

PROJECT NAME: TR202016—Monitoring Landslide on Route 465 Near Branson

PROJECT START/END DATE: April 2020 – November 2022

PROJECT COST: $149,992

LEAD CONTRACTOR: Landslide Technology, Inc.

PRINCIPAL INVESTIGATOR: Aine Mines, P.E.

REPORT NAME: Landslide Monitoring Methods: Application of Existing Technologies to Long-Term and Real-Time Monitoring of Slope Movements

REPORT NUMBER: cmr 23-002

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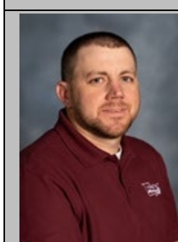
Project Manager



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