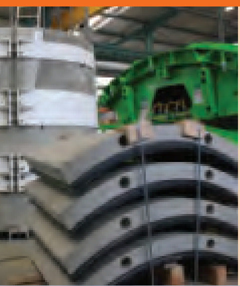
www.tunnellingjournal.com
April/May 2013

Tunnelling journal

The international journal for the tunnelling industry

SEE PAGE 18



SEGMENTAL INNOVATION

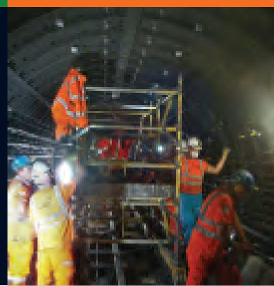
TJ LOOKS AT NEW TECHNOLOGIES AVAILABLE TO THE SEGMENTAL LINING SECTOR

SEE PAGE 34

PROJECT POLITICS

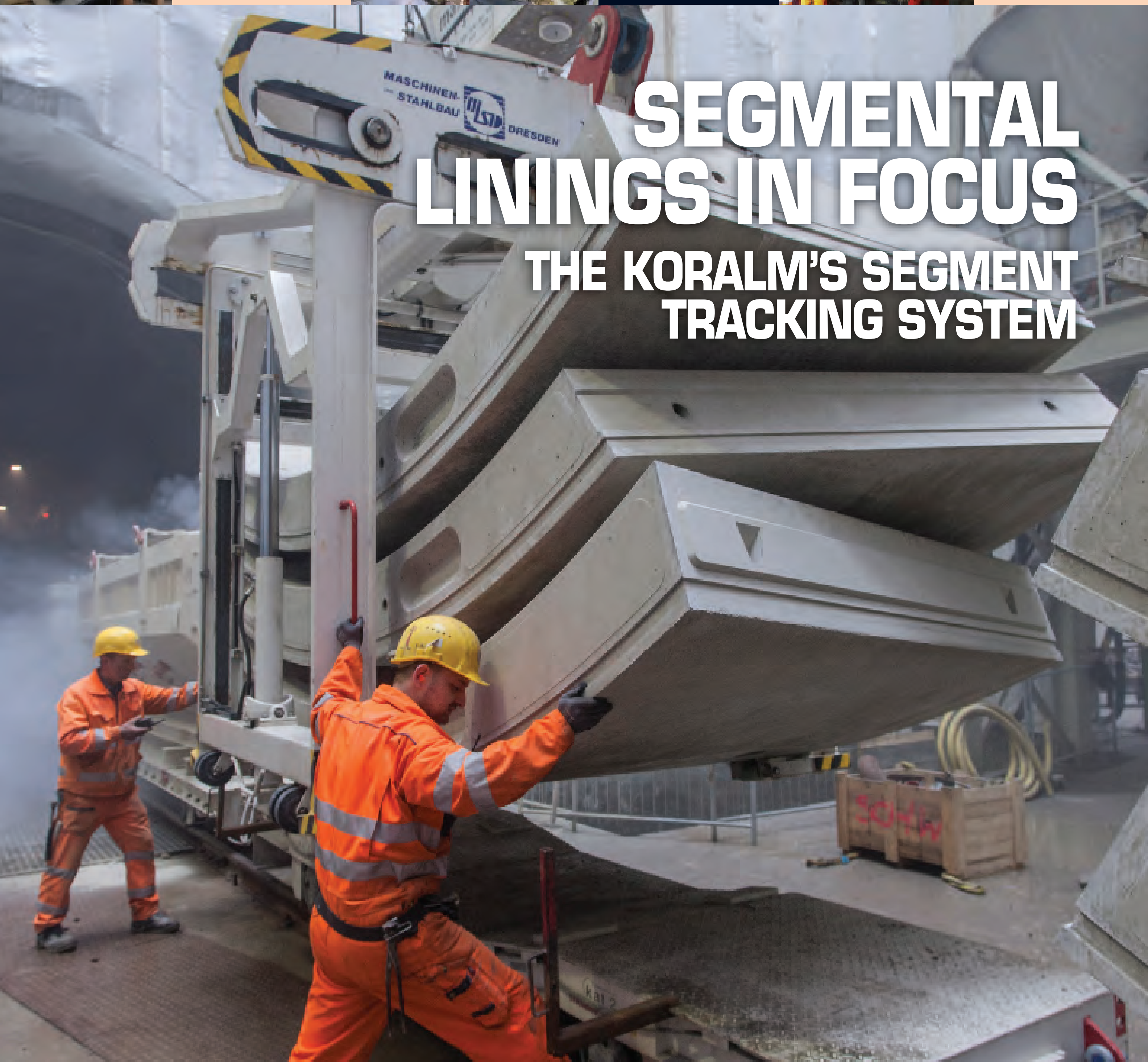
THE COMPLEX WORLD OF PROJECT POLITICS EXAMINED

SEE PAGE 40



JUBILEE REPAIRS

A FASCINATING INSIGHT INTO AN INTRIGUING GROUTING PROBLEM



SEGMENTAL LININGS IN FOCUS

THE KORALM'S SEGMENT TRACKING SYSTEM

The Koralm Project at a glance

Austria's new Koralm tunnel is one of the largest infrastructure projects in Europe outside of the three great Alpine pass crossings at Brenner, the Swiss Gotthard and France's Fréjus. At just under 33km long and with a maximum cover of nearly 1200m it is at least approaching the same kind of scale.

The twin bores for high-speed rail trains will form a critical link through Klagenfort in southern Austria and on to the north east via Graz and Vienna. Another major tunnel, the Semmering is also required and is currently under tender by the Austrian Federal Railways, which is also the client for the Koralm.

The Austrian route section in turn is part of a key trans-European route, the Axis 23 Adriatic-B Baltic corridor which will eventually connect Gdansk on the Polish north coast with Venice in north-east Italy.

The Koralm tunnel has been split into three main sections. A small southern contract has already formed the portal and an initial conventionally excavated 2km of tunnel. It starts near the little town of Deutschlandsberg sited in the vine and farmland valley countryside before the Koralm mountain range. It is almost complete.

Second and largest of the contracts, underway since late 2011 is for the central portion, with around 2km of conventionally excavated tunnel required for each bore and then long TBM drives through the hard rock of the Koralm mountains. These are slightly different lengths, 17.1km on the north side and 15.7km on the south. Both machines have just begun work.

The drive length difference is due to previous exploratory works on the third section and logistical issues which alter the breakthrough point on the southern bore, explains Wolfgang Lehner. He is project director for the joint venture carrying out the work, formed from an 80% majority of contractor Strabag with Austrian tunnel specialist Jägerbau.

"There was a shaft and fairly long exploratory tunnel of around 10km done for the Lot three," he says. The third contract, to be let shortly, is for 12.8km of twin tunnel, most to be done by TBM.

An exploratory tunnel was also done for the longest central section, to pin down the geology as much as possible and particularly to find the interface point between soft glacial ground in the west and the harder gneiss of the mountains. Strabag did that work in 2005-07, making a small 45m^2 cross-section bore.

"It was thought this might be a difficult area but in the end it was more straightforward than thought," says Lehner.

The interface fixes two different types of tunnelling for the project which uses conventional excavation in hard clays to the west and switches to TBM for the longer hard rock. This is mainly gneiss, a layered form first, with split planes - it is used locally for making roof tiles – and then solid older rock.

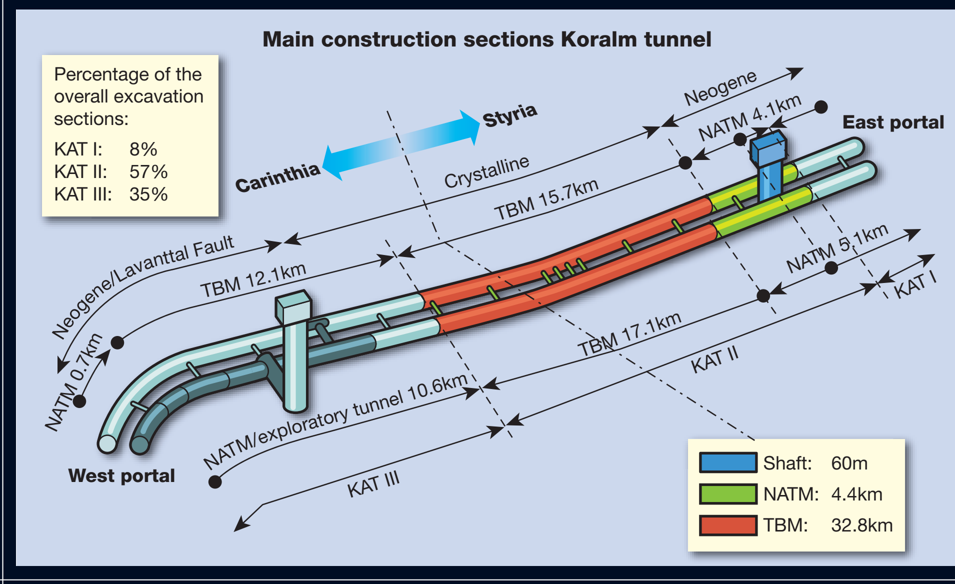
The main contract, for some 600M, was begun in January 2011 with formation of two deep access shafts and the conventional drives heading in both directions. They also saw the creation of two large parallel caverns for the assembly of the TBMs.

The Aker Wirth machines, each with a double head, arrived on site late last year and the first began driving in February with the second starting work just before Easter. They have an outside diameter of 9.93m. Swiss firm Rowa supplies the follow on back up train and segment delivery equipment.

They erect a six segment ring as they go, five pieces plus a full size key element; inner diameter of the rings is 8.8m and the ring segment thickness is 350mm leaving an annulus of 200mm which is filled with pea gravel.

Details of the tunnelling will be explored in a follow on article.

Above: plan map of the Koralm Tunnel location. Below: section showing the construction lots of the tunnel



KORALM TUNNEL SEGMENTS - complex monitoring and management

Strict quality control and tracking requirements are being met with the SDS computerised production control system for the segments going into the new Koralm tunnel in Austria. Adrian Greeman visited the site and files this report

DRIVES FOR THE MAIN sections of the Koralm high speed railway tunnel project began work at the beginning of this year, two 9.9m diameter TBM hard rock bores of 15.7km and 17.1km length respectively form the lines on the north and south sides of the alignment. They will take around three years to complete their eastwards progress, meeting eventually with 12km and 10km drives coming the other way by another contractor.

The Strabag-Jägerbau joint venture contractor for the central and largest section of the project, Lot 2, is pleased with the start it has made on the TBM sections. The first machine began in February on the southern bore and the second machine starting work earlier than expected, just before Easter.

Meanwhile in its first two years, the contractor has already made some 4.4km of tunnel by conventional methods in soft ground near the western end. But the hard rock drives are the key part of its €600M contract.

A key element of its work in the initial period of the contract has been setting up and preparing for the segment production and delivery to the machines which will consume eventually some 103,500 segments for the rings and another 17,250 larger invert segments. These 13.4t pieces are for a flat floor which is installed immediately behind the machine and to which are bolted twin railway tracks for personnel carriers, logistics and machine supply of segments and grout.

Strict requirements for quality of the segments have been set by the client ÖBB-Infrastruktur, the capital works division of Austrian state railways. As well as tight quality assurances it wants full traceability of the components in the segments to allow for easier trouble-shooting and investigation in the event of damage or failure within the tunnels.

The requirements arise particularly from caution about potential difficulties in the rock and particularly in the first seven or so kilometres of the drives through striated gneiss with significant slip surfaces in the rock. For this section there is also a very unusual requirement for an in situ lining.

"The TBM will install a basic segmental lining and then we will follow on with a waterproof drainage membrane and in situ inner shell cast using a travelling formwork as you would in a conventional tunnel," says Strabag project director for the joint venture Wolfgang Lehner.

In the later harder gneiss section the tunnel will use simply the plain segmental lining.

All these segments must be produced on site. The client ruled out segment production elsewhere and delivery to site because of the potential disruption it would cause. The area is a pleasant rolling landscape of farmland, vineyards and small townships.

"The delivery of so many segments by trucks over a three year period would have been impossible," says Andreas Lange, segment production manager. He says that it would also have been difficult to bring them in by rail, because although there is a line to the site,

installed as part of the mobilisation, it does not have sufficient capacity. "It is needed for supplies like the pea gravel, grout and so forth and for removal of spoil," he say.

But producing so many segments on site has its own difficulties, most of all the space. Within a tightly constrained area the contractor must have not only its tunnel access and spoil disposal handling but also two segment factories and a storage area. "That is very small," says Lange. For his purposes, he has a yard stretching approximately 150m in each direction from the central tunnel access shafts, and just 50m wide. Within this enough segments must be stored to allow for 28 days of hardening and supply to the machines. A supplementary area is available to the back of the site but it is not much.

Different rings

Complicating the picture is the need to produce various types of ring segment. There is a basic ring, and then a high strength ring with more reinforcement and a stronger mix design for the concrete. A third type of specially reinforced ring is needed for the points in the tunnel where the tunnel lining will be broken through to form cross passages, every 500m. These have more steel still and heavy 100mm diameter dowel bars at three points to connect to the next ring, to give the lining stability once some segments are broken out.

The big 4m long invert sections also have to be made and stored. They use a different concrete mix still.

"The invert sections mean you need extra space for those to have their own areas even if sometimes it is left empty," says Lange.

The solution to these problems, both tracking and checking elements and then storing and locating them has been a relatively complex database and tagging system developed by TBM guidance system maker VMT. Called rather prosaically the Segment Documentation System it has been given one

Above: the invert. Top left: segments delivered to the base of the shaft. Top right: segment installation at the TBM

of its first full outings at Koralm.

It works with two main elements, firstly a labelling and tagging system to trap and then enter information and then a relational database taking advantage of the ways that data can be added together, cross referenced and queried to bring up all the pertinent information about any particular item. Management audits, reports, and other information can be drawn out in myriad forms.

VMT has also developed software within the system for highly accurate measurement and virtual 3-d modelling of segments and the mould they are produced in.

"Modern segments are made to exacting tolerances," says Nod Clarke-Hackston, international sales manager for VMT, "and even a fraction of a millimetre can set it out."

The system uses input from modern laser scanners, two of which in fixed positions can be used either to scan the interior of a steel form or the final segments once removed. The factories at Koralm have a measuring space fitted with Faro scanners.

These can work in minutes compared to painstaking day long checking with total stations required in the past. A 3-d best-fit volume model is produced. VMT has specific software, TubGeo for this purpose.

Scans are carried out on a regular basis to check the forms and also on the output of segments with a specified procedure to check the first ten from each model, then to sample one-in ten and dropping to one in 500 if no deviations are being picked up.

The SDS also comes with a tagging and recording system using bar codes in this case, though RFID mini-chips can also be embedded for automated work. The various inputs into a segment are all tagged with their own individual identifiers barcodes.

At Koralm there are two factories for segments each using Herrenknecht made forms, moving around a production carousel with a seven-hour heat curing oven. There is a separate batching plant for each factory fitted with Liebherr pan mixers. An upper floor is used to assemble the steel segment reinforcement cages.

"Deliveries of cement, additives and in some cases, aggregate, are by rail," says engineer Robert Goliasch, "on a line we built for the project from the main line."

The various component streams into a segment each have a bar code, including the concrete batch, the steel form itself, and the reinforcement cage. Tags are heavy duty weatherproof plastic stuck on the outside or in the case of the reinforcement cages, are like airline baggage tags around one of the bars,

Above left: a partial Koralm Tunnel ring. Above right: barcoding of each individual segment

also in heavy plastic. Each barcode number references data on the particular elements such as details of time and date of mixing, water content, cement content and aggregate for the concrete, the rebar design for the cages or the particular mould and its laser scan details.

The workers in the factory have hand held scanners to record the particular barcodes as they go through the process and enter further details. Mould preparation, moulding, concreting, de-moulding, initial indoor curing storage for 24hours, and outside storage all see data entry.

"The scanners are quite easy to use, like modern Smartphones, with touch screens to call up the appropriate menu," explains Lange.

The final segment gets a new barcode as it leaves the mould, made up of the form code, the reinforcement and the concrete, and this then allows its progress to be traced.

That code is used to follow the segment through to the machine. The segment erection procedure at the machine also uses barcode readers so that the exact segment installed in

the exact position in the tunnel is detailed.

"It means that very precise information is available on every ring of the tunnel lining if any issues develop," says Lehner. "That allows for a high level of fault diagnosis. Was there a problem with the temperature, the concrete mix, the rebar etc?"

The individual segment tracking system has another function too, in storage of the segments. Because of the tight limits on space Lange wants to avoid leaving empty voids in the storage racks. But usually, to know where segments are, and equally to access them quickly, requires ordering then by type and age.

"But the database can track very precisely where a segment has been stored within the yard," says Lange. That means the segments can be piled up close and then to find any particular type of segment and especially to locate segments sufficiently aged for concrete strength, the database is queried.

The 60t capacity Künz portal cranes used in the yard work with such database storage tracking systems in the container ports, which the company primarily supplies and are able easily to work here with the positional information in the database.

VMT offers an optional interface between the database and the crane navigation displays in the cab and automation is also possible.

In consequence virtually no space is left free in the yard. To further save space the yard has adopted a double-stacked formation, with the six elements of one ring stacked on six more below. "That is the reason we chose a full size keystone design for the segment ring," explains Stephan Frödl, a design engineer for the segments at Züblin's design unit, now part of Strabag. "A half unit would have prevented stacking above it." Similar considerations made the use of a universal ring the obvious choice, since a left-right ring system would have needed greater space.

The tracking system also helps limit the number of high strength rings needed at any one time. The exact requirement for the stronger segments is not known until the TBMs reach a patch of bad rock along the bore. Rings are then needed immediately which means a reserve of stronger rings has to be kept and found on demand. "There is a small surplus needed all the time," says Lange. If there is still a surplus by the end of the drive he says they will simply replace basic rings for the last small section of the tunnel to use them up.

The database can also store visual images, which is particularly useful if there are cracks or faults in any segments, so that images of the problem can be attached to the other data all the way back through production and delivery.

All this will more and more come into play now as the two TBMs get into their stride on the tunnels and the consumption of segments reaches full use. Just how that works goes is another story - to be told in the next issue.

Preparation and arranging of the cages and the Herrenknecht Formwork segment factory