A Brief Update of FHWA Highway Geohazards Program and a Case History for Stabilizing 20-Acres of Sliding Material

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Geohazards Forum
Huntington, WV
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• Introduction
• Geohazards & Risk Definition
• MAP-21 Transportation Bill
• The DRIVE Act
• FHWA Geohazards Program Relations
• Study Plan
• Example Environment Cooperation
• Landslide Case History

**FHWA Highway Geohazards Program Overview**

SR 530 Oso, Snohomish County, Washington 41 life losses
Highway Geohazards Program

Introduction

Program Name:
Transportation, highway, or Geohazards Program etc...

Highway Geohazards Program: involves identification and evaluation of geohazards; their severity, frequency, and intensity; their interrelationship with extreme events and climate change; and provides mitigation strategies to avoid or reduce negative impacts to highway transportation infrastructure assets.

U.S. 89, AZ (20 miles Detour)
Geohazard Definition

Geohazard: *geological* or earth-material state and *environmental* conditions that may lead to widespread damage or risk.

- Geohazards involve short-term or long-term geological processes.
- Geohazards can be relatively small features, but also attain large dimensions.
- Geohazards may affect local and regional socio-economy to a large extent.

I-70 Glenwood Springs, CO
17 miles closed, detour up to 200 miles
Risk – Exposure to the chance of loss or injury.

*Future phenomenon; may or may not occur; has direct impact on a project or system*

\[
Risk = \text{Probability} \times \text{Impact}
\]

Route 248
Palmerton, PA
$4.8 m Risk Mitigation Work
- Establishes system performance requirements
- State Highway Agencies to develop asset management plan toward achieving national highway performance goals
  - *Risk-based* plan to improve and preserve assets and performance of the system
  - Must include pavement and bridges
  - Encourages inclusion of all assets within the corridor right-of-way

**MAP-21 – Transportation Bill July 2012**

Source: TDOT I-75 in TN
Repair Cost: $9.2 - $12.6m
MAP-21 National Performance Goals

- **Safety** – reduce fatalities and injuries;
- **Infrastructure Condition** – maintain the highway infrastructure asset system in a state of good repair;
- **Congestion Reduction** – reduce congestion on NHS;
- **System Reliability** – improve efficiency;
- **Freight Movement and Economic Vitality** – improve the freight network, strengthen ability of rural communities to access national and international trademarks, support regional economic development
- **Reduce Project Delivery Delays**

Highway 530, Oso, WA
DRIVE Act

- DRIVE – Developing a Reliable and Innovative Vision for the Economy Act
- 6-year highway reauthorization proposal covering FYs 2016-2021
- Total highway funding – $280 billion

Highway 530, Oso, WA
Initial Funding Sources

- FY 2014 Strategic Initiatives ($20.5 m)
  - R&T Leadership Identified 8 Areas of Interest:
    1) **Climate Change – Adaption and Resilience**
    2) **Transition to Performance-Based Programs**
    3) **Public Engagement**
    4) **Workforce of the Future**
    5) **Better Understanding of Travel Behavior**
    6) **New Vehicle Technologies**
    7) **Building and Retrofitting Bicycle and Pedestrian Networks in Urban Areas**
    8) **Safety**

Alaska Permafrost TEACR Project

U.S. Department of Transportation
Federal Highway Administration
Initial Funding Sources

- FY 2014 Strategic Initiatives ($20.5 m)
  - **Climate Change – Adaption and Resilience**
  - ✓ Proposal was submitted and funded under name “Geohazards, Extreme Events and Climate Change”

Alaska Permafrost TEACR Project
FHWA Highway Geohazards Program Relations

External Links

- **National:**
  - USGS Landslides
  - USGS Earthquakes
  - GEER
  - FEMA
  - Other USA

- **International:**
  - Int. Centre for GeoHazards
  - Safeland
  - Others

Internal to FHWA

- Highway Geohazards Program
- Geotechnical Assets Program
- Risk Management
- Performance Management
- Monitoring
- Climate Change
- Adaptation

U.S. Department of Transportation
Federal Highway Administration
The Work Plan for the Project Consists of Three Phases:

- **Phase I – Literature Review**
- **Phase II – Peer Exchange**
- **Phase III – Comprehensive Study**

Contract was Awarded to Parsons Brinkerhoff

Alaska Permafrost TEACR Project
Geohazards, Extreme Events and Climate Change Study Plan

- Phases I & II Contract:
  - **Technical Panel Members:**
    - Ben Rivers (Geotechnical)
    - Khalid Mohamed (Geotechnical)
    - Brian Beucler (Hydraulics)
    - Robert Kafalenos (Environment)

- Contractors Team:
  - Brian Zelenko (Task Manager) (PB)
  - Edward Kavazanjian – PI (AZ State University)
  - Erik Loehr – CO-PI (University of Missouri)

Alaska Permafrost Study
FHWA Transportation Engineering Approaches for Climate Resilience (TEACR)

- **Study Lead by:** Environment Office with Support from HIF Hydraulics Team
- **Geotechnical Involvement is for certain Projects**

- **Study Purpose:** Develop recommendations on ways to incorporate climate change as part of engineering practice
  - Engineering analyses of a diverse set of transportation assets around the country will be performed in order to identify best practices for improving the resiliency of the transportation system to extreme weather and climate change.
Case History

U.S. Department of Transportation
Federal Highway Administration
Project Location

- Searcy County, Arkansas
- Ozark National Forest
- 80 miles NW of Little Rock
Site Description

Landslide – 20 acres of slide debris consisting of soil and rock

Rock Failure

CR-1 Falling Water Rd

Zones

Richland Wilderness Area
Site Condition Description

Scarp height
Approx. 100 ft

6’ 3” (Objections! 😞)

25 to 30 ft high slide rock block
Project Challenges

• Difficult access
• Remote site (approx. 60 min. driving from paved road)
• Environmental limitations (adjacent to wilderness area)
• Cost effective design
• Ease of construction
• Long-term performance
• Safety
Project Challenges

Slide Continued to Slowly Move Completely Blocking the Road
Subsurface Investigation

Legend:
I - Inclinometer
P - Piezometer

Note:
1. Instrumentation installed immediately after regrading the slope, prior to anchor installation activities.
Subsurface Investigation

Drilling at Toe of Slide

Performing Seismic Survey

- Seismic survey lines were performed at slide areas not accessible with drill rig
## Subsurface Profile

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>(0-15 ft) – Very loose to medium dense weathered shale fragments little clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>(15-23 ft) – Dense to very dense weathered shale fragments some clay</td>
</tr>
<tr>
<td>Sta.</td>
<td>(23-41.5 ft) – Shale and Sandstone</td>
</tr>
<tr>
<td>10+00</td>
<td></td>
</tr>
<tr>
<td>to</td>
<td></td>
</tr>
<tr>
<td>13+30</td>
<td>RQD = 100%; UCS = 7,750 psi</td>
</tr>
</tbody>
</table>

U.S. Department of Transportation Federal Highway Administration
### Subsurface Profile (cont.)

<table>
<thead>
<tr>
<th>Zone 2 Center</th>
<th>(0-3 ft) – Soft clay some weathered shale fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.</td>
<td>(3-27 ft) – Stiff to hard clay some weathered shale fragments</td>
</tr>
<tr>
<td>13+30 to 16+67</td>
<td>(27-39 ft) – Weathered Shale</td>
</tr>
<tr>
<td></td>
<td>RQD = 21 - 66% (very poor to poor)</td>
</tr>
</tbody>
</table>

U.S. Department of Transportation
Federal Highway Administration
## Subsurface Profile (cont.)

<table>
<thead>
<tr>
<th>Zone 3 North</th>
<th>(0-4 ft) – Soft weathered shale fragments and clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta. 16+67</td>
<td>(4-33 ft) – Stiff to hard weathered shale fragments and clay</td>
</tr>
<tr>
<td>to</td>
<td>(27-49 ft) – Shale and Sandstone</td>
</tr>
<tr>
<td>Sta. 19+00</td>
<td>RQD = 59 - 88% (fair); UCS = 9,730 psi – 15,460 psi</td>
</tr>
</tbody>
</table>
Subsurface Profile (cont.)

- Three (3) seismic refraction survey lines were performed

<table>
<thead>
<tr>
<th>Soil Type/Density</th>
<th>P-wave velocity (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft weathered shale fragments and clay</td>
<td>0-1,500</td>
</tr>
<tr>
<td>Stiff to very stiff weathered shale fragments and clay</td>
<td>1,500 - 3,500</td>
</tr>
<tr>
<td>Hard weathered shale fragments and clay</td>
<td>3,500 - 5,000</td>
</tr>
<tr>
<td>Soft to moderately hard shale and sandstone</td>
<td>5,000 - 7,000</td>
</tr>
<tr>
<td>Competent rock (Hard shale and sandstone)</td>
<td>&gt; 7,000</td>
</tr>
</tbody>
</table>

- The seismic refraction survey revealed a depth to competent rock between 30 and 100 ft
Repair Alternative 1

- Excavation and removal of slide rock and unstable weathered material
  - Flattening slope to $1v:3h$ by removing the slide debris (soil, weathered rock and large boulders with sizes up to 25 ft in diameter)
  - Deep excavation of approximately 35 to 40 ft is expected to remove slide rocks from the top of the slope to reduce load and improve slope stability
  - **Benefit:** Eliminates the hazard from additional rock fall and reduce future maintenance
  - **Cons:** Requires a significant amount of excavation, making this option unfeasible due to high construction cost
  - **This alternative must be combined with other elements to reduce the amount of excavation**
Repair Alternative 2

- Partial excavation of slide material, installation of anchors with concrete blocks and a toe buttress
  - Flattening the slope by excavating the unstable material to an approximate depth of 30 ft near the top of the slope
  - Install anchors with concrete blocks and a rock toe buttress at 5-ft offset from the edge of the roadway embankment
  - The anchor blocks will be covered with on-site soil and the slope will be re-vegetated
  - Improve drainage
  - **Benefits:** Reduces excavation, re-uses of on-site rock, and keep the material out of the roadway if a future slide occurs
Repair Alternative 3

- Toe anchored or cantilevered soldier pile wall with drilled shafts socketed into bedrock and partial excavation
  - An anchored soldier pile wall system would be required because of the high lateral loads
  - Cons: The depth to competent rock and the size of the slide rendered this alternative inapplicable because of concerns with high cost for this low ADT road
**Design Process of Selected Option**

*Alternative 2* - Excavation of Slide Material, Installation of Anchors with Concrete Blocks and a Toe Buttress

A GRS Embankment was Selected for Reconstruction of the Roadway Embankment for All Three Options
Notes:
1. Install three trenches, located at approximately Sta. 11+75, 16+00 and 19+10. (See Sheet 629-02A)
2. Excavate rock slide material near the top of the slope as shown on Sheet 86 & 87, then grade at 5% toward the face of the slope.
3. Install anchors and concrete blocks at 12 ft C-C.
4. Backfill over the anchors and blocks with topsoil and seed mix; covered with rolled erosion control mat Type SC, use on-site soil as topsoil.
5. Provide Class 1 corrosion protection for the anchors.
6. Grade the side slope laterally towards trench drains located at Sta. 11+75, Sta. 16+00 and Sta. 19+10.
7. Place rip rap class 2 in the left ditch located between Sta. 16+60 to 16+65.
8. Install rolled erosion control mat Type SC, in the right ditch located between Sta. 11+00 to 12+00, Sta. 15+50 to 16+60 and 16+80 to 19+50.

U.S. Department of Transportation
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FALLING WATER ROAD  
Sta. 11+30.00 to 13+00.00 (Zone 1)

Notes:
1. Place a drainage layer consisting of #57 stone along the back of the bench with a min. thickness of 1.0 feet wrapped with Geotextile Type I-C.
2. Place underdrain at the toe and along the back of the excavated bench using #57 stone and 6 inches diameter pipe wrapped in Geotextile Type I-C.
3. Provide a minimum of 2 underdrain outlets at equal spacing using a 6 inches diameter pipe, embedded in #57 stone and wrapped in Geotextile Type I-C.
4. Provide a geogrid with minimum LTOE of 3000 lbs/ft. Place the first geogrid layer at 0.5 feet above the bottom of the excavation. Extend geogrid layers a minimum 16.0 feet of embedment depth at 1.5 feet vertical spacing.
5. Use excavate material consisting of unclassified borrow in accordance with Subsection 704.06.
6. Construct rock buttress using on-site sandstone in accordance with Section 252.
7. Lateral pay limits of clearing and grubbing extend two feet beyond slope stake limits; excluding roadway.
8. Place 6 inches layer of on-site topsoil and establish turf over the repaired slope according to Section 624 & 625.

NOT TO SCALE
Construction Process
Slide Debris

- 196,000 Cubic Yard of
  - Soil
  - Boulders
  - Tree Branches
  - Mud
Excavation of 5 to 30 ft slide debris
Good Portion of on-site Material was Reused to backfill Low Slope Areas
Prepare Benches for the Concrete Anchor Blocks
Anchors and Anchor Block Installation
Shotcrete was Used to Prepare Bench Back Cut for Block
Anchors and Anchor Block Installation – (2 rows)
Near Completion of Construction

Slope Stabilization Consisted of:

Anchors with Anchor Blocks (single and double rows)

Excavation (Reduce load)

Toe Rock Buttress

GRS Embankment

Drainage

Engineers Estimate = $5.2 millions
Low Bid = $3.8 millions!
Thanks You!

Questions?