WV Route 2
Follansbee to Weirton Road

Evaluation of Rockfall Protection Measures and Design of Landslide Correction Measures

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Existing Conditions

- WV 2 located on a narrow bench between steep hillside and railroad bench
- Existing hillside ranged from 250’ to 400’ above grade
Existing Conditions

- Near vertical exposures of jointed shale with heights of 80 to 100 feet
- Rockfalls caused frequent closure of WV 2
Existing Conditions

- Massive 90’ to 100’ vertical sandstone outcrops
  130’ to 160’ above WV 2
Existing Conditions

- Two existing soldier pile walls installed north of the Market Street Bridge in the 1970s and 1980s installed to repair slides between WV 2 and railroad
- Existing walls were anchored and cantilevered with a total length of 3,650 feet
- Existing soldier pile lengths up to 120 feet
- Landslides occurred between the walls and impacted WV 2
Project Objectives

1. Upgrade the existing 2-lane road to a median divided 4-lane facility
2. Mitigate existing rockfall hazards
3. Correct landslides occurring between WV 2 and the railroad
Project Soils

- Residual soils at the top of the hillside
- Interlaced colluvium and alluvium from WV 2 to the Ohio River
  - Relatively Weak
  - Slide Prone
  - Existing Slopes ~1.5:1 between WV 2 and railroad
**Project Geology**

- Pennsylvanian Age – Conemaugh & lowermost portion of the Monongahela Series
- Generalized Geologic Column:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth</th>
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<tbody>
<tr>
<td>Morgantown-Grafton Sandstone</td>
<td>90’-100’</td>
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<tr>
<td>Pittsburgh Redbeds – Interbedded soft claystone &amp; shale</td>
<td>60’-80’</td>
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<tr>
<td>Saltsburg Formation – Jointed Shale</td>
<td>80’-100’</td>
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Existing WV 2 Grade
Rockfall Analyses of Existing Slope

- Colorado Rockfall Simulation Program (CRSP) used to model rockfall
- All modeled boulder sizes reached existing WV 2 travel lanes (3’ 6, 9’ diameter)
- Rockfall simulations indicated full-height cut required to adequately reduce hazard
Design Alternates

1. Full hillside cut to accommodate 4-lanes
   - 8 million cy excavation ($$)
   - Preferred due to lowest cost

2. Existing 2-lanes + 2-lanes on widened railroad bench
   - Required ~ 2 miles of walls ($$$$$)
   - Shift ~ 2 miles of railroad alignment
   - Slope stability issues
   - Required hillside cut to mitigate rockfall

3. Full hillside cut with wall on hillside to eliminate ROW impact on cemetery
   - Required wall height of 60’ ($$$$$)
Construction Issues

- WV 2 is a trucking route – Desirable to maintain traffic during construction
- Detour length ~ 10 miles
- Significant risk of rockfall during excavation
- Narrow WV 2 bench provided little space for installing protective measures
- Rockfall Analyses – Boulders bounce off WV 2 and over utility lines
  - Extremely high impact energy ~ 100 to 8,000 kip-ft
Maintain Traffic = Rockfall Protection

- Evaluated Protection Options
  - Earth Berms (No room)
  - Temporary MSE Walls (No room)
  - Crushed Cars – (No room)
  - Temporary Catchment Area – (No room – Instability)
  - Catchment Fences – (~$6M – High damage rate)
    - Two fences – mid-slope & on WV 2
  - Rockfall Shed – (~$9M for 1,000’ – Impractical)
CRSP Analyses

- Rockfall analysis with fence at road grade
  - Entire roadway width required to prevent rocks from bypassing the fence
Conclusion

- Impractical, if not impossible to adequately reduce rockfall risk to perform excavation under traffic
- Road closed for construction
- Traffic detoured
- Incentive / Disincentive in contract documents
  - $24k per day
  - Maximum $1.5M incentive
Rockfalls During Construction
Landslide Investigation

- Area (1,300’) between existing soldier pile walls exhibiting significant movement
- Based on previous investigations a wall was anticipated
- Borings obtained to develop detailed subsurface profile and cross sections:
  - Along preliminary wall alignment
  - Below on railroad bench
  - Along hillside
Landslide Evaluations

- Soil – Colluvium: $\phi = 20^\circ$ & $c = 160$ psf
- Existing slope $\sim 1.5:1$
- Slope stability analyses indicated existing minimum FS $\sim 1.0$
  - Relatively shallow – Surfaces ended in RR ditch line
- Deep-seated failure surfaces – FS = 1.3 to 1.6
Stability Analysis – Existing Slope

WV Route 2 – Station 277+45 Existing Slopes
Ten Most Critical. I:277R3.PLT By: Robert Dodson 5/03/99 1:51pm

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<th>Unit Wt. Intercept (psf)</th>
<th>Total Saturated Cohesion Friction Angle (deg)</th>
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Factors Of Safety Calculated By The Modified Bishop Method
Regrading Evaluations

- WV 2 improved horizontal / vertical alignment provided sufficient space for regrading to at least 2:1
- Analyzed the use of slope regrading to improve stability
- Regrading to 2:1 slope – FS~1.3
Stability Analysis – 2:1 Regrading

WV Route 2 – Station 277+45 Using Proposed 2:1 Slopes

Ten Most Critical. I:277T1.PLT By: Robert Dodson 5/03/99 2:16pm

PCSTABLS5M FSmin=1.34 X-Axis (ft)
Factors Of Safety Calculated By The Modified Bishop Method
Conclusion

- Extending existing walls not required
- Regrade slope between WV 2 and railroad to 2:1 and flatter where possible.

Result

- Completed in 2002
  - Several significant precipitation events since completion (i.e. Hurricane Ivan – 9 inches of rain)
- No Signs of Instability
Landslide During Construction

- Landslide (L=600’) occurred during 2\textsuperscript{nd} contract south of Market Street Bridge prior to regrading
Landslide During Construction

- Failure of gravity retaining walls along the railroad within the slide
Evaluations and Conclusions

- Toe of slide appeared to be located in the railroad ditch line, but could not be verified without instrumentation.
- Insufficient time to install inclinometers and obtain readings.
- Decision made to install a soldier pile wall to support WV 2.
- Design: Cantilevered soldier pile wall with an exposed ranging from 6 to 12 feet.
  - Alternate Pile Sections:
    - HP12x63 – Grade 36; W12x53 – Grade 36, and HP 10x57 – Grade 50
  - Alternate Lagging:
    - Precast concrete or Steel Plate
  - Slope regrading (2:1) and removal of existing failed concrete walls.
Typical Wall Section
Completed Wall
Completed Project