I-40 ROCKSLIDE 2009

A 44-YEAR TRADITION CONTINUES…
I-40, Haywood County

- Fully closed 4 lanes at MM 2.5

- Average Daily Traffic
  22,000 Vehicles per day of which
  ~10,000 are Commercial Carriers

- Estimated Value to the World Economy
  $1,000,000 per day
Mountain History

• Formed at least 700 million years ago
• Between 400 – 500 feet tall
• Several Geologic Groups present ranging from Basement Complex (Oldest) to much younger sandstones and shady dolomite
• Highly indurated quartzite
• The Pigeon River Gorge is approximately 15 miles long
Why did the Slide Happen?

• Large amounts of rainfall
• Wedge forming planes with toe removed during original construction

• Occurred around 2 am on Oct. 25, 2009 and fully closed the highway
• Two accidents, one injury, no fatalities
Decision Process

Oh my!

What Do We Do?

What Happened?

Have the Rocks Stopped Falling?

What Should We Do?

Who Can We Call?

I’m hungry

What Day is It?

How are we going to pay for this?
Identify the Problem

• Survey the slope
• Determine the Scope/Limits of the Problem
• Determine what repair options exist and ultimately what is needed
• Who/What capabilities do the Contractors have
• Access? Safety? Success?
Aerial Photo with Topography
3D Model of the Slide
Field Data Collection
Stereonet Plot of the Failure Planes
Wedge Analysis Based Field Data
Scope of Problem

- Very Large Wedge to Remove or Stabilize
- Colluvial Mass to Remove or Anchor Down
Drilling Pre-Split Holes to Begin
Excavating the Wedge by Layers
Challenges With the Excavation Plan

• Where to start? Top? Bottom?
• Where to put the material....~350,000 yds
• Forest Service Wants it
• DOT will use it but can’t store it

The problem is it is still on the mountainside!
What to do next?

Excavate the whole wedge
~ 350,000 cubic yards
~42,000 Dump Truck Loads
~1 Football Field, 200 ft Deep

Scale what is unstable and anchor the remainder
What kind of anchor?
How many do we need?

1 3/8” 150 KSI Threaded Bars
592 Tensioned Anchors

~ 16 Million $
~8.9 Million $
Bolting Design Considerations

- Who Can Do the work?
- How will they access the site?
- How fast can they be installed?
- How large of a hole can be drilled?
- How deep can the Contractor drill… with accuracy?

HOW MANY WILL YOU NEED?
What Factor of Safety is Needed?

If we are bolting, what FS is acceptable?

FS = 1.3
The Wedge was analyzed using Roc Pak III and Swedge
Number of Bolts Needed based on the Desired Factor of Safety

Assuming 140 kip anchors

10 ~ 10,838

FS = 1.3 ~ 592

1.1 ~ 100

1.2 ~ 197

2 ~ 3291
Active Anchor Design

- 592 Tensioned Rock Bolts
- Lengths Vary from 70 feet to 125 feet
- Bonded Zone, 10 feet minimum
- Anchors Tensioned to 140 kips
- Anchors Bars – Grade 150, 1 3/8” Diameter, ~ 190 kips Min. Yield, Weight - 5.7 lbs/ft
NOTE: SEE SLIDEINT X-SEE FOR FACE BOLT PLACEMENT

ALL PATTERNS MUST BE INSTALLED AT A BOLTH 54° IN S.A.F.E

OCCUP 30° UP FROM LEVEL

INCLUDES FACE AND WEDGE

DRILL DEPTH = VARIOUS SHOWN

ANCHORS = EXISTING STRAND AS 1/2 X 200

REMARKS = BIT DO NOT USE ANCHORS
Slide Face: LiDAR Scan
Winter Weather

Between December and February, there was ~25” of snow
Which is ~15” more than the average
Anchor Installation

After your anchor locations are drilled and inspected for orientation, inclination and depth, it is time to install your anchor bars.

HOW?
Carry them up the slope?
Fly them in?
Strand Anchor Option

The contractor proposed using strand anchors for anchors that were longer than 60 feet.

The option was reviewed and ultimately accepted.
Strand Anchor Requirements

Capable of obtaining the same capacity as the bar anchors

Highly machined bearing face at the anchor head location
Anchor Testing

All tensioned anchors were incrementally loaded and tested for capacity, elongation, short term creep and long term creep, if required.

Was a hybrid provision between “proof testing” and “performance testing” common in PTI guidelines.
Problems with the Strand Anchors

These anchors were selected for the deeper anchor locations
The head alignment is very precise, better suited toward structures
The jacks weigh in at ~300 + pounds
Some anchor locations had depths where the elongation would exceed the capacity of the jacks….what now?
Two Basic Types of Anchors

Active Anchors
Load is applied to the sliding plane to increase the friction between the masses
Have both bonded and unbonded zones

Passive Anchors
The anchors are not preloaded and engage with very limited movement
The entire bar is bonded
Why Change?

Challenges with initial drilling
Very time consuming
Weather issues
Load testing issues
More water in the slope than was included in the initial design ~50% vs. 25%
Geologic characteristics make Passive design acceptable to NCDOT
Switch from Engineering to Geology to accept a passive anchor design:
Passive Design

Reanalyzed the sliding mass with respect to waviness and roughness along the failure surface as well as the persistence of the failure plane

Contractors ability to effectively drill a 4.5 inch diameter hole

The ability to install a larger diameter bar
Passive Design

544 bolts of which 130 were tensioned and installed above the passive system

1 ¾”, 150 KSI Threaded Bars with a minimum yield of 320 kips, 9.0 lbs/ft

Increased the bond depths below the wedge plane to 20 feet
Requirement of the Passive System

BOND STRENGTH

Assumed 150 psi in design

Performed 4 pullout tests, each with a 2 ft bond zone, and determined there was greater than 400 psi present
Future Monitoring of the Slide

Four Roctest Bor-ex Extensiometers
Two Vibrating Wire Piezometers
Two bar anchors instrumented with 5 vibrating wire strain gauges
Two Tuff Tilt 801 tiltmeters (+/- 3 degrees) for the face
All wired to a datalogger with cell phone access
Tuff Tilt Meter
Bolted Wedge Face
Meshed and Anchored Colluvium
Additional Work in the Gorge

5 additional sites were scaled and received anchors (active) and mesh as needed
Questions?

Involved parties:
Phillips and Jordan Construction, General Contractor
Janod, Ltd, Drilling and anchor installation
NCDOT Geotechnical Engineering
NCDOT Division 14 Construction staff
Fisher and Strickler Rock Engineers, Design Peer Review
Additional Information

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