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Artikel: Protection against rock falls, Sterling Mountain Tunnel, NC (USA)

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7. Protection against Rock Falls, Sterling Mountain Tunnel, NC (USA)

Owner:	*North Carolina Department of Transportation*
Engineer:	*Parsons Brinckerhoff Quade & Douglas, Inc.*
Contractor:	*Oman Construction Co., Inc./ Jensen Drilling, Inc.*
Works' Duration:	*9 months for design and construction*
Service Date:	*November, 1985*

Introduction

The 350 m long Sterling Mountain Tunnel in North Carolina, U.S.A. carries the Interstate 40 highway through the Blue Ridge Mountains about four miles from the Tennessee state line. The tunnel is composed of two rock bores lined with reinforced concrete. In March 1985, a 150 m by 100 m area of the mountain at the west portal failed cascading large rocks that completely destroyed the tunnel portal (Figure 1). No cars were passing at the time and no casualties were reported.

After removal of the debris, an emergency action was implemented to stabilize the side of the mountain and to reopen the tunnel to traffic. The construction also included protection against future large and small rock falls. This article describes the protection measures constructed in conjunction with the reopening of the tunnel.

Failure Modes

The potential future failure modes of the slope were evaluated based on the subsurface investigation data and the detailed geologic mapping performed at the mountain slope. These failure modes are controlled primarily by the bedding planes and the orientations of the joint sets. Two failure modes were identified: a wedge failure above the westbound portal cut and a block failure along the roadway similar to the rock slide that destroyed the portal. Protection measures were designed to accommodate both.

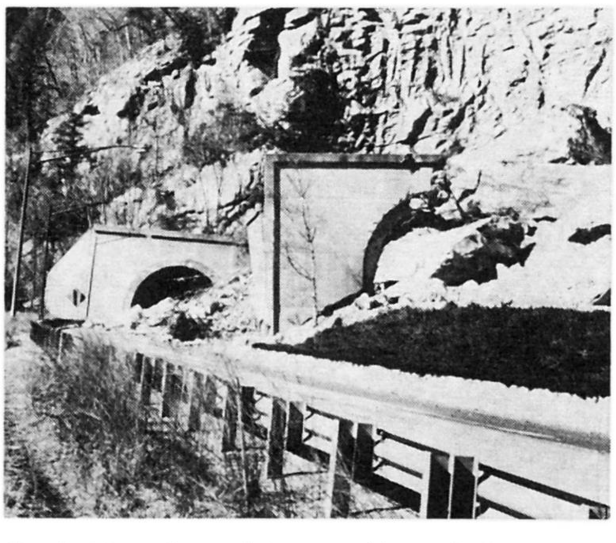

Fig. 1 Tunnel portal destroyed by rock slide

Protection Measures

The protection measures implemented at the site were designed to prevent two types of hazards: (1) a large-scale slope failure that can seriously damage and obstruct the roadway and tunnel, and (2) small-scale block failures (falling rock) that may be hazardous to motor vehicles passing through the area. A combination of rock reinforcement and horizontal drainage was used for the large-scale slope protection. To provide protection from small rock falls, a Reinforced Earth wall carrying a rock fence was constructed adjacent to the roadway.

Rock Reinforcement

Six major areas were stabilized by in-situ rock reinforcement. Loose small rock blocks were removed by scaling prior to reinforcement. Some large rock overhangs were removed by careful drilling and blasting. Reinforcement was provided by rock bolts 6 m in length, installed mainly on a 1.5 m by 1.5 m pattern. No. 9 (28 mm) ASTM A615 Grade 60 rock bolts were used. Galvanized chain link fabric was anchored to the rock bolts in one area to hold back small rock pieces that may break as a result of the blocky nature of the rock at that area. (Fig. 2)

Two potential large block failures were identified in an area of the slope parallel to the roadway. A large crack, 45 cm wide at the top, was measured behind two rock blocks 3 to 5 m thick. Because the loosened blocks were too large to be removed safely by blasting, they were stabilized by the installation of 12 m long high-strength bolts on a 3 m by 4.5 m pattern. Between these bolts, 6 m long rock bolts were installed at 1.5 m intervals vertically and horizontally to tie back smaller blocks and produce a final 1.5 m by 1.5 m pattern. Fig. 3 illustrates details of the high-strength rock anchors used on the project.

Drainage

The long-term stability of the rock mass may be influenced by continued surface runoff and possible wedging action due to ice formation in open joints during the winter. To remedy this situation and preclude pore pressure buildup from seepage along joints behind the slope face, 15 m long slotted PVC rock drains were installed in holes drilled at 6 m lateral spacing along the base of the slope, angled a few degrees above horizontal.

Reinforced Earth Wall

A reinforced earth wall was constructed parallel to the roadway to protect the vehicular traffic from small rock pieces that may move down the rock slope in the future. The wall and its reinforced embankment will serve as a buffer zone between the roadway and the rock slope absorbing the kinetic energy of the falling rocks, and accumulating loose rock behind a rock fence erected above the retaining wall. Aesthetic benefits were also derived from the reinforced earth wall configuration.

Three types of retaining walls were considered for the project: a reinforced earth wall, a gravity-type interlocking concrete modules wall (Doublewal) and a concrete-faced tie back wall. The reinforced earth wall was the most suitable considering schedule, cost, aesthetics and construction requirements. The constructed wall had a constant height of 10.6 m above the roadway and a 90 degree end wall abutting the rock face (Fig. 4). Partial excavation of the rock was required near the portal to accommodate construction of the reinforced earth embankment. The rock fence consisted of 4.5 m high mesh chainlink fabric tied to standard pipe rail and extra strong pipe posts anchored 2.5 m in the compacted reinforced earth embankment. The construction time including materials procurement was about two months for the 63 m long wall.

(George A. Munfakh)

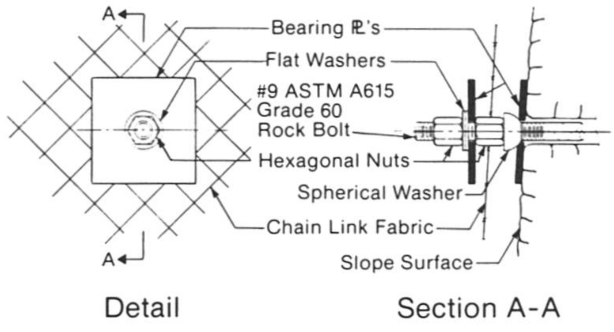

Fig. 2 Detail of chain link fabric/rock bolt assembly

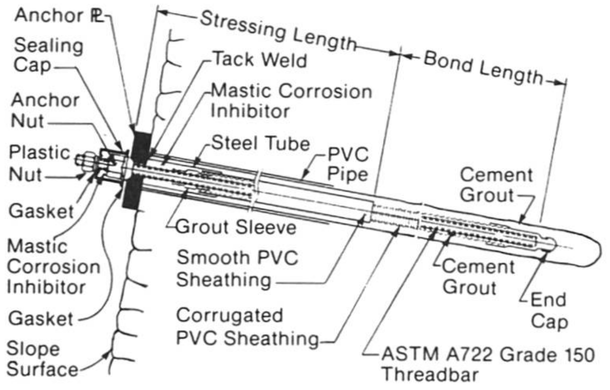

Fig. 3 Detail of high-strength rock anchor with double corrosion protection

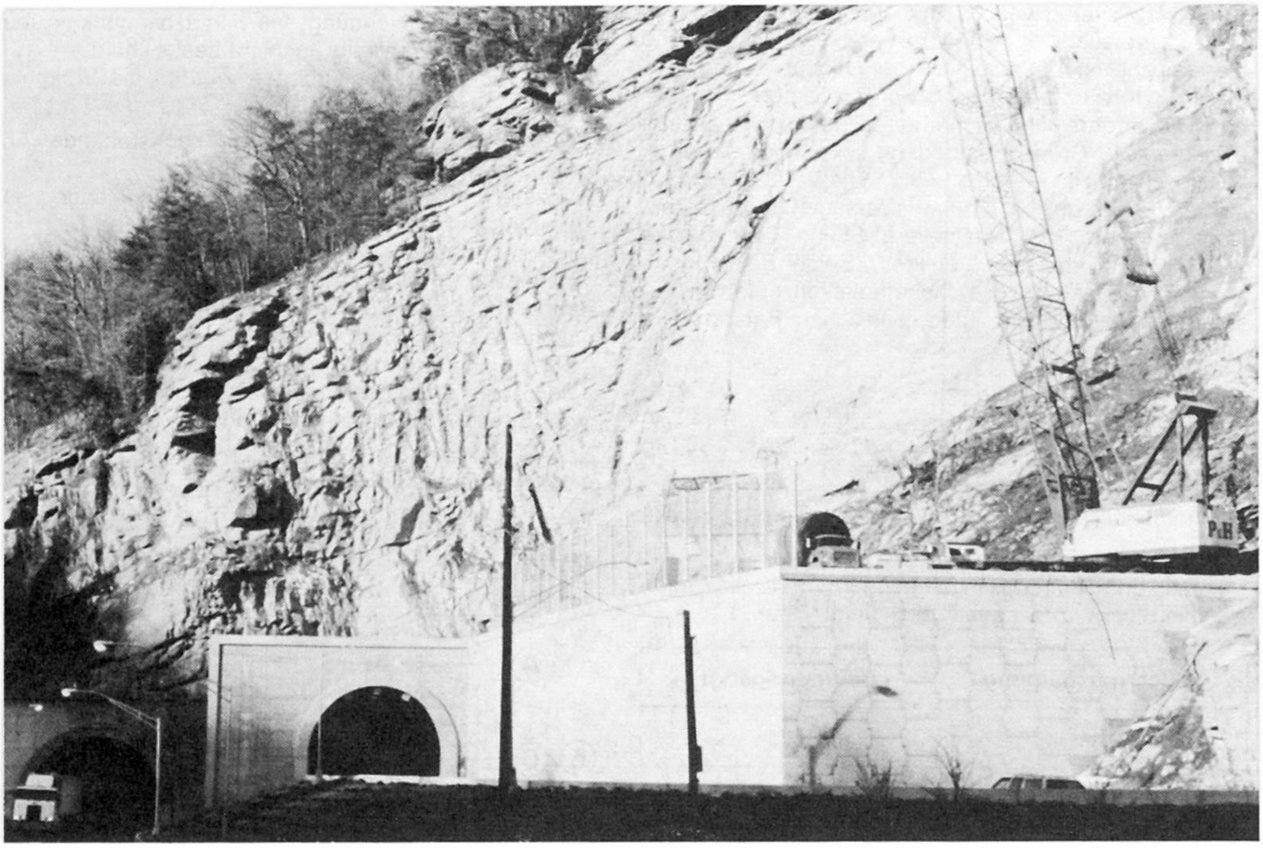

Fig. 4 Reinforced Earth wall with rock fence