TECHNICALLY speaking

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By Gunnar Nord, Senior Construction Advis

Achieving accurate contours in tunnelling operations dramatically improves the total economy of the project. And Atlas Copco's new contour control system, launched last year, is making its mark.

An inaccurate contour, or planned outline, of a tunnel following drilling and blasting has long been a problem for tunnellers the world over.

The dilemma is created by inexact drilling of the blast holes. This results in overbreak, or excess rock, being blasted out, leaving irregularities in the planned contour of the tunnel.

In simple terms, the more overbreak, the more time and money is wasted. Transporting the excess rock – perhaps a considerable distance – and restoring the tunnel to its smooth contour with reinforcement and lining all means time lost.

Facts and figures

The considerable costs of overbreak can be illustrated by this hypothetical example: A 70m^2 two-lane road tunnel, 1 km long, is being built and, according to the tender documents, only theoretical volumes of excavated rock as well as secondary lining will be paid for. So-called geological overbreak is compensated for and the perimeter length of the tunnel is typically 22m.

Gunnar Nord: "Dealing with overbreak brings big savings."

A reduced overbreak of 10cm resulting from more accurate drilling gives the contractor the following savings in euros: (EUR 1 = USD 1.1)

– Concrete secondary lining 2,200m^3 x 120 euros/m^3 = EUR 264,000.
– Reduced mucking out 2,200m^3 x 5 euros/m^3 = EUR 11,000.
– Reduced shotcrete 200 m^3 x 300 euros/m^3 = EUR 60,000.
– Reduced construction time 100 hours x 700 euros/hr = EUR 70,000.
– Total savings: EUR 405,000.

These figures illustrate the magnitude of the overbreak problem. However, placing holes accurately and with a proper alignment is not new. It could be achieved even in the era of hand-held drills, using short rounds. But the problem was the amount of time it took.

Best technique

As far back as the mid-80s, an overbreak of less than 10 cm was recorded on drill-and-blast sewage declines in Sydney, using both hand-held and mechanized drilling.

During the same period, on the Route 5 tunnel project in Hong Kong, mechanized drilling operations employed the best technique then available for accurate contours. It involved accurate setting out of the tunnel face, TAS (Tunnel Angle System) for the alignment of the feeds, an immediate monitoring of the profile – plus a bonus to the rig operators. The results are shown in ***Figure 1***.

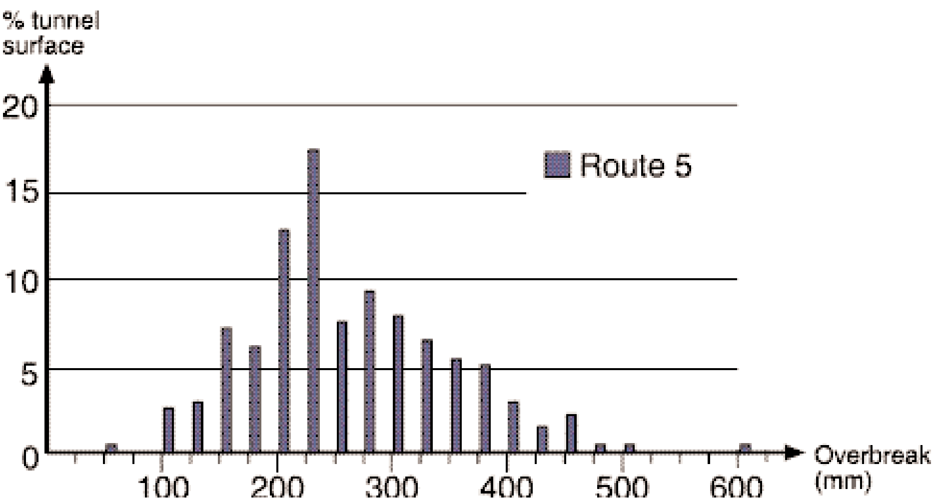

Figure 1: *Overbreak improvement at the Route 5 tunnelling project in Hong Kong.*

More light at the end of the tunnel came in recent years in the shape of a manual contour control system introduced by the Norwegian company Bever. It has been mounted on a large number of drill rigs – mainly Atlas Copco Boomer units – and the operator is guided by a TV screen in manually positioning the booms to achieve more accurately located holes.

And, in 1998, following years of development, Atlas Copco launched its own contour control system, which is being integrated into its new generation of rigs. So far, it is operational only in manual mode but is due to be available for automated mode later this year.

The following four examples of what

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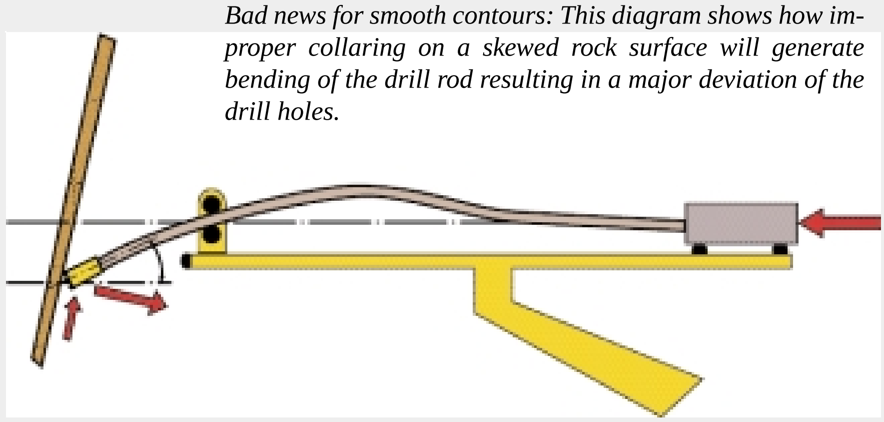
er, Face Drilling and Mechanized Bolting

Bad news for smooth contours: This diagram shows how improper collaring on a skewed rock surface will generate bending of the drill rod resulting in a major deviation of the drill holes.



can be achieved with Atlas Copco Boomer rigs equipped with Bever control are from projects over the past five years. The first two cases involve drilling with Robot Boomer rigs.

- **The Henriksdal sewage treatment plant, Stockholm, Sweden:** The contractor wanted very high drilling standards, although there was no secondary concrete lining in the design. The length of the rounds was 4.5m and the size of the opening some 80m^2. The rock was hard crystalline granites and gneiss, which was not expected to cause major deviation problems.

The skill of the operators was rated highly, conditions were favourable – but incentives were not strong, as there were no savings to be made on concrete. The average overbreak was 14cm outside the collaring line and the distribution is shown in ***Figure 2***.

- **The Escalette road tunnel project in southern France:** The two tunnel tubes were to be concrete lined with a strong incentive to keep overbreak down. Excavated sedimentary material was dominated by limestone, which had a clear bedding with a gentle dip.

Tunnels were some 700m long with an excavated cross-section of about 70m^2. Rounds were 4m or less, if ground conditions were poor. Tunnel sections with geological overbreak were excluded.

Results, shown in ***Figure 2***, were very similar to Henriksdal – although conditions were quite different – and showed what can be achieved by the equipment and good operators in moderate-size tunnels without difficult geological conditions.

- **The Mitholz tunnel in Switzerland:** This adit tunnel to the Lötschberg-Basis-tunnel showed the most encouraging results on overbreak using the Bever control. The 1.5km adit has an excavated section of 66m^2 and the rock has so far been limestone and shale. Normally, 4m rounds were drilled and the pull was 3.8m. In the 0.6m spaced perimeter holes, smooth blasting explosives were used with electronic detonators.

The drill rig was a Rocket Boomer 353 S and the contractor wanted as little overbreak as possible as he had to pay SFr 300 for every cubic metre of it that was more than 6cm outside the theoretical line. Over the entire tunnel length, this meant the penalty for every extra centimetre of average overbreak was SFr 93,000.

For the first 100–200m of the tunnel, average overbreak was 25cm. But by the time work had progressed to 700m, it had come down to 10cm as the skill of the drilling crews improved.

- **Boliden's Garpenberg Norra Mine, Sweden:** An Atlas Copco Rocket Boomer 352 S has been used on the latest section of the ramp tunnel (See article on page 24) and overbreak was reduced from more than 20% to 9%, or an average of 15cm. This resulted in a reduction of the muck volume of 3m^3 per lineal metre of tunnel and savings on transport from a depth of 800 to 1,000m.

According to the mine management, the savings achieved in one year paid for the extra cost of improving drilling operations at the mine.

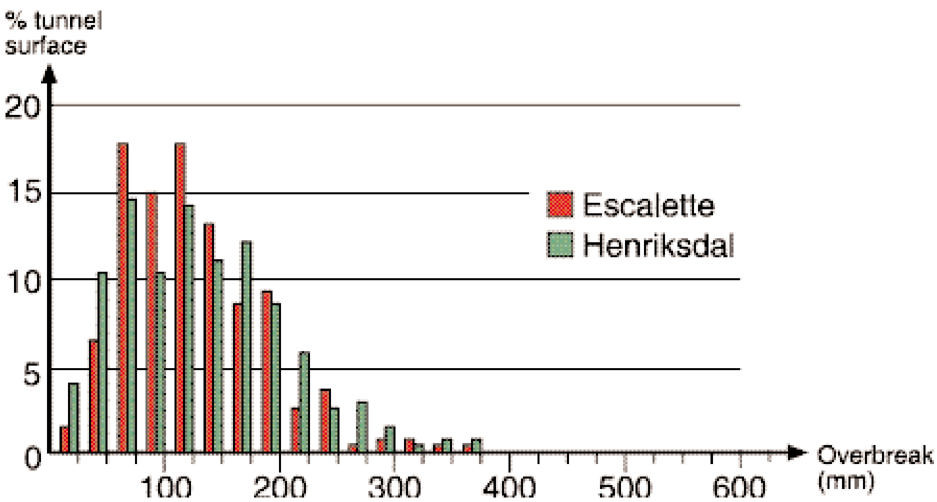


Figure 2: *Similar overbreak advances at the Henriksdal and Escalette projects.*

THE PERFECT SHAPE…

The reasons for the excellent results achieved at Boliden are due to the skill of the dedicated rig operators and the fact that the rock itself does not generate any noticeable overbreak.

So what are the main factors in reducing overbreak?

- First, the ambition of the site managers and operators is extremely important. Close monitoring of the tunnel face is a must in order to register undue overbreak and take counter measures – and a small bonus to the people involved can lead to great results.
- Geological conditions can have a great effect on hole direction. The drill string has a tendency to deviate perpendicular to the foliation in anisotropic rock like phyllite, schist and gneiss. The problem is more acute when longer rounds are used. A high frequency of joints in the rock can also influence the drilling direction.
- Blasting is extremely important, and employing the smooth blasting technique with electronic detonators in the periphery holes can contribute greatly to a smooth tunnel contour.
- Tunnel size affects drilling accuracy. When booms and feeds are extended to the full, they are not so rigid and deflections can occur. Exact computerized compensation is not easy to achieve – and the further out the booms are, the greater the collaring and orientation errors can be.
- Alignment of the feed is critical at the start of drilling and a tunnel face which is not orientated perpendicular to the drill rod may cause bending and an inaccurate starting point (see illustration on page 21). Low feed force and reduced impact at the start improves collaring and thus the straightness of the hole. The feed force should be just enough to maintain tight joints without bending the rod.

Fast and accurate drilling requires dedication, experience and reliable, state-of-the-art drill rigs. With these prerequisites, there are not many sites where the economic advantages of contour control can be ignored. M&C 1•99