Rockfall Mitigation On I-70

Eliminating the hazard of falling rocks on mountainous highways is impossible, but the risk can be substantially reduced

By Carol Carder

A friend who grew up in Georgetown, Colo., reminisces how her bedroom window faced the steep slope above town and how she liked to listen to the rattle of rocks falling at night from the heights onto U.S. Highway 6 below. Today the 2.2-mile stretch of Interstate 70 between Georgetown and Silver Plume, about an hour west of Denver, has earned the distinction as Colorado's most recognized rockfall hazard area.

"The area is high profile because there's so much traffic," says Ty Ortiz, engineering geologist, Colorado Department of Transportation materials lab. "The annual average daily traffic count of 30,000 vehicles means 21 vehicles pass through the identified rockfall area each minute, so rocks impacting traffic is greater than in lower traffic areas."

CDOT's historical data for Georgetown Hill show falling rocks have caused approximately 100 accidents with 17 injuries and three fatalities in the past 24 years. In April 2004 a rockfall took out the 12-foot-high fence installed in 2000 on the slope above the Georgetown Loop Overlook. Last fall Yenter Companies Inc. of Arvada replaced this fence and also installed a second attenuator fence approximately 300 feet higher up the slope to slow down rocks and to reduce the chance they will bounce over or plow through the bottom fence. This $475,000 project is the first phase to protect the highway. The next phase in fiscal 2005-06 will install other fences higher up the slope.

CDOT's rockfall hazard rating system, first published in 1994, identifies and rates over 750 cut slopes throughout the state using a combination of slope measurements, traffic data and geology. In this system Georgetown Hill is divided into 15 distinct cut slopes. However, the rockfall incidents that severely affect traffic come from far above the cut area.

CDOT prepared a rockfall potential study of Georgetown Hill mapping bedrock outcrops and rockfall chutes. In this area rocks can start from up anywhere on the 40-percent slope up to 1,800 feet above the highway and attain enough velocity to take out almost any fence installed at the bottom, according to Ortiz. The Colorado Rockfall Simulation Program (CRISP) models the speed, energy and bounce height of a rock as it rolls down a slope. With this study, CDOT is able to select specified locations for rockfall mitigation based on solid engineering analysis.

"In areas where you can narrow down the rockfall area to a few hundred feet, you can build a traditional rockfall barrier fence and not worry about rock bouncing over it or plowing through it, but in areas with these long rollouts, rock can gain enough velocity to bounce over or take out a fence," Ortiz explains.

Coiled wire mesh sections rests on the side of I-70 awaiting helicopter hoist to construction side on Georgetown Hill. Georgetown Hill photos by John Gross, CDOT

Crews prepare the metal spreader beam that will be attached to the wire mesh top to keep it from crumpling during transport.

The strategy on Georgetown Hill is to install a series of strategically placed attenuator fences. These fences drape over sections of the rockfall chutes and are installed without bottom support ropes so falling rocks slow down but don't take out the fence. Metal sleeves installed over the wire ropes making up the anchors will prevent shearing of the fence support anchors, which is caused by angular rocks moving with high rotational velocities. When hit by rock, the sleeves will spin rather than permitting the rock to slice the ropes, as happened to the barrier fence in 2004.

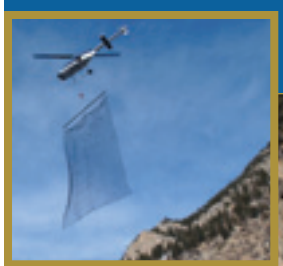
Installation a Tall Order

Yenter Companies faced some tall challenges installing the fences. The company brought in two helicopters, in December a Bell 206 B-3 to hoist the columns, then in February a jet-powered Bell 206 L-4 Long Ranger from Salt Lake City to lift metal netting sections.

"We had to haul everything to set the columns 275 feet to 300 feet up the 40-percent grade, so we built a pulley system to take up the equipment and materials," Mick Muller, P.E., Yenter project manager, explains. To control quality, Yenter crews batched the concrete at the bottom and sent it up in 5-gallon buckets.

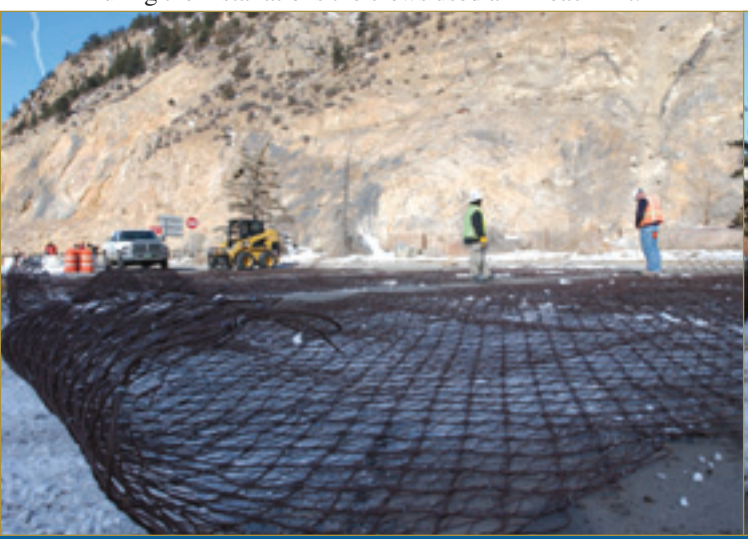
Because CDOT wanted the new fences up before the 2005 spring run-off dislodged rocks, the contract period was 25 working days. However, with the many bad weather days, the work spanned from November to mid-March. During the installations the crews used a temporary rockfall fence on the road shoulder and spotters above to warn the workers on the mountainside of any falling rock.

As the first step, the workers drilled the anchors 6 feet deep for the columns. Then the first helicopter hoisted in the 750-pound, 15-foot-high steel columns, and the crew anchored them into the holes with concrete. The next step was attaching the 1,200-pound sections of metal netting. This extra strong mesh is similar to chain link mesh used underwater by the military to seize submarines. Workers attached the top of the 15-foot-wide by 30-foot long chain link to a spreader beam to prevent it from crumbling during transit. Then workers kept the mesh spread out as the helicopter picked it up. Due to the weight of the chain link sections and the high altitude, the pilot was the only one on board the helicopter. Also, the helicopter carried just 10 gallons of fuel and refueled between each lift.



Above: The pilot carefully maneuvers a jet-powered Bell 206 L-4 Long Ranger over the chain link section where the ground crew attaches it for hoisting. The pilot is the only person on board to keep weight low at this high altitude. Inset: The chopper carefully lifts the heavy mesh before heading across I-70 to the rock fall mitigation area. High winds, common in mountainous areas, can challenge aerial deliveries even for experienced pilots. Below: The chopper pilot deftly lowers the mesh over the steel framework. Once the mesh is securely fastened to the frame, it is disconnected from the helicopter.

At the installation site, the crews on the ground grabbed a tagline to maneuver the mesh into place and attach it to the



The mesh resembles a large chain link fence with sections 15 feet wide by 30 feet long and weighing 1,200 pounds.

A worker reaches for the spreader beam that will be used to hoist the mesh section. Keeping the mesh spread out as it's picked up by helicopter is tricky.

steel framework. Once the net was securely attached, it was disconnected from the helicopter, and workers finished the installation while the pilot headed back for more fuel and another section of mesh.

During the helicopter-assisted installation of the support poles and netting, CDOT notified drivers of the up to 20-minute delays on I-70 with its Intelligent Transportation System Variable Messaging Signs (VMS). The VMS system started on the east side at Rooney Road, which is 35 miles from the project, and 50 miles away on the west side at Vail Pass.

The 12-foot-high bottom fence is 2,400 square feet, and the 15-foot-high fence on the mountainside is 1,100 square feet. The composition of the netting is 5/16-inch-diameter 6-inch diagonal weave cable net with wire mesh connected on the uphill side. One-half-inch wire support ropes are connected to the netting in a diagonal pattern to add additional support and weight. The netting is suspended from the 1-inch wire support ropes and is draped for approximately 15 feet on the ground.

The idea, according to Ortiz, is to have enough netting draped on the ground to slow rock as it hits the system but not so much as to accumulate fallen rock and debris which would add unwanted stress on the attenuator. Upon completion, CDOT tested the attenuators by rolling rocks into them and observing the reaction at impact. The attenuators worked as designed. The 3-foot to 4-foot rocks rolled from a distance between 300 feet and 500 feet impacted the attenuators with approximately 100 foot-tons of energy. As planned, the rockfall barrier at the shoulder easily stopped the rocks that made it over or through the attenuators. Observations from these rock rolling exercises will help CDOT engineers determine the location of the next set of attenuators on Georgetown Hill. A video of the rock rolling tests and a slideshow of the fencing installation is in CDOT's Spring 2005 edition of CoTrip Quarterly at www.cotrip.org. ■

Above: Crews secure the 1,200-pound piece of mesh into a huge chain link fence. This extra-strong mesh is similar to chain link mesh used underwater by the military to seize submarines.

Above: From their precarious perch on the mountainside, ground crew members dangle as they secure the mesh.

Above: Between airlifts of mesh, approximately 15 minutes apart, aviation crew refuels the helicopter with only 10 gallons of jet fuel to keep gross weight down.

Rockfall

In Clear Creek Canyon

Drilling crew working from crane basket prepares high rock face for blasting.

CDOT staff looks up at US-6 rockfall chute in Clear Creek Canyon. All photos by Gregg Gargan, CDOT

"Geologic hazards are inherent along the mountain highways in Colorado. Landslides – debris flows – avalanches – and rockfall," begins the audio for the video Colorado Department of Transportation prepared on the I-70 Georgetown Hill mitigation project. "Some forces of nature are unstoppable and unpredictable," CDOT geologist Ty Ortiz remarked. Mother Nature illustrated the truth of that statement on Tuesday, June 21, at 11 a.m. when 1,500 tons of rock slid off a 150-foot-high outcropping on a corner of US-6 just a mile and a half east of the SH-119 junction. A known trouble spot, the slope was draped with wire mesh net last year, but the rock slid right under it leaving the top anchors intact.

CDOT awarded a $760,000 contract to Ames Construction of Aurora to remove rock and repair the road damage in 25 days. It's ironic that just last September Edward Kraemer Construction fast-tracked replacement of three bridge decks in 12 days on this heavily traveled highway stretch. ("Kraemer Replaces Bridge Decks in Record Time," RMC, Dec. 13, 2004.) US-6 handles 12,000 vehicles a day on the canyon route to SH-119 that connects to popular mountain gaming communities Black Hawk and Central City.

The transportation department moved rapidly to address the emergency. A team of CDOT geologists led by Ortiz converged on-site that afternoon. Tony DeVito, P.E., Region One foothills resident engineer, recounts how CDOT immediately called in four experienced contractors to survey the damage. By 11 p.m., the team led by DeVito and Ortiz had issued generic specifications to the contractors for a bid. Additional information, such as protecting the creek during slope excavation with a berm of fallen rock, followed by noon on Wednesday. By 3 p.m., CDOT had received bids from Ames, Lawrence Construction and Kiewit Western.

"We were able to get a contractor on-site immediately because we have an emergency contracting procedure," DeVito explains. "A couple of years ago, just after the Vail sinkhole incident, Craig Siracusa, our chief engineer, instituted the procedure with the state controller." CDOT used the new emergency procedure for the first time in responding to a damaged bridge pier near Trinidad. Later, the procedure enabled CDOT to respond immediately to the rockfall incident in Glenwood Canyon on Thanksgiving Day 2004.

Gary Self, CDOT contracts and market analysis branch manager, says, "Essentially, the procedure allows us to get a qualified contractor on-site doing the work, then follow up with the required

paperwork and contract." According to the state's operational manual, "An emergency is a situation that creates an immediate threat to public health, welfare or safety…" and "there is insufficient time to obtain a written waiver of the requirements for issuance of a commitment voucher pursuant to this fiscal rule before requiring goods or services to respond to the emergency."

Unlike the bridge construction a year ago, safety mandates will prevent Ames from using creative scheduling and planning to expedite the work. It's illegal to blast at night.

Tom Flick, Ames Construction project manager, expected to move to two 10-hour shifts the week of July 10 "as soon as the canyon is opened up a bit." Ames is handling the blasting with in-house expertise to remove the bedrock judged unstable by CDOT geologists. Subcontractor Hark Drilling of Phoenix is stabilizing the rock face with rock bolting and wire mesh netting.

Complications arose quickly, however, and on July 15, CDOT had to announce, "Despite working 24 hours a day, seven days a week, the completion of the project has been delayed until mid-September to accommodate further mitigation." CDOT's Ortiz explained, "Through our rockfall mitigation efforts over the last several weeks, we have determined that in order to make this slope safe in the long run, the most appropriate course of action is to excavate a large amount of potentially unstable material from the mountain." Thus, Ames is to remove another 35,000 cubic yards of rock, and total cost of the work, including CDOT and Ames activity, is expected to reach $3 million. ■

The blast – cloud of dust with lots of rocks in air.

View of rocks on road. Note that wire stabilizing mesh installed last year still hangs from its top anchors.

Above and below: The mangled gravel hauling trucks that were caught in the slide.