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The Koralm tunnel is part of a new high speed line linking Austria's third city Graz with Klagenfurt in the West. The tunnel in turn is part of the the 44.2km long Wettmannstätten - St. Andrae section. It will be the longest tunnel in Austria when complete at 32.9km and comprises two bores between 40m and 50m apart, with cross passages every 500m and an emergency station approximately halfway along, which has a third central tunnel as a refuge.

The route is part of an overall railway corridor for the east side of Europe, the Baltic Adriatic which makes up the so called Axis 23 of the TransEuropean Network (TEN). The first part of the axis is a link from Gdansk in Poland to Bratislava in Slovakia with an extension running on to Venice and Bologna in Italy. The Koralm and another large tunnel, the Semmering near Vienna are part of the link extension, though go-ahead is awaited for the latter. The 27km long Semmering began construction last year.

Construction of the Koralm began in 2010 and will be completed by a third part of the contract which is currently in final tender negotiation. It should see construction finished by 2017. Fit out and commissioning was scheduled for 2020 service but it is likely it will be delayed until 2022 for budgetary reasons, and to synchronise with the opening of the Semmering tunnel.

Koralm's rail tunnels hit their stride in Austria

Above: The Koralm worksite earlier this year before segment production had got underway. Centre is the double shaft access and alongside the new rail line. The conveyor system runs out to spoil disposal area

Last issue TJ looked at segment production for Austria's Koralm tunnel. Now Adrian Greeman reports on the drive itself, off to a racing start with two Aker-Wirth TBMs. Pictures by the author.

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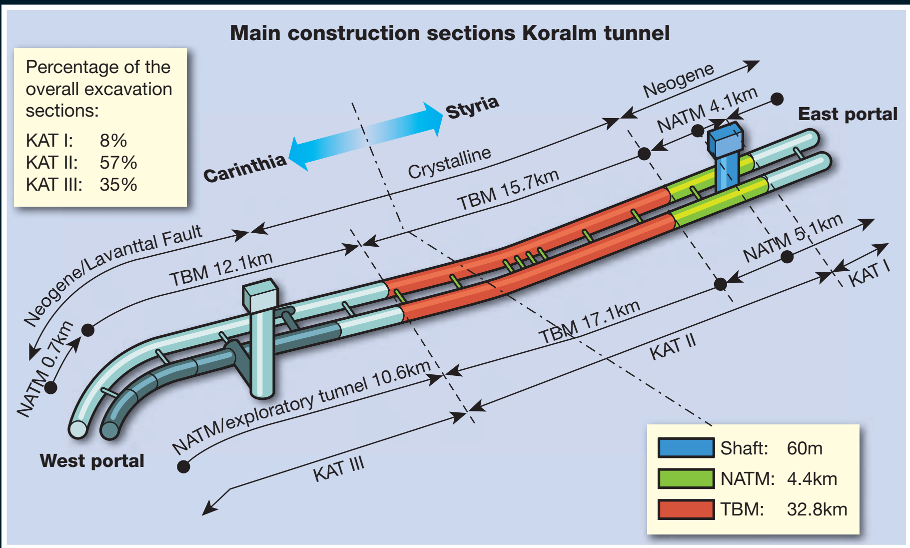


AUSTRIA'S TWIN BORE Koralm tunnel will be the biggest rail tunnel in the country when it completes in four year's time. With a length of just under 33km it also compares to some of the other great Alpine tunnels in Europe like the Swiss Lötschberg high speed rail tunnel, though it falls short of the 57km long AlpTransit Gotthard, or the still to be built Brenner in upper Austria.

It made sense therefore to break it into two major parts for construction, some 12km driven in from the western end and another 22km from the east. "Actually there is a third smaller section making up part of this eastern end covering the portal construction and an initial 3km of the drives," says tunnel manager Wolfgang Lehner for Austrian contractor Strabag. He says he does not quite understand why the client, the state railway's building division ÖBB-Infrastruktur, wanted it that way "but there it is."

It means his Lot 2 contract, being done in joint venture with local TBM specialist Jäger Bau, starts a way in from the western portal. It runs then for just over 19km on the south side and 17.7km on the north; the first 2km of each in conventional drives and the rest in TBM tunnel. The difference is due to the logistics of the drives on the Lot 3 contract which is yet to be let, but where a 10km long exploratory tunnel has already been completed.

The western end of the project also saw exploratory work back in 2005-7 when the scheme first began serious design work under a five firm design consortium led by PG-KAT. "The purpose was really to find the interface point between the soft sedimentary ground and the crystalline gneiss of the Koralm range itself," explains Lehner. Strabag, on its own, undertook that job, working from a shaft about 3km in from the eastern portal location.

"Actually we found the ground was not as difficult as it could have been with not too much faulting and no serious water ingress."

The main contract followed after extensive bidding rounds for what is after all, the largest single contract let in Austria, around €600M worth covering 57% of the total tunnel works. After the award in late 2010 the work got underway at the beginning of 2011. Lehner says the company is proud of itself for winning the prestigious job.

The main tunnel drives are to be carried out by TBM through the hard igneous rock of the Koralm range which is primarily gneiss and mica schist sequences with subordinate marbles, amphibolites and eclogites. The mountains, in the southern part of Austria west of Graz, are as high as some of the Alps to the north, but still a substantial obstacle for a high speed railway line, which must run with limited gradients. "The range is up to around 2000m high on the alignment which means we will have a maximum cover of about 1200m," Lehner declares.

This might involve some reasonably hot conditions, he says, at the deepest point, though nothing like the 45 degrees and more of the Gotthard tunnel drives which needed special measures.

"The client does not expect conditions to get to an impossible point or even put us above the limit for safe working which is around 28 (degrees C)," he says, "but there will be warmth in the rock and the action of the machine on the rock will create heat."

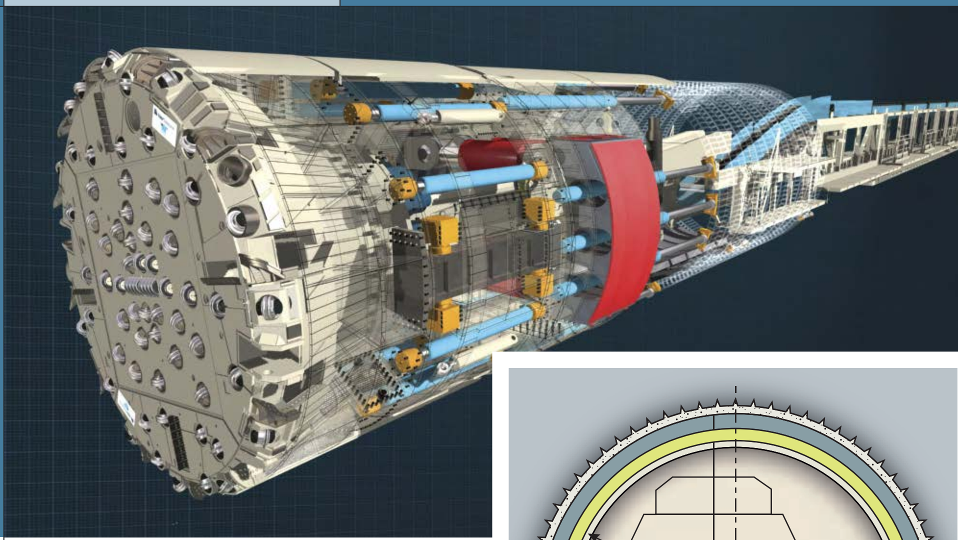
He says provision has been made for later with a Hergo cooling system likely to go in for the deepest sections.

Site preparation and first phase

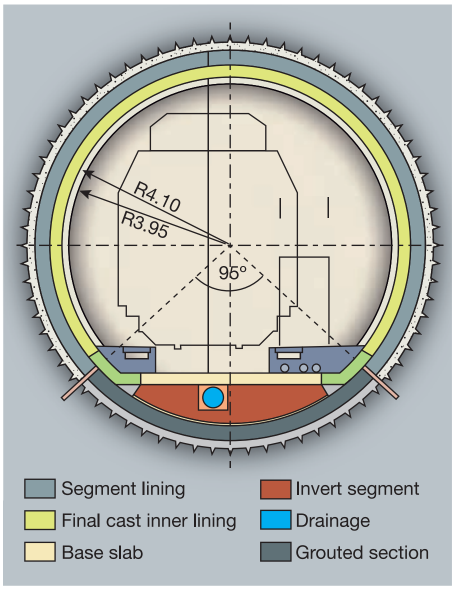
But before beginning that work there has been significant site preparation along with major tunnel excavation in soft ground. The JV's access point is about 3km in from the west with a site set in pleasant rolling farmland and woods close to the picturesque town of Deutschlandsberg. At this point the tunnel line is 60m deep and so it was necessary to build a shaft. "We already had built a small 30m diameter shaft for the investigation tunnel," says Lehner," but this was much bigger."

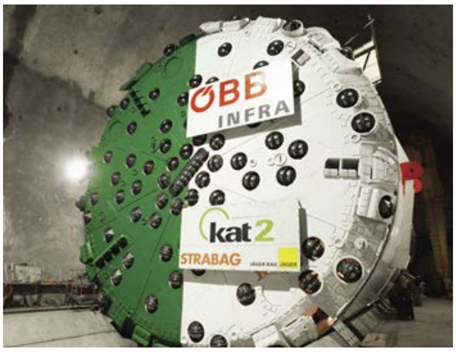
It comprises two interlocked shafts in fact, in a figure of eight configuration, built with secant pile walls 80m deep down through a solid clay ground, "which is quire firm and even requires explosives at some points" says Lehner. "It's very good for tunnelling in fact, quite firm. We have done many kilometres of tunnel in Germany for the high speed rail in ground like this."

Construction was primarily by tunnelling excavator using Liebherr 944 machines with shotcrete and rockbolt support. Mucking out was with diesel dump trucks running to the shafts where a gantry crane lifted muck filled buckets to surface. A conveyor system just installed for the TBM drives was ruled out he



Left: Schematic of the Aker Wirth TBM which has a double shield configuration with grippers hydraulic rams. Below left: Some 7km of the bore will have segments plus an in situ inner lining. Below: The conveyor system was being fine tuned in April





the steam curing happens in a short term closed store, protected from the weather, which can be cold in winter and quite hot in summer. Segments remain for 24 hours before being lifted outside for storage.

A complex computerised tagging and tracking system from VMT, the SDS segment documentation system is used for quality control of individual segments and then for organising their storage in the yard outside. By keeping a live database of all the individual segments, every one can be quickly located in the yard wherever it is positioned within a storage stack and then be lifted in or out by four 60t capacity Künz portal cranes running up and down. These have a 50m width and 12m hook height.

"That allows us to fill most of the space in the yard without wasting any places for separating different types of segment rings in order to know where they are," says Andreas Lange the segment production manager.

With only a 300m by 50m space to store the rings, 150m either side of the central shaft, this is important and not least because the rings come in three different types, normal, strong, and additionally reinforced, for cross passage areas. Each ring has six segments, including two with tapers and a full size key unit which means a variety of segment types and rings.

The computer tagging system not only allows tracking of these variants but also means two rings, each weighing 47.5t can be stacked one on the other, twelve segments high in the yard. Large invert units which later fit within the installed rings, weight 13.4t each and are also stacked 12 high.

When TJ was on site in April the yard was already full, though the factories were only just getting up to full production because the second of the TBMs below ground was just starting its drive.

TBM machines

These are Aker Wirth hard rock TBMs ordered after a detailed comparison with other options, including Herrenknecht and Robbins in America and Hitachi. Location of the works was among the factors guiding the choice, since the Aker factory is relatively nearby. "But Aker is also well known for its hard rock experience," says Robert Goliasch, one of the mechanical engineers in the site team.

Strabag's philosophy in procurement is not to take full packages of equipment he says. "Rather the company likes to examine all the options and then try and pick the most suitable, fitting it together ourselves and tuning the interactions."

For the tunnel machines this has meant selecting a backup train for the TBM from Switzerland's Rowa rather than the Aker Wirth option. The 9.93m outside diameter machines were ordered early on and delivered from the end of last summer when the underground start chambers were built.

These chambers were the last part of the NATM excavation work which formed 40m long caverns 20m high and 15m wide. The northern chamber was begun later as the clay excavation continued slightly further on this side.

The TBMS themselves are an unusual double headed configuration says Lehner, "which allows you to install a ring while continuing the drive ahead. The machine pushes from grippers in normal mode though there is an option to push forwards from jacks against the segment ring." Thrust is 80,260kN.

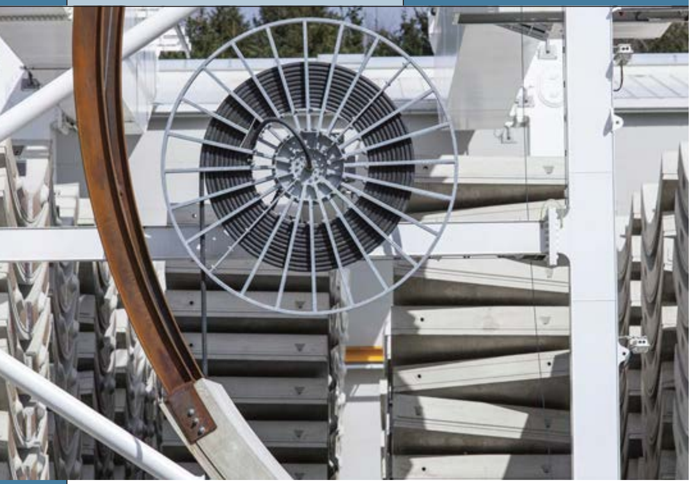
He is not expecting to have to use the jacking method very often he says as the ground is expected to be fairly solid.

The cutterhead is a hard rock configuration with 4800kW of power and using 17" cutter discs for carving through the gneiss which is likely to be around 170MPa maximum hardness. In the first 1000m or so driven on the first tunnel when TJ was on site, it had not reached that much says Lehner.

Lehner says he is not much concerned about whether 17" or 19" discs should be used which he says, "can get a bit like a religious dispute sometimes." The firm used 19" cutters on its recent Niagara tunnel job but, "our experience does not say it is crucial" either way. The decision is more one of economics he says.

Spoil disposal system

While the machines were being assembled last autumn the site was also being geared up for the TBM work. This is a very different phase of the job to the clay excavation, requiring the segments works to be underway, and a



completely different spoil system.

Strabag is using conveyors for TBM drive spoil, below ground, for the lift up the 60m of the shaft and then away for disposal at surface. For all this, it is using Swiss firm Agir whose distinctive yellow covered conveyor lines for the second machine were still being assembled in April.

These conveyor lines, one for each tunnel, run for some distance from the bucket conveyors at the shafts, carrying the spoil across the road alongside the site and to an eventual three disposal sites, two close by some 500m away on nearby farmland, and the third about 1.5km away.

The local disposal fits in with the client's philosophy of reducing the significant truck traffic in the area. Rail capacity would not suffice for the 2.9Mm^3 of crushed rock being removed by the TBMs and so a huge number of vehicle movements would be needed.

The conveyors are not simply dumping the spoil however, but deliver it firstly to a cleaning and sorting plant sited in the middle of the first and largest of the disposal areas. A part of the rock, around one third, is expected to be used in the concrete production as aggregate, "depending on its quality," says Goliasch. "There could be mica in the rock or other components which make part of it unsuitable."

The crushed rock spoil from the face is likely to contain a significant proportion of fines whatever the specifics, and so it is to be sifted and only the larger sized fractions will be recycled for concrete.

The TBM drives

With the early completion of the first tunnel work, an early start was possible for the TBM driving the southern bore, which began its drive in January and has currently completed nearly 1.8km, a satisfying progress says Lehner.

The machine is supplied with segments via a double track train system being laid in the invert behind the machine. The flat floor for the tracks is produced by installing precast invert units which are 4m across, and then laying and bolting the rails to that.

"We are using a conventional rail system because a high speed rail tunnel like this is not really big enough for rubber tyred vehicles, which need a wider passing space, and because this excavation is quite long at 17km," explains Goliasch. Inner diameter of the segment ring is around 8.8m.

Schöma locomotives are being used and segment delivery wagons are mainly from Herrenknecht, many of them brought from the work that Strabag did on the Lötschberg tunnel on Switzerland's AlpTransit programme.

The inner diameter will eventually be reduced further, at least in the first 7km or so of the rock drives. This is because there will be an additional inner lining cast in-situ.

Lehner explains that this unusual inner lining has been specified by the client because the gneiss is of two types. In the early part of the drives it is a foliated rock and then there is a harder more solid rock in the deeper part of the drives. "The client is concerned about the tunnel strength long term in the earlier part and therefore requires this extra lining" he says.

The double lined section will also have a waterproofing membrane. In the further section the tunnel is to be free drained.

For both sections however the segmental lining is similar. The TBM erects the six segment universal rings with a hydraulic erector in one of twelve orientations to achieve direction. The ring segments are 350mm thick which gives an outer diameter of 9.5m leaving a 200mm annulus. The space is filled with blown in pea gravel.

Left to right: Segments remain in the storage yard for at least 28 days. A rail system transports them to the shafts. Wolfgang Lehner is the JV project manager

"There is also some grouting of the lower part of the backfill," says Lehner. The grout additionally infills just over 90 degrees of the gravel ring and is done primarily for tunnel operational reasons, absorbing track vibrations from the high speed trains.

Initial TBM progress was good and the first machine was making 30m a day, which is just over 15 of the 1.9m long rings, "so it looks like we made the right choice for the TBM double shield system," says Lehner.

One of the complications of the drive which might slow the machines is the use of additional strength segments where the rock is deemed less sound or there is faulting, another requirement of the client in order to ensure long term usability for the tunnel.

"There are two segment types, one with more reinforcement than the other," explains Lehner. Deciding what to use is done as the drive proceeds using results from forward probe drilling with onboard core drills every second or third day. "We can do up to 100m if we need to," he says. He thinks about 10% of the rings might need to use the stronger type.

There are also additionally reinforced segments for the areas of the tunnel where cross passages will later be cut through and the lining has to be broken out. The cross connections, primarily for safety purposes will be every 500m and will be carried out with drill and blast conventional excavation.

There is also to be an emergency train evacuation station halfway along the final tunnel comprising a 1.1km section of additional excavation with a third tunnel set in between the two main bores and additional cross passages (see box).

Lehner is pleased with work so far. The second machine also made good progress since launch in late April and was already over 1km in in early June while the first machine has reached 1800m. With three months in hand from the first phase of work and the drive going well he is optimistic that the schedule can be kept for completion in 2017.