Innovative Slide Repair Techniques

A Guidebook for Missouri and Beyond

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Credit & Disclaimer

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Outline

• Brief review of stability terms
• Goal of the guidebook
• Discussion of selected options included in the guidebook
• Summary
Review of Soil Slope Instability

• Different Shapes
  – Falls, topples, flows, spreads, slides, and combinations

• Shallow or Deep Seated
  – Shallow < 10 feet deep
  – Deep > 10 feet

• Circular or Wedge (non-circular) Shaped
Typical Circular Slides

Deep Slide

Shallow Slide
Cause of Slides

- Slides occur when driving forces are greater than resisting forces.
- Driving or resisting forces change when:
  - Geometry changes (cut at toe or fill on top)
  - Water level increases
  - Weight added to top of slope
- Loss of vegetation
Possible Repair Options Considered for the Guidebook

- Aggregate Drains
- Horizontal Drains
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)
- Pin Piles/Micro Piles
- Soil Nails
- Rock/Soil Buttress
- Compaction Grouting
- Rammed Aggregate Piers & Stone Columns
- Soil Mixing
- Walls
  - Tied-Back Secant or Solider Pile
  - MSE
- Lime/Cement Injection
Guidebook Goal

Document with step-by-step implementation instructions for simple to moderately complex repair methodologies. Focused on methods that do not require extensive site investigation, testing, and analysis.
Guidebook
Included Repair Methods

- Rock/Soil Buttress
- Pin Pile and Micropile
- Tire Bale and Shredded Tire
- Polystyrene Block Geofoam
- Rammed Aggregate Piers and Stone Columns
- Aggregate Drain
- Horizontal Drain
- Mechanically Stabilized Earth (Wall)
Rock/Soil Buttress Repairs

• Consists of adding weight to the lower portion of the slide.

• **Deep** or Shallow Slides

• Can be completed w/o design

• Quick to start, no specialized equipment, low quality material can be used

• Large quantity of material required, toe access required, additional right-of-way may be required
Rock/Soil Buttress Repairs

Cross Section

- Original Ground Surface
- Post Failure Ground Surface
- Buttress (Flat as Possible)
- 1/3H
- 1/2H Min.
- Ground Surface Following Repair

Plan View

- Slope Crest
- Slope Failure Outline
- Scarp
- 20' Min.
- 20' Min.
- Original Slope Toe
- Buttress
Rock Buttress
Pin Pile and Micropile Repair

• Increases resistance to sliding
• Shallow Slides, ~5 ft. for plastic and unreinforced grout piles and ~10 ft. for steel and reinforced grout piles
• Can be completed w/o design, design is recommended
• Limited slope disturbance and required material, no excavation
• Specialized equipment, relatively expensive material, material may be hard to locate quickly, if slide depth is underestimated, no improvement
Pin Pile & Micropile Repairs

Cross Section

Ground Surface Following Repair

Slope Crest

Slope Failure

3' Max. Plastic Piles
5' Max. Steel Piles

Original Slope Toe

3' Max.

Plan View

Original Ground Surface

2' Min.

Pin/Micropiles

Post Failure Ground Surface

Estimated Slide Plane

Scarp

Pile, Typ.
Steel Micropiles
Tire Bale & Shredded Tire Repair

- Reduces forces driving the slide, tire bales may also increase drainage and strength
- **Deep** or Shallow Slides
- Can be completed w/o design
- No specialized equipment
- Material may be hard to locate quickly, unfamiliar material, small chance of internal combustion with shredded tires
Example of Tire Bales

Photo from Eagle International, www.eagle-equipment.com
Stacked Tire Bales

Photo from www.scrapmonster.com
Polystyrene Block Geofoam (EPS) Repair

- Reduces forces driving the slide
- **Deep** or Shallow Slides
- Can be completed w/o design; however, design recommended
- No specialized equipment
- Material may be hard to locate quickly, unfamiliar material, high material costs
- Blocks can float
Polystyrene Block Geofoam Repairs

Original Ground Surface

10' Min.

Geofoam Blocks

Post Failure Ground Surface

Required Excavation Sloped to Drain

Ground Surface Following Repair

Cross Section at Drain

Slope Crest

Scarp

Geofoam Blocks

Original Slope Toe

Slope Failure Outline

Plan View
EPS Blocks placed as lightweight fill
Rammed Aggregate Piers & Stone Column Repair

- Increases strength and effective stress along slide plane
- Deep or Shallow Slides
- Can be completed w/o design; however, design recommended
- Limited site disturbance and quick installation
- Specialized equipment and personnel
- If slide depth is underestimated, no improvement
Geopier Equipment

Photo courtesy of Geopier®
Summary & Questions

- Many options available for slide repairs
- Professional geotechnical input always valuable
- Without site-specific designs, buttress and aggregate drains are expected to have the highest likelihood of success for lower costs
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Typical Deep Circular Slide
Typical Deep Circular Slide
Rock Buttress
Completed Soil Buttress
Aggregate Drain
Aggregate Drain
Conventional Horizontal Drains
Example of Tire Bales

Photo from Eagle International, www.eagle-equipment.com
EPS Blocks placed as lightweight fill
EPS Blocks placed as lightweight fill
Geogrid Installation
Questions?

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MoDOT Scope of Work

- Literature Review
- Guidebook
- Presentation of Results to MoDOT
- Final Project Report
  - [http://library.modot.mo.gov/RDT/reports/TRyy1104/cmr13005.pdf](http://library.modot.mo.gov/RDT/reports/TRyy1104/cmr13005.pdf)
All Repairs Do One or More of the Following

- Decrease driving forces
- Increase resisting forces
Options that Decrease Driving Forces

- Aggregate Drains
- Horizontal Drains
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)
Aggregate Drain Repair

- Decreases water (weight) & increases effective strength.
- Deep or Shallow slides
- Can be completed w/o design
- Quick to start, no specialized equipment
- If water not a significant factor in failure, minimal improvement
Aggregate Drain Repairs

Original Ground Surface

5' Min.
10' Preferred

Post Failure Ground Surface

10' Min.

Constructed Aggregate Drain

Ground Surface Following Repair

Cross Section at Drain

5' Min.
10' Preferred

Slope Crest

Slope Failure Outline

Slope Toe

Drain, Typ.

20' to 40'

Original Slope Toe

Plan View
Horizontal Drain Repair

• Decreases water (weight) & increases effective strength.

• **Deep** or Shallow slides

• Can be completed w/o design

• Less slope disturbance, less required material, deeper installations possible than aggregate drains

• If water not a significant factor in failure minimal improvement, specialized equipment and material, clogging, possible drain damage
Horizontal Drain Repairs

Cross Section at Drains

- Original Ground Surface
- Drain, Typ.
- Post Failure Ground Surface
- Estimated Slide Plane
- Ground Surface Following Repair

Plan View

- Slope Crest
- Scarp
- Drain, Typ.
- Original Slope Toe

L = Slope Length

Slope Failure Outline

10' to 15'

10' to 15'

15' to 25'

30' to 50'

L/3

L/2
MSE Wall Repair

- Increases strength and possibly weight in lower portion of slide
- **Deep** or **Shallow** Slides
- Site specific design required
- High degree of success, materials generally available
- Design required, significant excavation, excavation in slots required that may lead to additional movement
Who is Shannon & Wilson?

- 12 offices in 8 states
- Employee-owned
- ~280 employees
- Founded in 1954 in Seattle by Bill Shannon & Stan Wilson
Who is Shannon & Wilson?

- Geosciences Consulting Firm
  - Geotechnical
  - Environmental
  - Natural Resources
  - Construction
Research Objective

Soil slides often require immediate action to keep traffic moving safely. This study will focus on developing newer (innovative) approaches to evaluate slope failures and provide cost-effective repair and mitigation techniques. Typically slides are repaired by excavating the slide material and then backfilling with more stable material. However, MoDOT is looking for the researcher to review newer more innovative techniques that have been deployed nationally by other State Departments of Transportation, Geotechnical journals, Geotechnical contractors and any organization that is responsible for the repair of landslides. The goal is to find repairs that provide for long-term stabilization, but that are more cost effective than the typical excavation method. The research is to develop a listing and description of these innovative slope repair techniques. The study shall provide MoDOT with descriptions of when these innovative techniques could be deployed and what are the resources, materials, equipment and personnel needs required to accomplish such repairs.
Literature Review

Goals

• Identify repair techniques meeting research objectives
  – Classic Literature Search
  – Specialty Contractor Interviews

• Group each technique
  – Appropriate
  – May Be Appropriate
  – Not Appropriate
Literature Review
Classic Literature Search

• Performed by Ms. Judy Bloch (S&W Staff Librarian)
• Total of 34 article/study abstracts published/underway since Jan. 2005 identified
• 11 articles reviewed in detail
Literature Review
Specialty Contractor Interviews

• Mr. Matt Caskey of Geopier Foundation Company
• Mr. Jeff Hill of Hayward Baker Construction
Slide Shapes

• Falls and Topples are most common in rock and uncommon in soil.

• Flows and Spreads tend to be very shallow and are often fast moving.

• Generic slides are the most common in soil in Missouri.
Typical Slide

- Original Ground Surface
- Zone of Depletion
- Head/Scarp
- Post Failure Ground Surface
- Zone of Accumulation
- Toe
- Approximate Equal Volumes
Typical Wedge Failure

Original Ground Surface

Post Failure Ground Surface

Active Wedge

Neutral Wedge

Passive Wedge

Slide Plane

Slide depth can sometimes be estimated at this location based on active wedge geometry
Appropriate Methods for MoDOT

- Pin Piles/Micropiles
- Soil Nails
- Aggregate Drains
- Rock/Soil Buttress
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)

- Compaction Grouting
- Rammed Aggregate Piers & Stone Columns
- Soil Mixing
May be Appropriate for MoDOT

- Horizontal Drains
- Drilled Shafts
- Tied-Back Secant Wall or Soldier Pile and Lagging Wall
- Mechanically Stabilized Earth (MSE) Walls
- Lime/Cement Injection
Slide Repair Activities to Avoid

- Loading or stockpiling material along the upper portion of the slope
- Unloading or excavating the lower portion of the slope
- Directing water to the failure area
- Removing vegetation
- Installation of irrigation