S.R. 11/15 Rock Slope Safety Improvement Project

Marysville, Pennsylvania
Project Team

Owner:

[Logo: Pennsylvania Department of Transportation]

District 8-0

Municipalities

[Logo: East Pennsboro Township, Cumberland County PA]

[Logo: Maysville PA Sesquicentennial]

Engineer

[Logo: American Engineers Group]

Contractor

[Logo: J.D. Eckman Inc. Construction Bridge Highway EST. 1945]

McCormick Taylor, Inc.

AWK Consulting Engineering, Inc.

ASC Group, Inc.
Outline

1. Location and Description
2. Geologic Setting
3. Purpose and Need
4. Alternatives Analysis
5. Detour
6. Slope Access
7. Rock Slope Stabilization & Rockfall Protection Methods
Project Location

Harrisburg
Original Construction: 1938
Pre-Construction (2016)
Original Construction: 1938

Mountain sliced away to provide safer road between Wormleysburg and Marysville

This unusual photograph taken by a staff photographer of THE PATRIOT shows how the new West Shore road is being improved through the end of a mountain. The Rockville Bridge over the Susquehanna can be seen at the extreme right, with the Blue Ridge Mountain in background.
Pre-Construction (2016)
Typical Cross Sections

- Narrow Roadway
- Steep Rock Face
Rock slope heights of 200’ +

Minimal ‘catchment’ area

6’
Steep slope down to RR tracks below

Dense Vegetation

Right of Way Constraints

Steep slope down to RR tracks below
Geologic Setting

- Ridge and Valley Physiographic Province
- West-Southwest to East-Northeast fold axes
- Sandstone, Siltstone, Shale, and Conglomerate
- Bedrock strikes perpendicular to roadway
- Bedrock generally dips steeply to the Southeast, on the South limb of the Cove Syncline
Stereonet Analysis

Conclusions

- Probability of rock failures along the primary joint set plane, and along the wedges formed by the intersection of the bedding planes and the joint set, for primary east-facing slopes

- Probability of toppling failures to occur locally

Basically, a confirmation of what we already knew...
Rockfall Hazard
Project Purpose and Need

**PROBLEM**

- Rockfall poses a safety hazard to motorists
- Constant maintenance to clear rockfall debris

**GOAL**

- Control or contain falling rocks to reduce safety hazard
- Determine the most practical design while considering cost and impacts to the public
Alternatives Analysis

Determination of Treatment Limits

Define existing rock cut limits
  • Field mapping
  • Topographic maps/surveys
  • LiDAR (DCNR - PAMAP)
  • Aerial Photography

Limited access to slopes with live traffic below, and locally dense vegetation
Alternatives Analysis

Four rock slopes identified that needed treatment
Alternatives Analysis

WHAT ARE THE SITE CONSTRAINTS?

The existing site conditions played a significant role in evaluating what means and methods were practical.

1. Access to slopes
2. Proximity of slopes to roadway (narrow shoulders)
3. Height of slopes
4. Limited right-of-way
5. Proximity to active Norfolk Southern Railroad
6. Overhead utilities
7. Narrow work zone
8. Heavily travelled route
Alternatives Analysis

WHAT WERE THE OPTIONS?

1. Do Nothing
2. Widen the cuts on one or both sides
3. Widen the roadway on the downslope side
4. Vegetation removal and rock scaling
5. Wire Mesh systems
6. Rockfall fences
7. Other slope stabilization methods
   (i.e. rock bolting, rock overhang support)

This type of work is only performed by a handful of qualified contracting teams from across the nation.
Several options including temporary stoppages, as well as alternating light-controlled traffic, were investigated.

However, a road closure was essential for protection of the workers and the public during completion of the hazardous work.
Road closure meant high impact for nearby communities and the region.

Economic and emergency management considerations were evaluated and discussed in great detail with elected officials, business leaders, school officials, and emergency response providers.

Traffic management and public outreach were critical to the project’s success.

- Media briefings
- 511PA
- Social media
- Truck alert radios
- Variable message boards
Numerous early action safety improvements were made to the local and regional roadway system to accommodate the primary 27-mile detour, 4 incident management routes, and a local EMS access route.

- Various road repairs
- New signs and guide rail
- Speed display signs
- Added pavement markings
- Increased police presence
- Contraflow gates on 22/322
Other than the primary danger of falling rocks and debris, another reason for the detour was simply that the equipment required took up almost the entire width of the roadway when in operation.

Work zone width = 42 ft.
Slope Access

A 200-ton crane was needed not only to reach 200 feet up, but also to extend a significant distance horizontally away from the roadway to reach top of slope.

The roadway was covered with a 24” gravel mat for protection from the weight of the crane and from falling rocks and debris.
Rockfall Protection Measures

- Rock Scaling (vegetation clearing)
- Rock Overhang Support
- Anchored Wire Mesh (Active system)
- Draped Wire Mesh (Passive system)
- Rockfall Fence

For many of these activities, a temporary shielding system was required.
- Significant slope heights
- Narrow work zone
- Proximity to active railroad
- Protection of workers

Hi-Tech Rockfall Construction Inc. performed the majority of work on the slopes, including rock scaling, anchor drilling, and mesh installation. Kane GeoTech, Inc. provided design and oversight for the wire mesh systems, and provided engineering support during work on the slopes.
Temporary Shielding

Designed to contain falling rock and debris, especially during rock scaling.

Analysis required to verify that crane and shield had capacity to withstand energy from falling rock.
Rock Scaling

- The purpose of rock scaling is to remove loose or unstable rock to create a uniform surface, typically prior to the placement of wire mesh.

- The removal of vegetation is usually required prior to performing effective rock scaling.
Rock Overhang Support

Used in areas where rock scaling is not appropriate, but support is required.
Rock Overhang Support

Before

After
Two types of proprietary wire mesh systems were specified for use on this project based on strength and durability.

Spider®: Used to ‘lock in’ larger rock blocks that remain on slope
Tecco®: Used as a drape to funnel smaller rocks down slope
Wire Mesh

The Tecco® mesh was used as a draped mesh, which is anchored at the top of the slope.

The draped mesh was used as the treatment option on the highest slopes and covered a large, pre-determined area.
Wire Mesh

• Prior to the placement of the draped Tecco® mesh, the slope conditions were evaluated.

• If ‘suspect’ areas were identified, the Spider® mesh system was implemented.

• The Contractor and AEG agreed on locations where the Spider® mesh was appropriate.
The Spider® mesh is secured to the slope face by a pattern of rock anchor bolts. A program called Ruvolum was used to determine anchor bolt spacing with separate calculations to determine the anchor embedment depths.
Spider® Mesh

Determination of Spider® mesh locations after rock scaling.

Cut 3

Limits agreed upon in the field at each rock cut
Mark out limits on slope face

Mark each rock anchor location
Drilling for Spider® Mesh
Spider® Mesh

Installed
Following the drilling and installation of the Spider® mesh, it was time to install the draped Tecco® mesh.
The Contractor decided that using a helicopter for installation was more efficient than the crane based on:

- Quantity of mesh rolls that needed to be placed
- The heights that needed to be reached

A helicopter landing zone was designated within the project area.

The mesh was first prepped on the ground and staged in long sections.

On the day of installation, the helicopter hoisted the unfurled rolls and delivered them to the crews that awaited on the slope.
Tecco® Mesh

Mesh Staging Area

Helicopter Landing Zone
Tecco® Mesh

Installation
Tecco® Mesh

Installation
Mesh Anchors

The mesh systems utilized two types of anchors.

- **Wire Rope Anchors** allow a support cable to be secured through a thimble
- **Anchor Bolts** are fastened with a Spike Plate to allow the mesh to be held against the slope face

![Diagram of Mesh Anchors]

1-⅜” Epoxy Coated Thread Bar

¾” Wire Rope
Mesh Anchors

Wire Rope Anchor with Support Rope

Rock Anchor Bolt with Spike Plate
Mesh Anchors

Rock Anchor Bolts

- **Tecco mesh**
  - 132 rock anchor bolts ➔ 2,230 LF

- **Spider mesh**
  - 391 rock anchor bolts ➔ 3,774 LF

Wire Rope Anchors

- **Tecco mesh**
  - 21 wire rope anchors ➔ 210 LF

- **Spider mesh**
  - 56 wire rope anchors ➔ 336 LF

Roughly 1.25 miles of drilling into rock face!
Mesh Anchor Testing

The specifications indicated that a certain number of each type of anchor must be tested to ensure that the bond strength was being attained so that the systems could support the anticipated loads.
Mesh Anchor Testing

### CUT 3 SS-B ANCHOR TEST SCHEDULE

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<th>ANCHOR ID</th>
<th>TEST TYPE</th>
<th>MAXIMUM TEST LOAD (KIPS)</th>
<th>CREEP (INCHES)</th>
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*NOTE: SACRIFICAL ANCHOR ONLY USED FOR GROUT SOCK TESTING.*

Courtesy of KANE GeoTech, Inc.
Installed Mesh Locations

Cut 1
Spider: 25,466 ft$^2$
Tecco: 188,940 ft$^2$

Cut 3
Spider: 12,272 ft$^2$
Tecco: 28,860 ft$^2$

Courtesy of KANE GeoTech, Inc.
Rockfall Fence

• Rockfall fence design was based on models developed using the Colorado Rockfall Simulation Program (CRSP)

• Fence design had to follow three primary design criteria:
  1. Height (Elevation)
  2. Energy Rating
  3. Deflection

The first two criteria were based on the typical rock sizes found at each cut location
Rockfall Fence

Rock Size Determination

Overall: 10'H x 5.5'W x 30''D
Note: Four primary beds within, 1.5', 1', 1', and 2'. Depth based on exposure near base.

Overall: 8'H x 18'W x 2'-3'D?
 a. 2.5'H x 18'W x 2'D?
 b. 3.5'H x 4'W x 2'D?
 c. 1'H x 8''W x 1'D?
Note: Depth uncertainty
Rockfall Fence

The rock size information collected was used in the CRSP models to determine the anticipated rock bounce heights and kinetic energies at each fence location.

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**Analysis Point 1**

Analysis Point 1: $X = 24, Y = 381$

Spherical Rock: 2.25-in dia., 975-lb

Total Rocks Passing Analysis Point: 5000

<table>
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<tr>
<th>Cumulative Probability</th>
<th>Velocity (ft/sec)</th>
<th>Energy (ft-lb)</th>
<th>Bounce Height (ft)</th>
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Note: Velocity and kinetic energy are analyzed assuming a normal distribution. Bounce height is analyzed assuming a log distribution.

**Analysis Point 2**

Analysis Point 1: $X = 24, Y = 381$

Spherical Rock: 4.1-in dia., 5900-lb

Total Rocks Passing Analysis Point: 5000

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Note: Velocity and kinetic energy are analyzed assuming a normal distribution. Bounce height is analyzed assuming a log distribution.
Rockfall Fence

- Rockfall fence design was based on models developed using the Colorado Rockfall Simulation Program (CRSP)

- Fence design had to follow three primary design criteria:
  1. Height (Elevation)
  2. Energy Rating
  3. Deflection

The deflection criteria was based on the available shoulder width at each fence location. Recall that there is not much space available at the edge of the roadway.

The fence was designed so that it would not deflect into the travel lanes.
Rockfall Fence

The fence heights and energy ratings were optimized along the length of each fence section.
The Contractor’s fence designer provided the required fence post spacing, cabling and anchorage requirements, and mesh panel specifications.

Fence designs provided by:
- Schnabel Engineering
- Maccaferri USA
Rockfall Fence

Construction

Drilled Caisson
diameter = 18” to 30”

Rock Socket
length = 5’ to 15’

Post length = 27’ to 47’
Rockfall Fence Construction

1,400 Lineal Feet of Fence Checking Sag

Energy Dissipaters
A 90-day road closure was allowed. The Contractor successfully reopened the roadway in 55 days.
Final Product
Thank You

Questions?