Research Brief

Wisconsin Highway Research Program
Project 0092-21-06
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Geotechnical Asset Management for Slopes

Research Objectives

- Develop a GAM for slopes framework to better understand potential slope failure along highways
- Create a GIS-based slope failure susceptibility model that identifies key risk factors for slope failures and is flexible (with appropriate adjustments) for use statewide

Research Benefits

- This project identifies a method to leverage readily available data to help WisDOT engineers and officials better understand slope failure susceptibility and make informed decisions regarding project prioritization and planning

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Background

Slopes along highway corridors are geotechnical assets that need different tools and procedures to be managed compared to other asset classes. Due to natural variability, large geographical extent and difficulty accessing slopes, efficiently characterizing the condition and failure susceptibility of these slopes is difficult. The goal of this project was the development of a Geographic Information System (GIS)-based Geotechnical Asset Management (GAM) process in which a model can efficiently characterize slope failure susceptibility. To accomplish this task, researchers evaluated historic slope instability events and public and WisDOT data to build a model that statistically identifies key attributes associated with up-slope (cut slope) failures along a section of Wisconsin State Highway 35 (WIS 35) in Crawford County. The model was also informed and verified through field mapping observations. The resulting model characterizes slope failure susceptibility along the WIS 35 corridor. With appropriate adjustments to account for geographic differences affecting slope instability, the GAM framework and model can potentially be expanded across Wisconsin to provide WisDOT engineers and management with additional information to better prioritize and plan future projects and maintenance efforts.

Methodology

The model developed for this project uses an inventory of known slope failures within the WIS 35 study corridor along with geometric inputs taken from aerial LiDAR data and geological data from field mapping and published sources to inform a weights of evidence calculation of slope failure susceptibility for any segment of highway within the study corridor.

Based on information provided by WisDOT and field verification, the researchers interpreted that past failures were fundamentally similar enough to be grouped together statistically. The documented slope failures tended to be governed by slope geometry, the geologic materials of the slope such as the inherent strength of the rock mass and soils, and proximity of those slopes to the highway. Geologic materials were mapped at an outcrop scale and a GIS-based analytical model was developed that extracted the geometric parameters of adjacent slopes in an automated way. The data extraction methods and principles applied to the susceptibility calculation are generic and can be deployed anywhere in the state. However, the weights of evidence found from the geology and topography combined with the records of past failure is unique to the region, in this case, the Driftless Area.

"The GAM framework and model developed during this project is an efficient way to use existing data to provide high-level evaluation of slopes along our highways to potentially identify areas of concern and prioritize use of limited resources."
– David Staab, WisDOT

Interested in finding out more?

Final report is available at:
WisDOT Research website

Representative photos for each of the three hazard mechanisms identified along the study corridor (A. Rockfall B. Fragmental rockfall and rockslides C. Shallow colluvial slides). Photos from BCG Engineering.

Results

The main project output is a slope-failure susceptibility model and GIS map that categorizes the study corridor slopes based on factors statistically correlated to slope instability. The model can be used within a GAM framework to provide WisDOT with additional information to prioritize and plan future projects and maintenance efforts. For example, the model can help manage the slope asset class by identifying high susceptibility corridor segments, including where failure has not yet occurred. In other words, it is not simply an event-based inventory. Proactive inspection and mitigation of high susceptibility slopes is similar to asset preservation activities for other asset classes and helps WisDOT manage risk and achieve its performance objectives of safe, reliable corridors at low life-cycle cost.

Additional work could measure the costs and benefits associated with different scenarios, enabling WisDOT to make informed decisions regarding future efforts on the areas with the greatest risk or largest benefit. Similar susceptibility maps could be developed for other parts of the state. Adopting a GIS-based system to methodically track slope conditions and events statewide would provide WisDOT an opportunity to expand its knowledge of threats from natural hazards and deteriorating assets in a way that builds upon event history but is not limited by it.

Recommendations for implementation

As part of the research the following recommendations are suggested for future applications of the model:

- Expansion of the shallow slope failure susceptibility model within the Driftless Area of Wisconsin
- Development of an embankment (down-slope or fill slope) failure susceptibility model
- Statewide landslide susceptibility mapping

This brief summarizes Project 0092-21-06,
"Geotechnical Asset Management for Slopes"
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