CASE STUDIES IN EMERGENCY RAILWAY GEOHAZARD MITIGATION
Stephen Harrison, Geostabilization International, PO Box 4709, Grand Junction, CO, USA; 970-986-7465; Stephen@gsi.us
Colby Barrett, Geostabilization International, PO Box 4709, Grand Junction, CO, USA; 303-909-6083; Colby@gsi.us

2,121 words

Abstract
Landslides and rockfall events are a perennial drain on budgets and personnel resources for all segments of a railroad’s operation. Traditional methods of landslide stabilization can result in high design and construction costs as well as lengthy track service outages. Traditional rockfall mitigation on most railroad track systems involves placing a trip wire or slide fence near the track to signal dispatch operators of a possible problem. This low-cost approach requires train dispatchers to have the track surveyed to verify train safety will not be compromised before the train can operate through that section at normal speeds, and does nothing to actually fix the underlying problem – unstable rock slopes above the track.

This paper will present five innovative geohazard mitigation case studies dealing with stability concerns in both rock and soil, including:

1. A rock stabilization project that involved using a Geosynthetically Confined Soil wall to infill an unstable cave opening above an active railway;
2. a retaining wall stabilization project in North Dakota where launched soil nails faced with reinforced shotcrete repaired two failing wooden retaining walls, which allowed for construction from the track within normal open windows;
3. an emergency landslide repair project in Pennsylvania where hollow bar soil nails faced with tensioned wire mesh facing kept a track in operation throughout construction; and
4. two rockfall mitigations projects (in Colorado and Illinois) where helicopter-mobile rope-access scaling teams removed multiple large unstable rock outcrops using limited access equipment to mitigate rockfall events affecting the track below

Tennessee
A cave in the rock face adjacent to railroad tracks posed a constant maintenance burden for the railroad. The heavily weathered rock above constantly overfilled rockfall containment ditches and fences. Evaluation of the cave and surrounding rock determined that the condition and location of some rock could lead to a massive failure and track closure. It was also apparent that removing this rock by scaling the slope would likely cause the entire hillside to unravel, which would require the removal of massive amounts of material. A decision was made that it would be better to fill in the cave, thereby supporting the surrounding rock.

The first step was to carefully scale the rock face, removing only rocks that posed an immediate threat to workers involved in the repair. Rock bolts were also installed in select locations to prevent loose rocks from falling on workers. Rock bolts consist of a steel member, bonded to the weak rock and the stronger rock beneath using either epoxy or Portland cement grout.

With the cave temporarily stabilized, workers were then able to begin filling the cave. Stone was moved from the delivery point to the cave pneumatically, through a hose. To eliminate the need for track closures, a 12” pipe was installed beneath the rails allowing shotcrete and gravel hoses to pass through. The stone fill contains closely spaced, full width, fabric inclusions. This fabric is installed between each 8” lift of stone. The stone is then compacted. Standard concrete masonry blocks were used as a facing and formwork to hold the stone during construction. This created what is known as a Geosynthetically Confined Soil (GCS®) wall. The closely spaced inclusions prevent dilation of the soil mass, and require any failures to develop through the stone pieces themselves. A GCS® wall differs
distinctly from an MSE wall in that there is minimal load on the facing elements of a GCS® wall. Rather than relying on high strength concrete facing panels which are tied back in to the backfill, the stability of a GCS® wall comes from the confined soil fill itself.

Once the wall elevation was high enough to prevent workers from entering the space between the top of the wall and the ceiling of the cave, shotcrete was used to fill the remaining space. Shotcrete is a pneumatically placed concrete that is pumped from the delivery point to a nozzle at the end of the hose. At this nozzle, compressed air is added and used to project the shotcrete to its placement location. The GCS® wall and shotcrete now support the rock cave and prevent rockfall hazards from impacting the track below.

Figure 1 - GCS® wall constructed to stabilize an unstable cave opening.
North Dakota
A steep fill supporting a track experienced sloughing and erosion issues. In an attempt to stabilize the track, the railroad installed retaining walls constructed from stone and timber piles. These retaining walls proved to be insufficient to stabilize the fill and began to fail themselves. When wildfires caused further damage to the already failing stabilization system, the problem required immediate attention. Traditional repair methods were evaluated by the railroad and were expected to require months of construction time. Additionally, the section of track to be repaired was busy, and destabilization of the fill slope during construction – leading to track closures – was not acceptable. Seeking a faster repair method, launched soil nails were employed and successfully stabilized the fill.

Launched soil nails consist of a 1.5" diameter, twenty-foot long, hollow, galvanized steel tube that is equipped with a solid tip. Nails are launched into the ground using a compressed air cannon that will accelerate the nail from a standstill to over two hundred miles an hour in less than one-quarter of a second. This cannon is a modified and repurposed military tool, which was formerly developed by the British to launch chemical weapons. With the cannon mounted on a tracked excavator, work could be conducted while sitting between the tracks and working over the side of the embankment (Figure 2). By doing this, the need for large working benches in the embankment was eliminated, allowing the track to stay open.

The biggest advantage of launched soil nails in this project was the installation time. A launched soil nail can be installed every 90 to 120 seconds. With clear track times of around 15 minutes, maximizing efficiency was critical to the completion of this project. Launched soil nails are immediately effective after launching and do not require grout to function, although they may be post-grouted to increase capacity. After nail installation, reinforced shotcrete was applied to the face of the embankment to protect from erosion of the fill.

Due to the speed at which a launched nail enters the ground, they cause very little disturbance to the surrounding soil. Unlike something driven in to a soil mass, a launched nail generates a shock wave at the tip that causes the soil to elastically deform and essentially jump out of the way of the nail. This leads to significantly higher bond strength when compared to a similar object that is driven in to the ground. This deformation also serves to densify the soil surrounding the nails, as it is unable to relax fully due to space now occupied by the nail. Another advantage of this elastic deformation is that launched nails experience no significant abrasion upon entry, leaving the corrosion protection (galvanizing) intact.

Using this technology, the railroad was able to stabilize their embankment with no lost time due to track closure and no concerns about construction activities destabilizing the track.
Illinois
A weathered rock face adjacent to existing railroad tracks posed an imminent hazard to the safe operation of trains on this track. The cut had originally been made through layers of strong sandstone and relatively weak shale. Although differential weathering can occur on any slope, the process was enhanced due to improper control of surface water. Over time, the shale layers eroded away much faster than the overlying sandstone. This lead to heavily undercut layers of sandstone that were likely to break off the slope and fall on the track. Another contributor to the condition of the slope was “root jacking” or the breaking of rock due to the growth of roots contained within. A protective fence and catchment ditches were in place along the railway but was determined to be insufficient size to prevent larger rockfall events from impacting the tracks. In addition, the slope geometry contained “launch” features capable of projecting falling debris away from the rock face and on to the tracks.

After a rockfall event occurred, the railroad operator decided to have the slope evaluated for other areas in imminent danger of failing. Two locations were identified that posed this imminent risk. The best repair for this problem was determined to be a technique known as “scaling” in which specially trained rope access technicians work on the slope and remove rocks deemed to be hazardous. During this operation, trees that pose a risk are also removed.

Scaling operations adjacent to railroad tracks present the challenge of protecting the tracks from damage as rocks are removed from the slope. By using specially designed blasting mats, the scaling was completed without damage to the tracks. Other special equipment used included air bags which are placed in rock crevices and inflated to topple larger rock structures. Scaling was completed quickly and removed imminent rockfall hazards without incident. A second phase of this project may
be executed in which shotcrete is applied to the exposed weak shale layer to prevent future weathering and undercutting of the sandstone.

Figure 3 - Scaled Rock Slopes
Pennsylvania
The operator of a high-speed passenger rail service noticed horizontal and vertical displacements in their track due to instability of the rail bed embankment. The railroad was planning to install concrete caissons at the toe of the slope as a permanent repair. To prevent stability issues during the relatively long construction time for concrete caissons, the railroad looked to other options for a temporary fix and elected to use soil nails due to the very fast installation time.

Self-drilling soil nails with a wire mesh facing were used to stabilize the embankment. Soil nails are distinctly different from tiebacks due to the lack of an unbonded zone on a soil nail. Since the nail is bonded along its entire length, facing loads are dramatically reduced which allows the installation of inexpensive mesh facings rather than heavy structural panels. The mesh facing is required mainly to reduce surface erosion. Self-drilling soil nails consist of threaded hollow steel bar, couplers to join lengths of bar, and a sacrificial drill bit. With a self-drilling soil nail, drilling and grouting operations can be completed simultaneously, known as injection drilling. This process allows for soil nails to be installed in soils that will not hold an open hole and would require casing to prevent the hole from collapsing. An additional advantage of injection drilling is that the grout injected at the drill bit increases the effective hole diameter by mixing grout with the soil surrounding the hole. Increased hole diameter has a dramatic effect on pullout strength due to the increased surface area of the grout column.
Colorado

A failing rock face in adjacent to a section of track posed an immediate threat to safe operation of trains along this track. The specific location of the site along with the surrounding steep terrain made access extremely difficult, even for the initial evaluation. A helicopter was used to observe and characterize the site from the air. This observation confirmed that there was no safe way for workers to access the slope from below.

A remediation plan was developed that first required rockfall technicians to be brought to the top of the slope using a helicopter. The workers then removed loose rock and other hazards above the work site, progressing downward and creating a lane that they would use for access. Once this lane was clear, daily entry and exit of the site was possible without the use of a helicopter. The track was flooded with ballast to prevent damage from falling rock. As the technicians identified and removed loose rock during scaling operations, it was removed from the bottom of the slope by railroad personnel. All rocks posing an imminent threat to the railroad were removed, and once the extra, protective ballast was removed the track was again ready for service.
Conclusion
In the projects highlighted above, railroad operators were able to save time and money by utilizing innovative methods to fix their landslide and rockfall hazards. Rather than attempting to protect the track from geohazards, these operators elected to remove the geohazard. The methods used to remove these hazards were uniquely tailored to each site to ensure the most efficient use of time, materials, and equipment. Doing so reduces ongoing maintenance costs for these operators, and most importantly keeps the track open.
Presentation Outline

- Harvey Fill, ND Retaining Wall Repairs
  - Technology Highlighted: Launched Soil Nails
- Southeast PA Landslide Repair
  - Technology Highlighted: Hollow Bar Soil Nails
- Kremmling, CO and Blueford, IL Rock Slope Stabilization
  - Technology Highlighted: Rock Scaling/Helicopter Access
- TN Cave Stabilization
  - Technology Highlighted: GeoSynthetically Confined Soil (GCS®)

Harvey Fill, ND

- Steep through-fill with old retaining walls constructed from stone and timber piles; damaged by grass fires
- Traditional repair methods would require months of construction time
- Busy track required a fast fix that did not take the track out of service for long periods
The Soil Nail Launcher

- British Military Technology
- Dynamic Installation
  - Pullout capacity 10x that of driven or vibrated rods
  - Increase soil density
- Can be perforated (drains)
- Can be post-grouted
- Full articulation to work around obstructions
- SHRP2, USFS, FHWA
The Soil Nail Launcher

Powered by a custom mounted auxiliary air compressor

The Soil Nail Launcher

Launching sequence is controlled by a microprocessor ensuring correct and safe operation

The Soil Nail

Collet
Assembled Nails

Barbed End

Guide Tube

Open Breech

Breech Interlock
Breach Valve
Breach

Noise and debris shroud

• Nail engaged within cylinder and breech closed.
• The onboard accumulator is charged to the desired air pressure.
• The maximum air pressure is ~4,000psi but can be varied depending on soil type and design requirements.
• Launched Nail is lifted into position and aligned in the desired direction.

• Baseplate must be in contact with ground to fire and personnel must be clear of the area.

• Following a sequence of auditory warning sirens, the nail is fired.

• The compressed air suddenly released against the collet forces the collet and nail through the barrel, much like a dart through a blowgun.

• The force acts upon the tip of the nail, placing the nail temporarily in tension, and preventing it from buckling.

• The collet breaks away as the nail enters the soil.

• The ground around the nail is displaced by compression at the tip, creating a shockwave in front of the nail tip that causes the soil particles to “jump away” from the main shaft of the nail. The nail subsequently enters the earth without significant abrasion or coating damage.

• The soil particles then collapse onto the nail providing a high pullout resistance.

• Nail is launched in 1/5 of a sec.
Southeast PA

- High-speed passenger rail operator noticed vertical and horizontal track displacement.
- Permanent repair of landslide would take 18 months using caissons.
- Self-Drilling Soil Nails (30') were installed in less than 2 weeks.
Kremmling, CO

- Large rockfall event in narrow canyon
- Emergency scaling required for safe passage of train traffic
- All scalers had to be brought in by helicopter
Blueford, IL

- Differential weathering caused multiple small rockfall events
- Remedial scaling using airbags maintained mobility through the corridor
- Scaling is relatively inexpensive, but needs to be repeated on a regular cycle
TN

- Cave adjacent to tracks posed a constant maintenance burden
- Concern over massive failure and track closure
- Cave was filled with GeoSynthetically Confined Soil (GCS®)
Conclusions

• Innovative technologies can save time and money
• Design/Build contracting is appropriate for geohazard mitigation
• Sometimes the hazard should be removed entirely, other times it should only be mitigated