Aerial View of the Site

Landslide area
S.R. 237 was originally built in 2003. This particular slope is approximately one-half mile long and was designed to be 2:1 and up to 112 feet high.
Geotechnical Challenges

- High embankment fills
- Slopes designed as steep as 2:1, placed on sloping natural ground
- Variations in rock surface elevations
- Fills consist of soils, shale and sandstone
- Environmental constraints
Slope after original construction.
In May 2010 during heavy rain, the slope moved.

The road edge and guardrail experienced vertical displacement.

Northbound driving lane closed.
First Slope Failure
First Slide

- **Possible causes for the first slide:**
  - Actual slope measured steeper than 2:1 with the height of 112 feet, combined with the type of fill used (co-mingled soil and shale) was unstable.
  - Possible inadequate benching.
  - Water pouring from slope (excessive groundwater).
  - Heavy rainfall in spring.
Boring location plan for the first slide.
First Slide Correction in 2010

- A soil nail wall with a design-build contract requiring a seven year warranty.
- Extend outlet drainage pipe to the toe of the east slope.
- The contractor proposed a new H-pile encased in concrete wall with tiebacks and a shotcrete facing after the bid which was accepted by INDOT.
First Slide Correction in 2010

Contractor’s Design
After First Correction
Second Slope Failure

- In April 2012 during heavy rain, the slope in front of the wall moved. It gradually dropped vertically approximately 12 feet due to new failure.
Second Slope Failure
Second Slope Failure
Second Slope Failure
Second Slide

- **Possible causes for the second slide:**
  - Surface slide triggered by heavy rainfall.
  - Failure of outlet pipe of spring box which was buried underneath the roadway.
  - Insufficient investigation after the first slide. Borings were only 40 feet deep.
Boring location plan for the second slide.
Design for Second Slide

- **Phase-1 Design**
  - Drainage correction: includes spring box repair & horizontal drains

- **Phase-2 Design**
  - Rock backfill (chosen)
  - Three tier soil nail walls
Correction Using Rock Backfill

Roadway

Tie Back Wall

Existing Slope

Rock Backfill

Note: This option may not be used in any area where 50 feet of additional slope toe width can't be acquired.

Excavate at 1:1 slope with benches
Filter Fabric Required

Drainage Pipe

#6 Crushed Stone

Minimum of 50 feet beyond toe of existing slope

Des No: 1005625
County: Perry
SR 237 Slope Failure

Indiana Department of Transportation
Correction Using Three Tier Wall
Problems With Rock Backfill

- Slide aggravated further after letting in March 2013 due to heavy rains.
- Massive amount of water seeped out of the slope.
- The rock backfill was not viable option anymore because it would require the 1:1 temporary slope.
- Potential destabilization of existing soldier pile wall.
Another Surprise:

- During exploratory excavation for the spring box repair, coal mine shafts were uncovered.
Mine Shaft Discovery
More Investigation

- Resistivity study done to search for mines.
More Investigation

- Resistivity study done to search for mines.
- More borings to verify the locations of suspected mines under the roadway as per geophysical study (resistivity testing).
- Borings reveal several collapsed mine shafts under roadway.
Revised Solution

- **Phase-1 Design**
  - Drainage correction
    - Mine shaft interceptor drain
    - Grout the mine shafts

- **Phase-2 Design**
  - Drilled pier (3 ft. dia.) with tieback socket into rock
Interceptor Drains
Drilled Shafts and Drain Layout
Drainage Correction
Grouting to Fill Mine Shafts
Constructability Concerns

- The new drilled pier wall was originally proposed to be 15 feet from the existing wall.
- The construction of new drilled pier wall affecting the integrity of existing soldier pile wall.
Additional Changes to the Design

- Move the proposed drilled pier wall 40 ft away from existing soldier pile wall (25 ft further) to provide safe excavation for inside lagging and backfill.

- Change temporary casing to a permanent casing for drilled piers due to possible co-mingled fill material.

- Provide casing for tieback un-bonded length to avoid major loss of grout due to unclassified fill material.
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Questions?