

**DESIGN AND CONSTRUCTION OF A TEMPORARY ROCKFALL MITIGATION  
SYSTEM AT THE BELLWOOD QUARRY RESERVOIR TUNNEL, PHASE 1 WATER  
SUPPLY PROGRAM, ATLANTA, GEORGIA**

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## **ABSTRACT**

The City of Atlanta is commissioning a new 1-mile-long, approx. 13-ft. diameter, lined, water conveyance tunnel as part of Phase 1 of the Water Supply Program. The tunnel will be excavated through bedrock with a TBM and will provide the City with potable water from the soon-to-be-filled Bellwood Quarry Reservoir. Construction of the tunnel and ancillary features was initiated in spring of 2016 and is expected to be complete in 2018. The previously mined Bellwood Quarry will serve as a reservoir to impound and distribute the water.

Prior mining activities have resulted in steep pit slopes, some as high as 350 ft., with an abundance of loose rock. In order to help maintain a safe and functional site for site access and tunneling, a temporary rockfall mitigation system was constructed (and is currently being maintained) above the main water supply tunnel and a secondary adit. Critical elements of the temporary system included post-scaling design and construction of draped netting, rock dowels, and two rockfall canopies. The draped netting and canopies were connected as part of a “slot” system, where falling rocks will be contained behind the drape and subsequently guided into (and arrested by) the canopy system.

This paper details the elements of the temporary rockfall mitigation system being utilized during tunnel construction, and will describe the challenges associated with installation of near-horizontal rockfall canopies at elevated, difficult access locations.

## **KEYWORDS**

Rockfall, Barrier, Canopy, Design, Deflection, Temporary, Quarry, Tunnel, Reservoir

## **INTRODUCTION**

The City of Atlanta is commissioning a new 1 mi.-long, approx. 13-ft. diameter, concrete lined, water conveyance tunnel as part of Phase 1 of the Water Supply Program. Subsequent phases of tunneling will result in the construction of another 4 mi. of tunnels to tie the underground water conveyance system together. Tunneling commenced from within the Bellwood Quarry Reservoir (currently drained), which is located approximately 2 miles from downtown Atlanta. The Phase 1 main tunnel consists of an initial short segment of drill and blast starter tunnel, with the remaining drive completed by means of a bedrock tunnel boring machine (“TBM”). Additionally, two pump station shafts were excavated within 200 ft. of the pit slope face, and a series of adits are being excavated that will connect the main tunnel to the pump station shafts. The previously-mined Bellwood Quarry will serve as a proposed 2.4 billion gallon reservoir with which to impound and distribute the water. The new tunnel system will provide the City with potable water from the soon-to-be-filled Bellwood Quarry Reservoir. The area surrounding the reservoir will be landscaped with walking trails, in what will eventually be designated as Westside Reservoir Park. Construction of the tunnel and ancillary features was initiated in spring of 2016 and is expected to be complete in late 2018.

The Bellwood Quarry has been the site of active rock extraction for over 100 years, providing a source of construction stone and aggregate. This principal lithology exposed in the quarry is biotite gneiss of the Clairmont Formation; however, the bedrock is also frequently referred to as granitic gneiss in public domain geologic literature. Prior drill and blast mining activities were utilized to develop the quarry, and have resulted in steep pit slopes, some locally as high as 350 ft. These exposed slopes have been subject to weathering processes, and as such, presented an abundance of loose rock. The exposed silica-rich bedrock is generally highly fractured, and very hard which can present a challenge to drilling operations.

In order to help maintain a safe and functional site during tunneling, a temporary rockfall mitigation system was constructed (and is currently being maintained) above the main water supply tunnel portal and secondary adit. Critical elements of the temporary system included scaling, post-scaling design and construction of draped netting, rock dowels, and two rockfall canopies. The overall site, rock slope and underground features are shown in Figure 1.

## **TEMPORARY ROCKFALL MITIGATION ELEMENTS**

The temporary rockfall mitigation work at the site consisted of initial highwall scaling, followed by installation of a wire mesh rockfall drape, rock dowels, and two individual segments of rockfall canopy. In addition, system monitoring and maintenance efforts are also being conducted over the tunnel to maximize performance over the construction period. The temporary rockfall mitigation system was designed by Scarptec, Inc. (“Scarptec”) and Brierley Associates Corp. (“Brierley”), and was constructed by Apex Rockfall Mitigation, LLC (“Apex”). Periodic field engineering visits during installation of the temporary system were also completed by the design team. The underground workings are being constructed by Guy F. Atkinson Construction.

### **Highwall Scaling**

Initial rock slope scaling took place in the spring and early summer of 2016, prior to mobilization of tunneling equipment, with efforts being highly productive. Previous blasting activities and exposure to the forces of weathering resulted in an abundance of loose rock prior to construction activities. In order to minimize the quantity of potentially unstable rock material, Apex completed scaling efforts using manual methods; (e.g., scaling bars, rope access techniques) and mechanical methods; (e.g., pneumatic air bags) which were employed using specialized rope access techniques.



**Figure 1 – Northerly view of quarry highwall, tunnel and adit (on bench)  
(Photo by Scarptec, Inc.)**

### **Draped Rockfall Netting**

Draped steel netting was used for both temporary and permanent rockfall mitigation purposes. The temporary application was installed in June 2016 and was intended to mitigate rockfall potential during the 3-yr. period of tunnel construction. The permanent netting application, put forth by the tunnel designer and engineer-of-record (Stantec), considers mitigation of long-term rockfall occurrence to prevent large quantities of rock from clogging the tunnel entrance and impeding the flow of water. Transition from temporary to permanent protection systems will require a series of field-determined retrofits at the end of the tunnel construction period, and are described later in this paper.

Draped netting consists of galvanized G65/3mm Tecco® Mesh manufactured by Geobrugg supported at the crest of the slope by a series of 20-ft. long, ¾-in. dia. IWRC-EIP wire



rope cable anchors and a top rope. The draped segment of slope in the vicinity of tunneling operations measures approx. 365-ft. in plan length along the slope crest by approx. 315-ft. in slope height. The top set cable anchors were subject to pull testing at both axial (i.e. vertical) and angled (45 deg.) loading configurations in order to verify minimum load-carrying capacity.

In order to maximize rockfall capture, the temporary draped netting was locally tied into the canopy system. The intent of the connection between the canopy and drape was to create a “slot” with which falling rocks could be contained within the system and could not exit the limits of netting; in other words, the canopy formed the lower limit of the temporary drapery system.



**Figure 2 – Constructed rockfall drape  
(Photo by Scarptec, Inc.)**

### **Rock Dowels**

In order to design the temporary canopy-drape netting system, the Scarptec-Brierley design team needed to define the upper limits of rock block size and energy that could potentially compromise the system. Rock blocks greater than this critical size, conservatively assumed to be

falling from near the slope crest, would require bolting if such blocks appeared to be loose based on field observations. Based on kinematic calculations and rockfall analyses of rock block free fall from 285 ft. in height, the critical rock block size that could exceed the maximum barrier deflection criterion of 28 ft. was estimated to be a cubic block measuring approx. 2.5-ft. (or the equivalent of 15-c.f.). Rock blocks greater than this size required rock reinforcement to arrest potential movement.

Passive rock dowels were chosen to reinforce potentially unstable rock blocks above both canopy systems due to their relative speed and ease of installation; however, to stiffen up the rock mass and pin down suspect key blocks without the benefit of tensioning requires that additional steel be installed. As such, the initial phase of rock reinforcement called for installation of 74 rock dowels that were marked-out in the field (Figure 3) and submitted to the Owner on plan sheets with calculations.



**Figure 3 – Rock dowel layout with paint using rope access  
(Photo by Scarptec, Inc.)**

Rock dowels were comprised of 1-1/4-in. dia. grade 75 epoxy coated bars fabricated by Williams Form Engineering. Minimum embedment depths by location were provided to rock remediation technicians from Apex, who then drilled and installed the dowel bars using wagon drills. In two instances, temporary wire rope cable lashing was required as a precaution to stabilize rock blocks prior to drilling. Rock dowel lengths generally ranged from 10 to 20-ft. in total embedment length.

### **Rockfall Canopies**

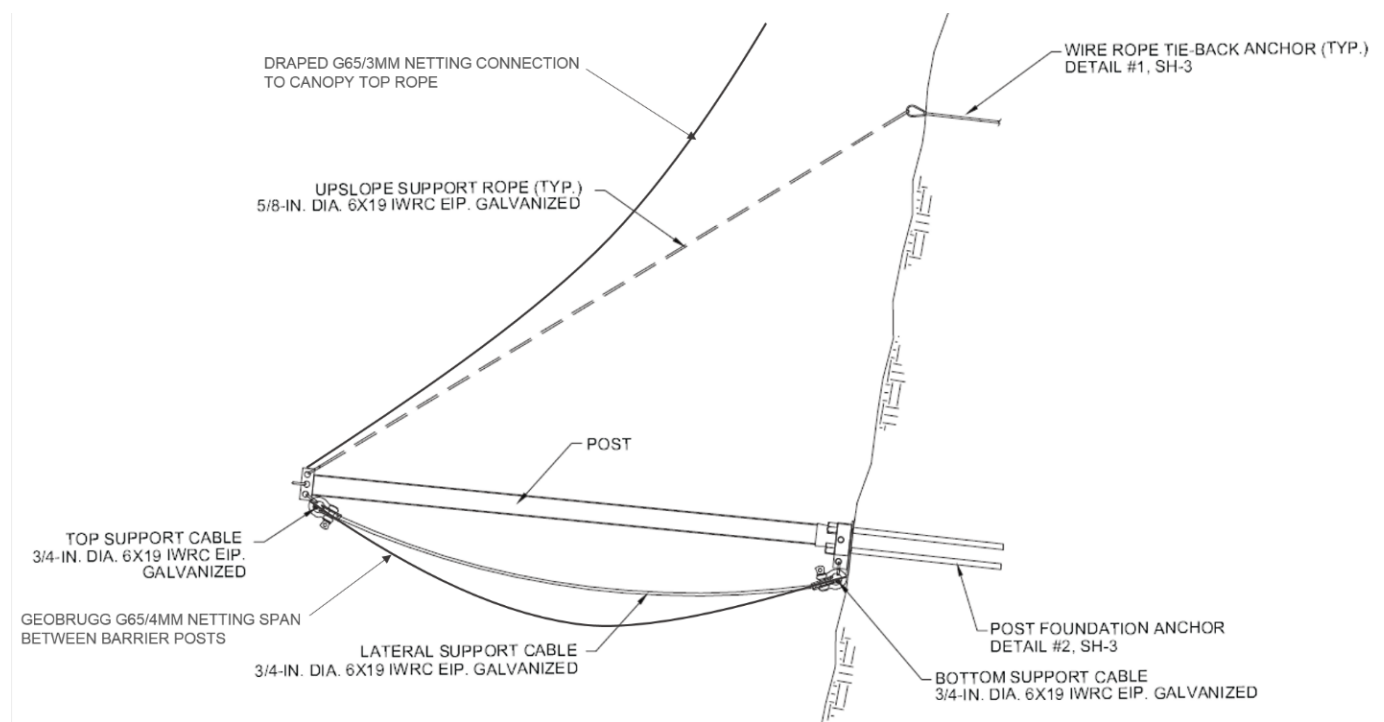
Initially, a traditional barrier approach was considered whereby a barrier would be constructed along the crest of an intermediate bench slope; however, it quickly became apparent



that vertical posts would not work for all locations given the complex geometry of the slope and need for access by tunneling personnel. Therefore, the design team opted for use of two rockfall canopy barrier arrangements, located above the tunnel and adit portals. Both canopies were adapted to the field conditions and would also not restrict construction access by the tunneling crews.

The temporary canopy barriers were constructed with GBE-1000-A rockfall barrier components from Geobrugg that includes segments of G65/4mm Tecco® mesh fabric spanning between the posts. Posts consist of 13.1-ft. long steel sections that are set at 25 ft. centers for a total of four posts with an effective length of 75 linear ft. above the main tunnel portal and adit (Figure 4).

Both canopies were connected to the draped netting as part of a “slot” system, so that falling rocks remain behind the drape and are subsequently guided into (and arrested by) the canopy system. To establish a “closed system”, a cut line was established along the Tecco® drape and an additional segment of Tecco® mesh was connected between the drape cut line and the upper portion of the barrier post top cables (Figure 5).



**Figure 4 – Canopy post section detail**  
(Image adapted from Scarptec- Brierley construction drawings)





**Figure 5 – Canopy construction and drape tie-in  
(Photo by Scarptec, Inc.)**

### **Monitoring & Maintenance**

In order to maximize the reliability of the temporary rockfall mitigation system, the slope and constructed elements described herein are subject to periodic monitoring and maintenance efforts at the frequency of one visit every 6 months unless specific observations or events dictate more frequent monitoring. Geotechnical monitoring efforts generally consist of assessment of the following:

- the capacity and need for cleaning of rock debris within the canopies and drape;
- need for additional slope scaling;
- condition of canopy anchorage elements;
- need for additional spot rock dowels;
- condition of drape anchors;
- assessment of drape damage/over-stressing; and,
- canopy system tensioning and netting sag adjustments

Maintenance of the system over the tunneling construction period was (and continues to be) completed by Apex, based on monitoring visit observations. Small fragments of rock debris were removed from the tunnel canopy system in January of 2017 (Figure 6), and minor adjustments to the canopy system cabling were also completed.



**Figure 6 – Adit canopy rock debris subject to maintenance cleaning  
(Photo by Scarpotec, Inc.)**

## **TRANSITION TO PERMANENT CONDITION**

The permanent condition will consider the effects of nearly full-submergence of the rock slope as the old quarry transitions to a long-term water supply reservoir for the City of Atlanta. Upon completion of the approx. 3-yr. construction period (temporary condition), the two rockfall canopy segments will be removed from service. Any interim connections between the drape and the canopies will be disassembled. The temporary rockfall drape will be converted to a permanent system through a series of minor repairs (if needed) and localized geometric reconfigurations which will be field-fit around the tunnel, adit, and any hard slope breaks. Within approx. 6 months of project completion, the temporary rockfall mitigation design team will consult with the tunnel designer regarding the transition from temporary to permanent system.

## **CONCLUDING REMARKS**

The construction of temporary rockfall mitigation features during Phase 1 of the Water Supply Program are critical to site safety and will help provide for minimized down-time while tunneling continues from below. Design-during-construction efforts required the Apex-Brierley-Scarpotec team to evaluate and adapt to field conditions “on-the-fly”. Development of the canopy system concept initially posed some challenges given the complex slope geometry, height-related difficult access conditions and multitude of other construction priorities directly below the canopies. These initial challenges were overcome with solid field engineering input from the team during construction.

Although most surface and underground blasting is now complete, additional destabilizing forces from construction vibrations (e.g. TBM advancement), surface water and

fracture-controlled drainage, and bedrock weathering may result in periodic rockfall at the site, all of which underscores the importance of this temporary rockfall mitigation system. To-date, the system has performed as intended and will be maintained as necessary to mitigate both the frequency and effects arising from potential rockfall events.

#### **REFERENCES:**

1. Turner, A.K., Schuster, R.L., *Rockfall – Characterization and Control*, National Academy of Sciences, Transportation Research Board, Washington, D.C., 2012.
2. Geobruugg, *Rockfall Product Range GBE-series 150303e*.
3. Geobruugg, *GS-1104us 140827 GBE-1000A System drawing, Layout1*
4. Geobruugg, *Tecco® Properties*, Doc. No. 1.402.29.EN 1403