Rumble in the Ragged Mountains

Bradshaw Construction used the drill-and-blast hand mining method on a water-main tunnel on the New Ragged Mountain Dam in Charlottesville, Virginia (US)

Tunnel boring machines (TBMs) are regularly specified to excavate hard-rock tunnels, particularly near sensitive structures such as dams, where vibration damage is considered critical. The drill-and-blast tunnel method is not always considered to be an option.

However, depending on the length of the tunnel, the rock conditions and the proximity to critical structures, drill-and-blast hand mining can be accomplished as safely as the TBM method, yet can be more economical.

In April 2012, the Rivanna Water and Sewer Authority (RWSA) awarded a contract for the New Ragged Mountain Dam project west of Charlottesville. The purpose of the project was to increase the existing reservoir's storage capacity.

WORKS IN DETAIL

The work included constructing a new dam and spillway downstream of the existing dam, demolition and removal of portions of the existing dam and appurtenant structures.

All construction had to be completed without interruption of normal operations of the existing 18in (457.2mm) raw-water lines to the water treatment facility until the new raw-water line was in service. RWSA obtained permits from the US Army Corps of Engineers and the Commonwealth of Virginia Department of Environmental Quality for this project.

The installation and finishing of the rock tunnel was subcontracted to Bradshaw Construction by Thalle Construction Company, the general contractor. This tunnel was 484 linear feet (147.52m) of 9ft 6in minimum excavation, horseshoe tunnel supported by rock bolts and additional localised shotcrete support as needed.

A new 36in ductile iron pipe raw-water main was installed in the tunnel to replace two 18in raw-water mains buried in the existing dam. These provide drinking water for the city of Charlottesville. The remainder of the tunnel cross-section was channelised to serve as the primary reservoir spillway. Cutoff grouting was used to minimise reservoir seepage on the upper end of the tunnel. Tunnel excavation was specified as the hand-mined method using controlled drilling and blasting.

The site is located in the Blue Ridge Physiographic Province of Virginia. The geotechnical investigation found the rock at tunnel level to be granitic gneiss. It was strong to very strong with low hydraulic conductivity. The unconfined compressive strength ranged from 7,000 to 28,000psi. RQD was typically 90-100% except at the portals where the rock had weathered. ►

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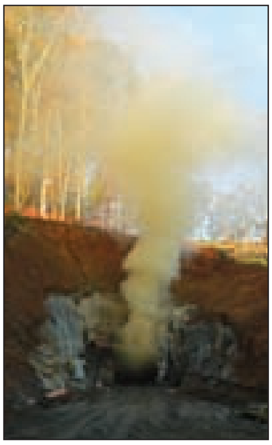

Below left: blast smoke at the tunnel access portal

Bottom left: 114in horseshoe tunnel excavation

Drilling the blast pattern at the tunnel face

Opposite page: loading the blast pattern and mucking the blasted rock

CRITERIA AND QUALIFICATIONS

The client specified that the tunnel contractor's personnel had to be experienced in drilling and blasting. The tunnel project manager had to have at least 10 years' experience in rock tunnel construction by drill and blast and to have successfully managed a similar tunnel project to completion within the last six years.

The tunnel engineer had to have a Bachelor of Science degree in civil, mining or geological engineering, as well as both office and field experience in tunnel engineering of closely controlled and monitored tunnel excavations utilising rock bolts and shotcrete as ground support. The contractor's blasting supervisor on each shift had to have a minimum of a decade's experience in tunnel excavation with the blasting methods and all required licences.

"Drilling and blasting's perceived risks can be controlled by experienced contractors and engineers, as this project shows"

Tunnel construction methods had to preserve the inherent strength of the rock mass surrounding the tunnel. The strength of the rock mass had to form the foundation of permanent support for the tunnel.

Controlled blasting consistent with USBM RI-8507 required the particle velocities to be kept less than the limits below when measured at the nearest permanent structure. The Peak Particle Velocity (PPV) limits were standard US Bureau of Miners (USBM) safe blasting levels. These levels were established as a recommended vibration limit that would be highly unlikely to cause even cosmetic damage to fragile building materials such as drywall. The limits are as follows:

Frequency	Maximum PPV
>40Hz	2.00 in/sec
≤40Hz	0.75 in/sec

The drill pattern and depth for controlled blasting were designed and modified to achieve the highest possible smoothness. If these conditions were not met as determined by the engineer, the contractor had to modify his blasting procedures until the required results were met.

The tunnel line and grade and tunnel cross-sections were to be surveyed at maximum 20ft stations. Tunnel cross-sections were to be plotted and submitted to the engineer verifying excavation clearances throughout the tunnel before starting the application of any final lining.

All equipment, materials and personnel accessed the tunnel portal (spillway outlet) via a two-mile (3.2km) long, winding gravel mountain road. Minimal improvements were made to this road to preserve the forest conditions and not transform it into a highway. Any loads delivered on trailers longer that 25ft had to be transferred to smaller trucks at the project's staging area, or in the case of cranes, excavators, etc, had to be driven onto site under their own power.

At the tunnel receiving portal (spillway inlet) the general contractor was building the new raw-water intake structure while the tunnel was being excavated. The final tunnel blast was within 6ft of freshly poured concrete.

Even for this remote project location, there were concerns for adjacent property and business owners. Fears were expressed by a local summer camp that served disabled children that blast vibrations and air blasts would frighten their participants and horses. These important public concerns required the effective use of controlled blasting.

Drill jumbo at the tunnel face

The owner and engineer prepared a rigorous and well thought out drilling and blasting specification. This included qualifications submitted with the bid demonstrating that the proposed tunnel contractor had extensive experience using controlled drill-and-blast methods.

DRILL AND BLAST CONSTRUCTION

Tunnelling began with the installation of portal supports. The inlet portal required three rows of 11 epoxy-coated rock bolts (each 15-25ft long, of type #11) tensioned to 75 kips. The outlet portal required one row with four rock bolts of similar type and length. Due to a seam of decomposed rock encountered at the inlet portal, significant additional bolting was required to secure the overhang. 2in of shotcrete was applied to all surfaces.

At each end the tunnel cross-section was enlarged by over-blasting to create a 5ft-long transition complete with additional shotcrete, rebar and waterstops. This isolated the tunnel from the reservoir at the inlet and the backfill at the outlet.

Tunnel drilling and blasting was based on a pattern of 8ft-deep drill holes on 2ft spacing. The dynamite pounds per delay ranged from 16 to 40 (7.26kg to 18.1kg) for each range using a powder factor between 8 and 12 pounds per CY. Holes were drilled with an air-powered two-boom jumbo. Mucking of the tunnel was by a 2 CY scoop tram.

Blasts were monitored using solar-powered remote seismographs with cellular communications. The first was installed on the western end of the existing dam closest to the tunnel to monitor the vibrations transmitted to the dam by the blasting operation. The seismic trigger was set at 0.1in/sec, well below the allowable USBM levels. This trigger

level was rarely reached despite being less than 600ft from the blast location. In fact, the seismograph was triggered far more often by haul trucks passing it than by blasting operations.

As the tunnel excavation approached the on-going construction of the inlet structure, a second seismograph was installed on the structure footer. Vibrations at this location only exceeded the USBM limit once when the blast was 15ft from the structure with only 8ft of rock separating it from the tunnel. The blasting pattern and depth was adjusted to complete the tunnel given the close proximity. No damage whatsoever from vibration, flying rock or otherwise was found on the inlet structure, not even to the protruding waterstop.

Rock bolts and welded wire fabric was installed in only one 15ft section of the tunnel as it was mined. Once the tunnel was completed, additional supports were installed. The final tunnel supports consisted of the following:

- 372ft of spot rock bolts;
- 100ft of rock bolts, 4in WWF and 2in of shotcrete; and
- 12ft of lattice girders and 6in of shotcrete.

CONCLUSION

Drill-and-blast hand mining has been in use for well over 100 years. It is extremely cost-effective for tunnels under 2,000ft in length. And while TBMs are clearly the faster excavation method, they are rarely as flexible with geologic conditions or providing the preferred horseshoe tunnel cross-section for utility tunnels such as this one.

Drilling and blasting's perceived risks can be controlled by experienced contractors and engineers, as this project clearly shows. In spite of the concerns for vibrations, transport and handling of explosives and unfounded public fears, this project demonstrates successful and economic use of tunnel drilling and blasting in the 21st century.

This article was written by Lester M Bradshaw, Jr, Todd Brown and Eric Eisold from Bradshaw Construction

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Publisher Simon Thompson
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Annual subscription –
UK and Europe £95.00 (160.00 euros)
Rest of the world US$170.00. Additional current copies are available to subscribers at £12 (US$21; €18) each

World Tunnelling (ISSN 1756-4107) USPS No: 023-551 is published monthly (except January & July) by Aspermont Media, 120 Old Broad Street, London EC2N 1AR, UK.
Printed by Stephens & George Magazines, Merthyr Tydfil, UK

The 2013 US annual subscription price is US$170. Airfreight and mailing in the US by Agent named Air Business, c/o WorldNet Shipping USA Inc, 155-11 146th Avenue, Jamaica, New York, NY11434. Periodicals postage paid at Jamaica NY 11431

US Postmaster: send address changes to World Tunnelling, Air Business Ltd, c/o WorldNet Shipping USA Inc, 155-11 146th Avenue, Jamaica, New York, NY11434

Subscription records are maintained at Aspermont Media Ltd, Chancery Exchange, 10 Furnival Street, London EC4A 1YH, UK

 ISSN 1756-4107
A member of BPA Worldwide