

# Rock Stabilization of Two Historically Sensitive Rock Slopes Using Shotcrete

by Daniel Journeaux

The need to stabilize these rock slopes was driven by the construction of the Hudson-Bergen Light Rail Project, which was being extended into Weehawken, NJ. The location of the light rail was along the previous Conrail line that ran along the base of the Palisades in Hoboken and Weehawken. There were two slopes along the line in Weehawken that needed immediate stabilization. The first slope was the King's Bluff

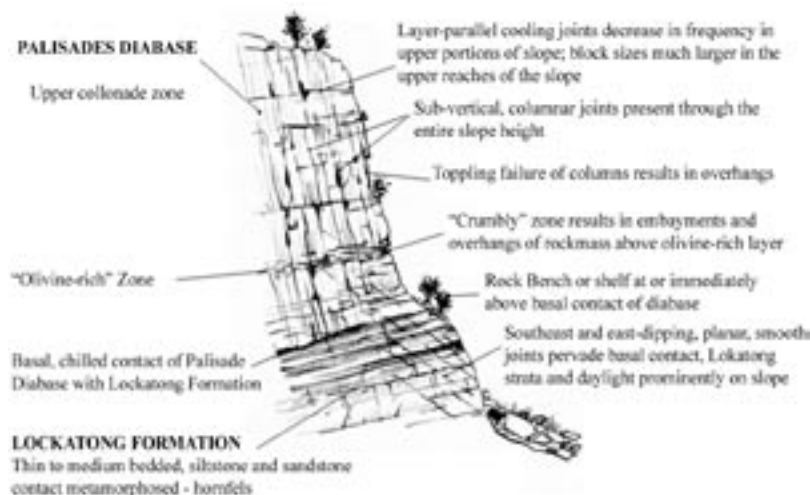
slope, 197 ft (60 m) in height, and the Weehawken Tunnel East Portal, 174 ft (53 m) high. King's Bluff and the Tunnel Portal were difficult stabilization projects for numerous reasons. The two major difficulties were the fact that, due to time constraints, the work at the base of both slopes had to continue while the work on the slope face was being performed. The second major difficulty was the fact that the people of Weehawken were very concerned about the appearance of the Palisades. The Palisades Preservation Committee has done extensive work in preservation of the beauty of the Palisades.

The original designs called for pattern bolting and wire rope nets to stabilize and contain any loose material. The original design did not take historic and aesthetic concerns into consideration. The mayor of Weehawken, Richard Turner, found the concept of having wire rope nets draped all over the slopes unacceptable. Mayor Turner knew how important the visual impact of the slopes was to his constituents. There was one structure on the East Portal slope that the locals referred to as the "gorilla's head." The original design called for the removal of this structure before installation of mesh and anchors. If the work had been allowed to proceed as was originally designed, the slope would have been altered beyond recognition.

Mayor Turner had no choice but to stop the work until an acceptable solution could be found. As one of the founding members of the Palisades Preservation Committee, he could not allow the slopes to be altered in such a way as to remove the beauty of the rock faces. New Jersey Transit (NJ Transit) and the Washington Group were faced with the difficult task of stabilizing the slopes without causing any visual impact. Janod Inc. and Golder Associates were called in to work as a team to come up with a solution. After the initial analysis, Janod and Golder proposed to stabilize the slope by using a combination of techniques—rock bolts strategically located to stabilize individual blocks of marginally stable rock; steel fiber-reinforced shotcrete for the structural support of the rock structures; and sculpted shotcrete to make all the work "disappear" and blend into the existing appearance. The plan was presented to the Mayor Turner. The mayor approved the approach and



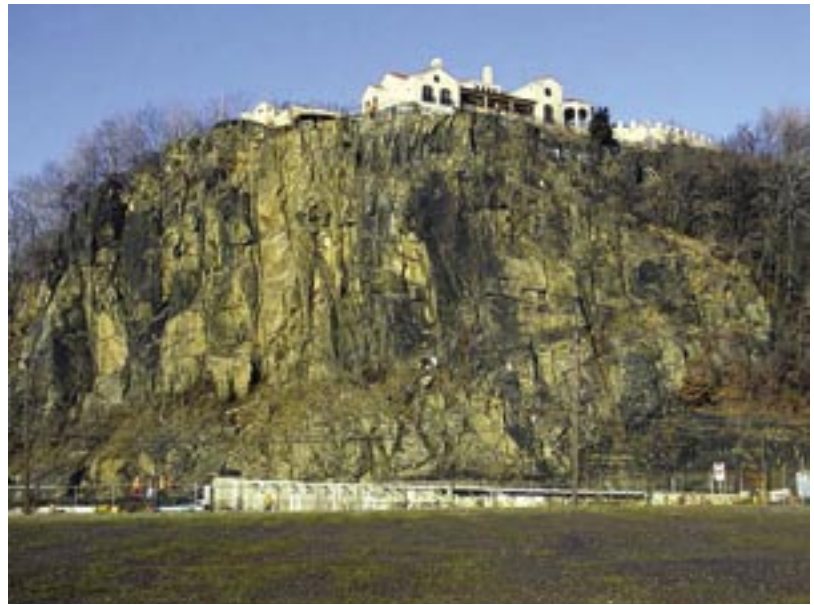
Location of the projects in the New Jersey/Palisades area



Detail of slope elements on Palisades Ridge



*"The Wedge" at King's Bluff*



*King's Bluff before the start of the project*

allowed the work to proceed. Mayor Turner issued a stern warning to all involved that he would hold everyone to their promise to produce a finished slope that did not show any signs that it had been worked on.

Because of the schedule, the project was set up as a design-build contract. This allowed the design to proceed as the work was performed. The first phase of the project was to scale the slope to remove loose rock that would pose a danger to the workers, and allow Golder's engineering geologist to rappel down the slope and visually survey the rock structures before deciding on the final design. The engineering geologists from Golder worked closely with the rock remediation technicians from Janod and Vertec to come up with the final quantities of rock bolts and steel fiber-reinforced shotcrete required for the work. Anchor drilling and grouting logs were kept and recorded to map out the structures in the slope. While the final plan was being designed by the geotechnical experts at Golder Associates, the rock remediation technicians started installing rock bolts in the slope. For the more unstable rock structures, it was decided to shoot an initial layer of steel fiber-reinforced shotcrete using the dry-mix process to stabilize the structure sufficiently to allow bolting to continue safely. Further shotcrete was then applied after bolting to complete stabilization of the rock structure.

It was important to get the best possible results on this project. AUS Corporation of Vermont was contracted to apply the shotcrete. In addition, King Packaged Materials Company was given the assignment to develop and produce pre-packaged, dry-mix shotcrete materials for this project. Janod Inc. and AUS Corporation have used King Packaged Materials formulations throughout North America because of the superior quality of its products and its unique expertise in this field.



*King's Bluff finished product*

The combination of expert applicators and superior materials allowed for a finished product that could not be attained otherwise.

Janod and AUS have been perfecting the technique of using shotcrete for structural support on natural rock faces for several years. The process had been described as "dental shotcrete." The shotcrete is applied to support rock where the original weaker material has deteriorated. Once the structure has been stabilized with shotcrete, additional anchors are installed to add support. Additional shotcrete is then applied for a long-term solution.

The dry-mix process was used on the slope because most of the work had to be performed with the nozzleman working off of ropes. Not only were





*Application of wet shotcrete in preparation for sculpting at East Portal's gorilla's head landmark*



*East Portal sculpted shotcrete application*



*Test section for approval of sculpting*



*Rough finish of test area*

the Janod/Golder team able to come up with a solution to deliver the people of Weehawken a satisfactory finished product, but because of the work methods of the rock remediation technicians and the nozzle men from AUS Corporation, the light rail construction work below was allowed to continue without interruption.

Once all the rock structure stabilization work was completed, it was time to bring in the artists from Boulderscape of California to sculpt a layer of wet shotcrete and transform the structural shotcrete into a sculpted rock formation. The artisans, working from ropes and large manlifts, applied, sculpted, and textured a special wet shotcrete mixture designed by Boulderscape. After the shotcrete was dry, it was colored to match the surrounding rock.

The Washington Group and NJ Transit requested that a test panel be completed to allow them to inspect and approve the finished product before the whole area was stabilized, sculpted, and colored. An area 16 x 49 ft (5 x 15 m) on the slope was chosen. Rock bolts were installed and structural shotcrete was applied. The layer of shotcrete for the architectural finish was then applied, sculpted, and colored. The Washington Group and NJ Transit representatives were asked to evaluate the finished test panel. Upon their arrival at the site, they were directed to the general area of the test panel by the site Foreman, Marc Thibeault. Much to the delight of those creating the test panel, the Washington Group and NJ Transit representatives conceded they could not distinguish where the stabilized rock ended and the unstabilized rock began until it was shown



to them. Approval to continue with the sculpting was given shortly after.

There were two rock features that were of particular importance on these sites. At King's Bluff there was a large, unstable rock wedge that would involve a large mass of rock if it were to fail. At the East Portal, there was the gorilla's head that had to retain its appearance as well as be stabilized. The wedge had already shown signs of previous failures at the base of the structure. The remaining material at the base of the structure was severely fractured, an indication that gravity was causing considerable stress on the base. The only way to stabilize the structure was to carefully build up the shotcrete at the base and install dowels for additional reinforcement until Janod's rock remediation technicians could lock in the structure to the point that it was safe enough to safely install bolts through the top portion of the rock formation. Once all the structural work was completed, the artists moved in and matched the look of the fractured rock to make all the structural shotcrete "disappear." The gorilla's head was stabilized in the same way. For the gorilla's head, however, even the structural shotcrete had to be carefully placed to preserve the unique profile of the projecting rock.

The final quantities of the remedial work were as follows:

Rock bolts: 8327 linear ft (2538 linear m);  
Steel fiber-reinforced shotcrete: 236 yd<sup>3</sup> (181 m<sup>3</sup>); and  
Colored sculpted shotcrete: 3240 m<sup>2</sup> (3875 yd<sup>2</sup>).

In the final analysis, the successful completion of this project was due to a combination of perseverance, innovation, cooperation, and hard work. Because the work below the slope was allowed to continue, NJ Transit and the Washington Group ended up with a stabilized slope without impacting their own tight schedules. The people of Weehawken ended up with a stable, natural-looking slope that future generations will be able to enjoy.



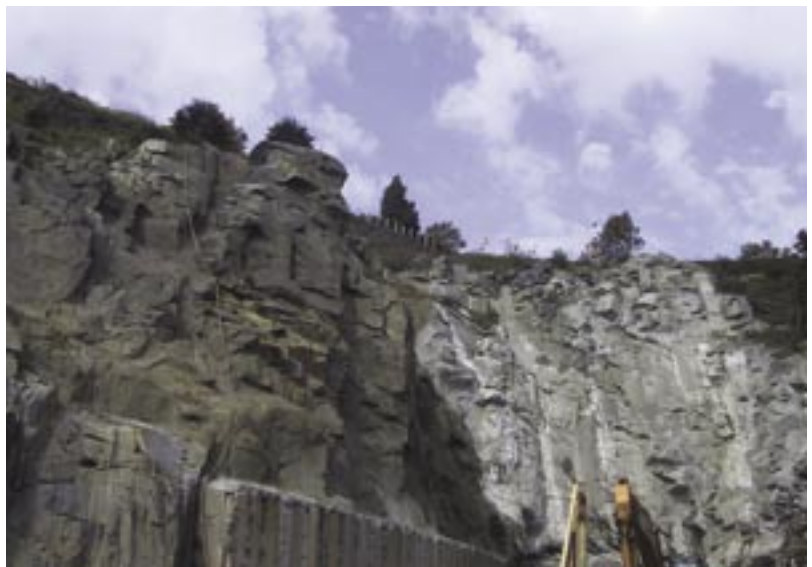
**Daniel Journeaux** has more than 25 years of field experience on rock stabilization projects across North America and has been President of Janod Inc. since 1993. He has been an invited speaker by the University of Laval, Queens University, The Federal Highway Administration (Northwest and Southwest), quarry and mining associations, departments of transportation, and railways. Journeaux has been published in quarry and mining magazines.



*Sketch outlining gorilla's head landmark at East Portal*



*Gorilla's head formation above Weehawken Tunnel East Portal*



*Completed, sculpted, and stained face at East Portal*