INTERSTATE HIGHWAY I-40 SLOPE REPAIRS IN WESTERN NORTH CAROLINA
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ABSTRACT
In September 2004, heavy rains from the remnants of hurricanes Ivan and Frances caused severe flooding in western North Carolina including damage to Interstate Highway I-40. The water level in the Pigeon River that follows the interstate highway rose approximately 20 feet and washed away the embankment slopes below the highway at 5 locations with a portion of the eastbound lane falling into the river. The North Carolina Department of Transportation working under a very tight schedule developed a set of contract documents and selected contractors through a 2 step selection process to implement repairs to 2 of the damaged slopes or slides. The contractor mobilized on November 1, 2004, and all 4 lanes were reopened in February 2005 to traffic. The repair work involved the building of a tieback-anchored wall at the top of the slope and reinforced rock embankment at the toe at both locations. A third slide location was added later to the contract but it only required the rock embankment at the toe. The wall design proposed by the geotechnical contractor used steel circular pipe piles as the solid beams, ground anchors through concrete walers and a shotcrete facing. The rock embankment used steel ring nets as the reinforcement layer between the rip rap and on the face of the rip rap. The contractors worked through the winter, the work was completed in November 2005.

1. INTRODUCTION
Interstate highway I-40 is a major artery through the Smokey Mountains in Western North Carolina and Eastern Tennessee for the movement of goods and people. Without it, the route through the mountains is along 2 lane roads and the trip takes much more time. When I-40 was closed several years ago by a landslide near the North Carolina/Tennessee state line, the need to keep it open became obvious because of the impact on commerce.

The highway follows the Pigeon River and passes through a tunnel at milepost 4 before crossing into Tennessee. At the tunnel, the river goes around the mountain and rejoins the highway.

2. PROBLEM
The 2004 Hurricane Season was an unusual year for weather in the Eastern United States. Tropical storms Ivan, Francis and Jeanne crossed over Western North Carolina in September and caused widespread damage.

The rainfall amounts varied from 10 to 25 inches and caused flooding, mudslides and slope failures.
The rain inundated the region and, in turn, saturated the soil and filled all the small streams. The saturated soil conditions lead to slope failures and mudslides throughout the region. The streams eventually overflowed and flooded property and homes. The streams eventually drained into the Pigeon River causing the water level to rise from a level of 3 feet to 18 feet. All this water came down the river in a large torrent at a rate of 17,100 cubic feet per second and caused scour and erosion damage at 5 locations along the I-40. The worst damage was at the 90 degree bend in the river at the West tunnel portal.

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4. SOLUTION

After the water subsided and the extent of the damaged was determined, the next step was to develop a solution. The North Carolina Department of Transportation closed the eastbound lanes of I-40 in the slide areas and this reduced the highway to a 2 lane road.

Figure 2 – View Looking Upstream

3. RESULTS

At the 90 degree bend, a portion of the east bound lane fell into the river at 2 locations and referred to as slide 1 and slide 2.

The river caused severe erosion and scour of the embankments at the other 3 locations did not damage I-40 and they required some type of mitigation against any future problems. The North Carolina Department of Transportation closed the eastbound lanes of I-40 in the slide areas and this reduced the highway to a 2 lane road.

4. SOLUTION

After the water subsided and the extent of the damaged was determined, the next step was to develop a solution. The North Carolina Department of Transportation decided to have their Highway Design Branch develop a solution using the following criteria:

1. Safety - Stabilize Slope, Protect Construction Personnel
2. No Maintenance - Design and Build a Permanent Durable System
3. Open I-40 lanes ASAP - Our Main Customers - The Traveling Public
4. Non-Rigid System at Toe - Flexible System That Can Withstand Water and Rocks
5. Prevent Future Toe Scour - Protect the Toe from Future Undermining
6. Environmental Concerns - Minimize Any Impacts to the Pigeon River and Area

The Highway Design Branch was tasked with developing a solution as quickly as possible for slide areas 1 and 2 in order to reopen the closed east bound lanes as soon as possible. They branch immediately went to work and it took them 3 weeks to have a final design completed including contract plans.

The branch used 2 teams to develop a solution. One team looked developing a retention system at the top of the slope and the other team looked at developing a system to protect the toe. The team working on the retention system at the top decided to use a tieback anchored wall system to rebuild the slope. The team working on the toe came up with an innovative design using high strength ring nets to wrap large diameter rocks and pin the nets into the river bed and slope. The final design for the retaining walls and toe scour protection is shown in the following figures.

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The Highway Design Branch considered several alternatives for the toe scour system and the selected final design met the criteria of being non-rigid and able to prevent future problems from erosion and scour. The design is essentially a reinforced rock slope using rings nets in lieu of fabric for reinforcement and large diameter riprap.

5. CONTRACTOR SELECTION

The bidding process was unique for the department of transportation. The first step was to invite 4 geotechnical contractors to submit a proposal/design for the 2 retaining walls. As part of the process, each contractor had to give an oral presentation. After a geotechnical contractor was selected, 4 general contractors were invited to bid on the overall project including the retaining walls using the selected geotechnical contractor.

The geotechnical contractor selection process was also unique because the award was not based solely on low bid. Each contractor was given a quality credit and it was derived from a grading criteria. The credit was used to adjust the bid price and this was used to select the geotechnical contractor. The grading criteria used to determine the quality credit included the following items:

1. Safety Plan 30 points
2. Schedule and Milestones 25 points
3. Long Term Maintenance 20 points
4. Innovation 10 points
5. Environmental Stewardship 10 points
6. Interview 5 points

The final contract was awarded on October 2004 and the contractor mobilized in November 2004.

6. INSTALLATION

With the design complete and a contractor selected, the next step was the installation. The general contractor could not start the toe scour work until the geotechnical contractor had completed first row of soldier beams and tie backs. Slide area 3 was added to the general contractor's scope of work and it did not have a wall but the slope had to be cleared, cut to a 1:1 slope and the toe scour system installed.

Once the work commenced, it went thru the winter and the 2 eastbound lanes of I-40 were opened to traffic on February 25, 2005.

The Geotechnical contractor’s design was an anchored tieback wall with steel circular pipes as the soldier beams and using ground anchors through concrete walers behind the beams. Plus, the design used a shotcrete facing instead of concrete panels in between the concrete walers.
After the first tie backs were installed, the contractor was able to start on the toe scour protection system along the edge of the Pigeon River. The first step was to install the rock bolts along the edge of the river and, after they were in place, the bottom layer of ring nets could be installed. After the bottom rows of ring nets were installed, the layers of large diameter rip rap with ring nets placed to make 4 layers. The final step was to bring a layer on nets over the rip rap and anchor them back to slope.

The toe scour work started after the retaining walls were partially installed and the Department of Transportation considered it safe to work at the base of the slope. The work on the three slides areas was completed in May 2005.

The North Carolina Department of Transportation is confident the toe scour protection systems will protect the slopes along the Pigeon River and prevent the same problems from occurring in the event of high water in the river. Of course, no one hopes to have a repeat the rains and all the related problems.

References