# NATM: a significant support approach

## The New Austrian Tunnelling Method (NATM) looks to British Coal for approval, while the Yugoslavs prepare to adopt it to sink a shallow but difficult shaft

**By Peter Darling**

The recent Austrian Tunnelling Seminar, held at Nottingham University in the United Kingdom, concentrated on modes of tunnel failure, their monitoring and the various packages available for providing long term support, all of which involve rock bolting and shotcreting in some form or other. The New Austrian Tunnelling Method (NATM), although the name talks of tunnelling, is in fact a support technique.

The conventional method of support with steel sets relies on a number of ill-conceived assumptions. At one end of the spectrum support is required for all the weight of a loosened rock mass, whilst at the other extreme no account is taken of eccentric or inclined loading, the optimum delay between excavation and support, whether loading of the side-walls necessitates employing floor insets, the use of secondhand steel sets or their capacity to support after movement has 'started'. The inevitable compromise has led to the present system where steel sets are placed, say, at every 1m interval and should this be found to be insufficient then the interval is simply 'closed up'. These opening comments were made by Professor Golser of Geoconsult, Salzburg, Austria. His colleague Dr. Peter Schubert elaborated further on this theme. NATM provides a flexible method of support to control the progressive failure phenomenon. By placing rock bolts and shotcrete at the optimum time one is attempting to prevent the onset of disintegration by covering the first area of weakness.

In deep tunnels, rather than using shotcrete in an attempt to stop deformation, it has been found through trials in an underground power house in Colombia that the ideal method was to install steel supports with sliding connections, and once closure had decreased to use shotcreting, Dr. Schubert reported. Although shotcrete is a very plastic material, its characteristics are very time-dependent, whilst its capability to deform is limited to only 8-10mm/m. An alternative method is to use rock bolts and shotcrete with a coupling gap; this has the effect of dividing the shotcreted surface into segments, and should one area succumb to cracking this will not propagate further into other areas. Alternatively, various types of rock bolts have been developed, which by incorporating a yielding shank, give up to 8% extra carrying capacity before necking occurs.

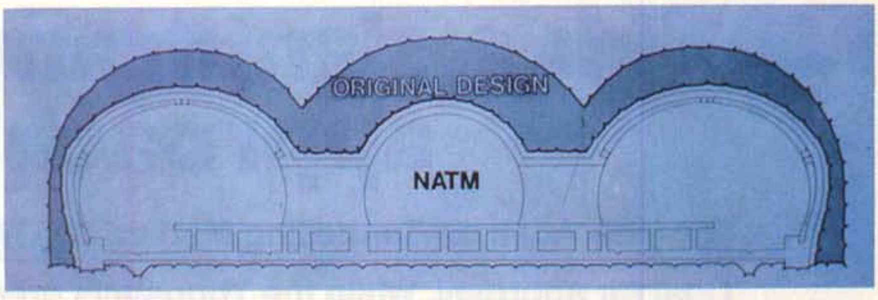
*NATM being used in a D-shaped tunnel where reinforced mesh (seen at the top of the final section) is placed prior to arch girders, shotcreting and final rockbolting.*

A new anchoring system has recently been developed which has been successfully used in the stabilising of a swelling footwall in a coal mine drift, according to Dr. Harald Wagner from Mayreder, Krous & Co. of Austria. The footwall, composed of clay, silt and a great deal of water gave what could only be described as muddy ground conditions with a 'stand up' time of zero. Anchor support was not possible, (indeed under their own weight 3m roof bolts would become half 'submerged' within minutes). Cut and cover or ground freezing methods were both considered too expensive, so a dewatering system was devised. This system, known as electro-osmosis, involves the insertion of an electrode (a hollow rock bolt) into the ground where it will remain to act as both an anchor and as a conduit for the grouting. Dewatering is achieved at 50V, but depending on the nature of the clay/silt the direction of flow between electrodes must be determined to give the maximum benefit; that is to say, a homogenous result is more important than a mixture of excellent to poor dewatered ground. A recent test showed that the moisture content of a clay/silt material was reduced by between 28-38%, enabling the anchoring abilities of bars to be increased ten-fold. It should be noted that not every clay/silt combination will respond to electro-osmotic dewatering and that the spacing of anchors is important.

"The time-honoured practice used by experienced miners of relying upon the squeaking of overloaded timbers to prove their effectiveness as supports has been replaced by geotechnical measurements. This bridges the gap between theory and practice, or rather the face worker and the engineer in the office", according to Dr. Purrer of ILF Consultants, Innsbruck, Austria, "and more importantly enables today's designer to use statistical analysis."

The question of timing with respect to the placement of supports has been long misunderstood; initially regarded as of little importance, support requirements were then fanatically installed at the first opportunity with little regard to settlement modes, measurements or load directions. At the Shakespear Cliff marshalling tunnel on the English side of the Channel Tunnel, geotechnical monitoring together with the use of NATM concepts enabled the state of equilibrium of the chalk marl to be determined. This indicated the right time to install the invert and subsequently meant that the shotcrete thickness could be reduced from 250mm to 150mm.

In another example, the excavation of a recently constructed high-speed railway tunnel was conducted in three stages using NATM. The initial D-shaped excavation was roof bolted and shotcreted in sections; this was followed by the construction of a central ramp which had provided access to the upper bench, but unfortunately the ramp was affected by squeezing or punching due to sideways forces. It was initially thought that this deformation of the ramp and the subsequent excavation of the second bench would render the pre-




*The substantial reduction in the size of the initial excavation means less production time and support materials per metre of development work.*

*Shotcreting has a rebound of only about 12%, and with the addition of an accelerator the placement of material can be achieved by a skilled operator without reworking.*

viously installed shotcrete ineffective. However these fears were unfounded as it was realised that there was such good interaction between the shotcreting and the rock that the transfer of loads (even when the support layer had been undermined) was unaffected.

Dr. Gerhard Sauer, of Fels-und Tunnelbau, Puch, Austria, acted as the consulting engineer on the recently completed drifts to access ore at British Gypsum's Barrow-upon-Soar mine in central England. Hydrogeological information proved that the Lower Lias hydraulic limestone was capable of a water influx of 50,000m$^3$/day under subartesian pressure. Thyssen (G.B.) Ltd. won the contract on the basis that it was able to guarantee completion date, predict costs with the minimum risk of overrun, provide stability of the lining with a water influx of less than 25 litres/min per drift, and avoid disturbance to the environment with no pollution to the aquifer.

The lining through the Lias consisted of three stages of work. The primary support, (NATM), consisted of reinforced 15mm square mesh of 6mm indented high tensile wire held in place by a three piece arch lattice girder, which ensured that there was no 'shadow cavity' behind the arch. Additional support included radi-

*Accurate measurement has led to the realisation that initial rapid support is not always the best policy. In certain circumstances, initial movement should be allowed.*

ally set rock bolts and rebar dowels for spiling ahead. The whole was sprayed in-situ with shotcrete without the need for longitudinal struts. The anticipated rebound of material was only 12% and the only additive to the sulphate resistant cement was 5-7% by weight of a sygnite accelerator. Since this primary shotcrete lining was not designed to withstand hydrostatic pressure, water had to be bled from behind this layer by small diameter plastic drainage conduits. These conduits remained in place until the final lining (with its associated seals) had been constructed. The second stage was the placing of a two part membrane; a geotextile was pinned to the shotcrete, then 1.8m strips of PVC were heat welded to washers held on the pins and the strips were electric-roll welded. The third stage was the construction of an in-situ concrete lining behind a conventional 8m long shutter.

Representatives of British Coal were optimistic about the future of NATM but pointed out that it was not only the management but also the Mines Inspectorate and the unions that would have to be persuaded that it was a safe and workable system. Various tunnels have been supported along their lengths by NATM, but as soon as any complication occurred the back-up system of steel sets was called into usage. When things get interesting for the geologists, they can become difficult for the engineer. Although NATM has been successfully used for various shaft inserts in the past it was the lack of long-term monitoring that had been achieved to date which was causing some concern.

It was also felt that the level of achievement had been impressive, although the highly stratified nature of the rock associated with coal mine roadways in Britain, and the difference in depths between these largely civil engineering as opposed to mining projects, could make NATM a system suitable only for shallow applications.

Elsewhere in Europe, the Velenje lignite mine is planning to sink a 350m shaft through soft formations using NATM. Uroš Bajželj of the Rudarski Inštitut of Ljubljana, Yugoslavia, explained how a 7.5m diameter shaft would be sunk using NATM and only once the final depth had been reached would the permanent concrete lining be installed.

At the end of the seminar Dr. Gerhard Sauer concluded that "if you ever wake up a mountain, you'll never get it to sleep again" and that whilst NATM may not be ideal for every application, it could become an established tunnelling method, especially where rapid tunnelling through soft or water bearing strata is required.

The concept of the New Austrian Tunnelling Method has been in use for a number of years, and up to now, its main area of application has been in civil construction work. That it is a successful method in the right conditions is now well proven, and it will be interesting to see whether in the future the mining industry will adopt it on a much wider scale than has has previously been the case, not only in the European context, but also worldwide. **• IM 1988**