Case Study: West Virginia US Highway 19 “The Narrows”
Rockfall Mitigation

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• U.S. Highway 19 connects Weston, West Virginia primarily as commuter route to neighboring counties
• Site parallels the New Fork River
  – Also known as “The Narrows”
• Along a cut-slope
  – approximately 900-ft long
  – On-going rockfall problem
“The Narrows”
Participants

• Project was bid as a conceptual design with design-build aspects
  – Owner, West Virginia DOT

• Joint Venture
  – Ameritech Slope Constructors, Asheville, North Carolina
    • Contractor
  – Geobrugg North America, LLC, Algodones, New Mexico
    • Rockfall mitigation system manufacturer
  – KANE GeoTech, Inc., Stockton, California
    • Design engineer

• General Contractor-Orders Construction
1. Conceptual plans developed by WVDOT
2. Preliminary investigation prior to slope clearing
   • Review and assess the original conceptual plans
3. Initial analyses and 90% design
4. Preliminary construction drawings
5. Slope was cleared of all vegetation
6. Construction began
7. Second phase of investigation
   • Optimize design and refine approach
8. Engineer was present during the entire construction process
   • Ensured conformance to plans
   • Made any necessary changes as construction progressed
   • Provided technical support to the contractor as necessary
• Located within the Appalachian Mountain range
• Continental climate
  – Hot, humid summers
  – Cool to cold winters
• About 45-50 inches of precipitation annually
• Mostly of flat lying Pennsylvanian Age strata
  – Inter-bedded sandstone
  – Shale
  – Coal
  – Differential weathering of the shale and coal layers beneath massive sandstone beds
  – Cantilevered sandstone beds
    • Relatively resistant sandstone beds become vertical cliffs
    • Relatively weak shale beds form recessed slopes
    • Create rockfall hazard
Site Conditions

- **Cut slope**
  - Approximately 900-ft long
  - Vertical slope heights varying from approximately 20-ft to 65-ft
- **Upper slope was composed of a 20-ft thick massive sandstone bed**
- **Directly underneath the sandstone was a 35-foot thick layer of black to brown shale with coal seams and lenses**
- **Just beneath the shale layer was a 5-ft section of massive sandstone**
- **Massive rockfall**
  - Large joint spacing in the sandstone
  - Combined with rapid weathering of the underlying shale and coal layers
Large, cantilevered, sandstone blocks
• Project divided into three sections
  – Nature of the hazard
  – Relative risk of rockfall
• Sections 1 and 3 had Geobrugg Rolled Cable Net (RCN) with a secondary chain link mesh backing
• Section 2 was to have 76 pattern rock bolts
  – Secure large, massive sandstone blocks at the highest portion of the cut
  – Draped over the entire cut slope with RCN and conventional chain link mesh
• Conducted prior to construction
• Verify original WVDOT conceptual mitigation plan
• Collect data
  – Analyses
  – Design
  – Prepare working drawings
• Evaluate existing global slope stability
• Further evaluate potential rockfall hazard
Data collection

- Slope was densely covered with vegetation
  - Difficult to get a good picture of conditions
  - Data collection was difficult and time-consuming
- Standard field data collection procedures were used
  - Slope height and angle
  - Geology
  - Potential rockfall sizes and shapes
  - Surface conditions
  - Rockfall run-out data
  - Soil properties
  - Photographs and notes
- Large outcrops in Section 2 were measured for size
Slope clearing and beginning construction

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• Slopes were analyzed for kinematic global slope stability
• Decision to consider anchored tensioned mesh system in Section 2
  – Replaced rock dowels and drapery system
• Because of the unknown depth of the large jointed sandstone blocks WVDOT specified that the SPIDER anchors be drilled 25-ft into the sandstone
  – Anchored the tensioned mesh
  – Anchors served as rock dowels
RUVOLOM® ROCK software

- Used to design tensioned wire mesh, rock block stabilization systems
  - Geobrugg SPIDER S4-230 mesh
- Utilizes limiting equilibrium analyses
  - Determine force vectors necessary to restrain a large block onto a slope face
  - Program output
    - Pattern of anchors around the block
    - Necessary tensioning forces to achieve a specified factor of safety.
- Drapery and SPIDER anchor depths
  - Determined and checked using the Post-tensioning Institute (PTI) guidelines

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• Conducted after brush cleared and construction begun
• Refine drapery layout and anchor locations
• Landslide hazard revealed
  – Loose soil and colluvium and additional loose material removed
• Phase 2
  – Provided much additional insight into the project design
- Final mitigation plans for each section were completed
- Final layout and anchor plan was developed
• Detailed calculations and plans from Phase 2
• Finalized change from a rock bolt and draped slope at the top of the middle section to a tensioned SPIDER system
  – Design was more effective for the purpose of full retention of the outcrops in Section 2
1. Initial rockfall project designs should be open to changes

- Once slopes are cleared of vegetation, rockfall conditions can be quite different than initially thought
- Initial designs should be general enough to allow for modification
  - But specific enough to allow a realistic bid process
2. Consider design-build

- Sometimes in-house personnel lack rockfall analyses and design experience
- Owners should consider design-build concepts by joint ventures between contractors, manufacturers, and engineers
- Specialty professionals have a great deal of experience and expertise that they can bring to bear on projects
3. Require engineered designs

• Many projects in the past were designed and built using on-the-fly solutions
• Methodologies for investigation have evolved as the discipline has developed over the years
• Many tools, based on sound engineering and scientific principles are available to provide well-engineered designs
4. Retain the original design engineer for construction oversight and require that the contractor use the manufacturer’s representative

– Rockfall mitigation systems are not that commonplace
– Inexperienced inspectors generally are not able to identify problems or irregularities during construction, or ensure conformance to the original design concepts
– Retention of the design engineer for at least periodic inspections is essential to prevent large problems at the end of the project
– Reputable manufacturers supply a certain amount of technical assistance with the sale of the products
THE END

Thanks for your attention!