SEMMERING BASE TUNNEL

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ABSTRACT:

Semmering Base Tunnel is one of the major infrastructure projects in Europe currently under construction in Austria. As part of the Baltic-Adriatic Railway Corridor the new tunnels will replace the existing railway line with a steep gradient and small radii, which does not fulfil the requirements for modern rail traffic.

The tunnel system consists of two 27.3 km long single-track tunnels, numerous cross passages, a complex underground emergency station with two 400 m deep shafts and two temporary access points. The maximum size of the caverns in the emergency station is in the range of 20 m by 18 m, which are also used for site installations during construction. The temporary accesses include a 1.2 km long access tunnel with two 120 m sub-surface shafts at its end, two additional 100 m shafts from the surface and numerous caverns at the shaft head and toe.

The applied construction method for the majority of the underground structures is NATM. In the eastern part of the tunnel, due to the given geological condition, a section of about 8 km of the running tunnels is excavated by TBM. At the peak time of construction works 12 NATM and 2 TBM headings are running at the same time.

The maximum overburden is in the range of 950 m in difficult geological conditions within a wide range of geological units. This includes also extensive fault zones and a water inflow of up to 300 l/s in certain sections. In order to meet such conditions complex heading concepts, extensive support measures and partially special ground improvement works such as grouting are foreseen.

Construction works are ongoing from 2014 until the planned start for operation in 2026.

1. GENERAL

After finalization the 27 kilometre long Semmering Base Tunnel will form part of the Austrian section of the Baltic-Adriatic Railway Corridor stretching across Europe connecting Gdansk in Poland at the Baltic Sea and the Bologna in Italy at the Adriatic Sea. The tunnels are located approximately 80 kilometres south of the Austrian capital Vienna connecting the towns of Gloggnitz in Lower Austria and Muerzzuschlag in Styria (see Figure 1.).

The new tunnel system will replace the existing world heritage site Semmering-Railway, which includes numerous tunnels and viaducts built in the mid-19th century. The alignment of the existing railway with steep gradients and small radii does not fulfil the requirements for the operation of efficient and modern rail traffic. Heavy cargo trains require the use of an additional locomotive for the route. The newly built tunnels will improve the travel quality and time for passenger and freight trains crossing the mountainous landscape. The existing Semmering-Railway line will remain in place for maintenance purposes of the new tunnel, for local traffic and as a tourist attraction due to its breath-taking scenery.

The total investment costs for the project are around 3.3 bi. Euros, whereas 1.5 bi. Euros are related to the civil construction works. Pre-construction works started in 2011 and underground excavation in 2014. The final opening for operation is scheduled for 2026.

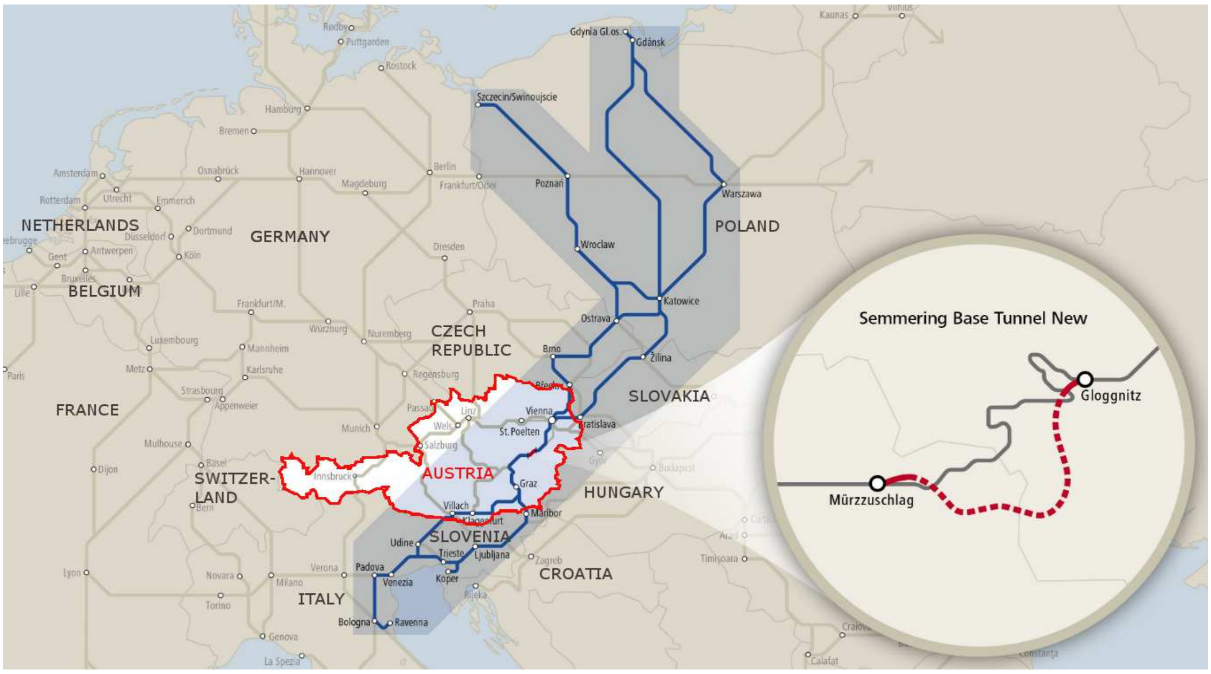

Figure 1: General location overview (source: OEBB)

2. TUNNEL AND CAVERN SYSTEM

The final tunnel system includes two single track tubes connected by 56 cross passages with a maximum spacing of 500 metres and a central underground emergency station with two 420 metres deep ventilation shafts. For construction purposes four additional, temporary shafts are required. Two of the shafts will be excavated starting underground via a 1.2 kilometre long temporary access tunnel located around 200 metres above the main tunnel alignment. The spacing of the mostly parallel running tunnel tubes is around 40 metres, which is enlarged at the underground emergency station as well as in massive fault zones and reduced in the portal areas. The alignment of the tunnel is based on a maximum train velocity of 230 km/h with a maximum inclination of 8.4 ‰.

Due to the envisaged completion date and for logistic reasons, the main underground works for the tunnels, shafts and caverns are divided into three separate construction lots designated SBT 1.1, SBT 2.1 and SBT 3.1 (see Figure 2.). An additional construction lot (PMZ 2) includes the cut and cover and open cut tunnel section with a total length of 650 metres at the southern portal as well as the modernization of the adjacent railway station in Muerzzuschlag.

The excavation works for the underground structures are carried out by means of NATM for a total length of 19 kilometres in the northern and southern parts of the tunnels. At the peak of the excavation works a total of up to 12 NATM headings at various locations in the main tunnel tubes will be running in parallel. Due to the geological conditions for about 8 kilometres in the central section of the main tunnel tubes, TBM method is applied.

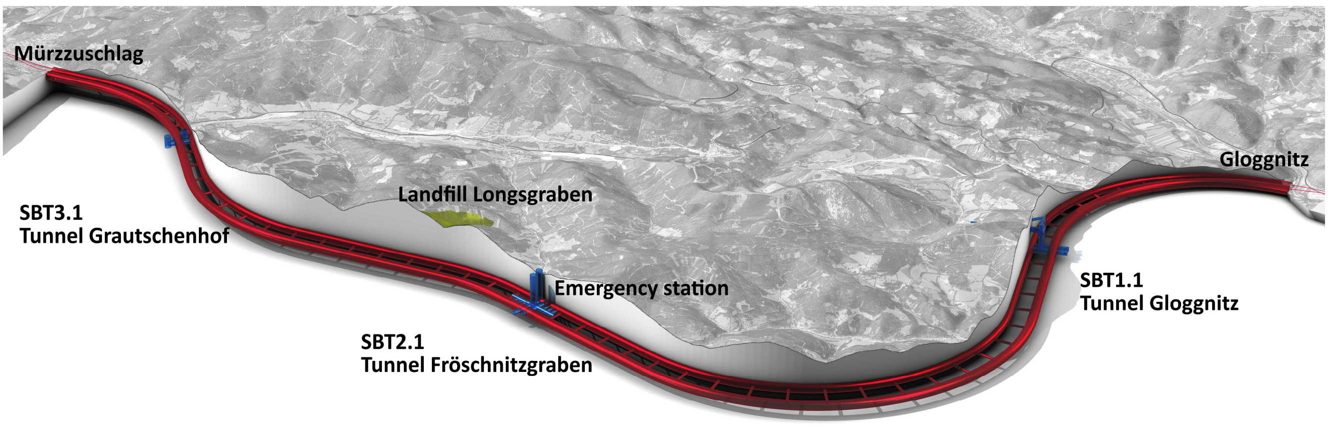

Figure 2: Scheme of tunnel system and construction lots (source: OEBB)

3. GEOLOGY, HYDROGEOLOGY AND GEOTECHNICS

Overall the geological conditions of the tunnel system can be described as an area of intense tectonic imbrication. The main units are the so called Greywacke zone, the Semmering unit and the Wechsel unit.

Within frequently changing conditions rocks consisting of metasediments such as phyllite, schist, quartzite, locally sulphate rocks and metasandstone of various tectonic units as well as carbonate rocks and highly fractured metamorphic crystalline schist and gneiss will be encountered. The geological units are separated by distinct fault zones which formed during the orogenesis with extensive folding and nappe stacking, leading to an imbricate structure. Out of the numerous fault zones especially the ones consisting of cataclastic fault material with high overburden are challenging the construction procedure. Within the carbonate rock formations a considerable water inflow of up to 300 l/s is expected.

For the design and implementation, the tunnel was divided into 33 rock mass zones, of which more than 40 ground types were evaluated by the geotechnical design team. Rock mass zones can be characterized as tunnel sections, which show similar conditions in terms of geological structure or units, proportions of ground types and hydrogeological conditions. A ground type consists of a rock mass with similar in-situ properties, which refers to a volume of geotechnical relevance for the project.

4. MAIN STRUCTURES

4.1 RUNNING TUNNELS AND CROSS PASSAGES

The main tunnels are single track tubes based on the clearance requirements of the Austrian Federal Railways for high capacity railway lines. The excavation area of the regular cross sections is around 75 m^2 for both excavation methods. The inner contours of the tunnels include space for electrical and signalling installations and an emergency walkway. Certain sections of the tunnels are widened due to geotechnical or logistics reasons increasing the excavation area to a maximum of approximately 180 m^2.

The foreseen 56 cross passages between the main tunnels will act as emergency connections in case of an accident. In addition, the cross passages are equipped with technical rooms for electrical and communication purposes as well as maintenance installations. The excavation area of the cross passages is around 35 m^2.

The cross sections of the single track tubes, the cross passages and the caverns are designed with an outer and inner lining system (see Figure 3.). Where the NATM method is applied, the outer lining system consists of reinforced shotcrete with additional support measures such as rockbolts and forepoling pipes. A segmental lining system forms the primary lining system for the TBM method.

The inner lining for both methods is made of cast in-situ concrete, which is normally unreinforced. Exceptions with a reinforced inner lining are in areas of fault zone crossings or intersections with cross passages only. A fibre reinforced inner lining is applied in sections underneath residential areas or the main infrastructure where an improvement of the fire resistance properties is required.

The inner and the outer linings are separated by a waterproofing system consisting of a smoothening shotcrete layer, a waterproofing membrane and a geotextile. Groundwater will be drained off by lateral drainage pipes placed at abutment level in between the inner and outer linings.

In order to keep vibration and noise emissions below acceptable limits underneath residential areas the installation of a mass-spring track bed system is required for certain sections of the tunnel. For the main length of the tunnel a slab track system will be installed.

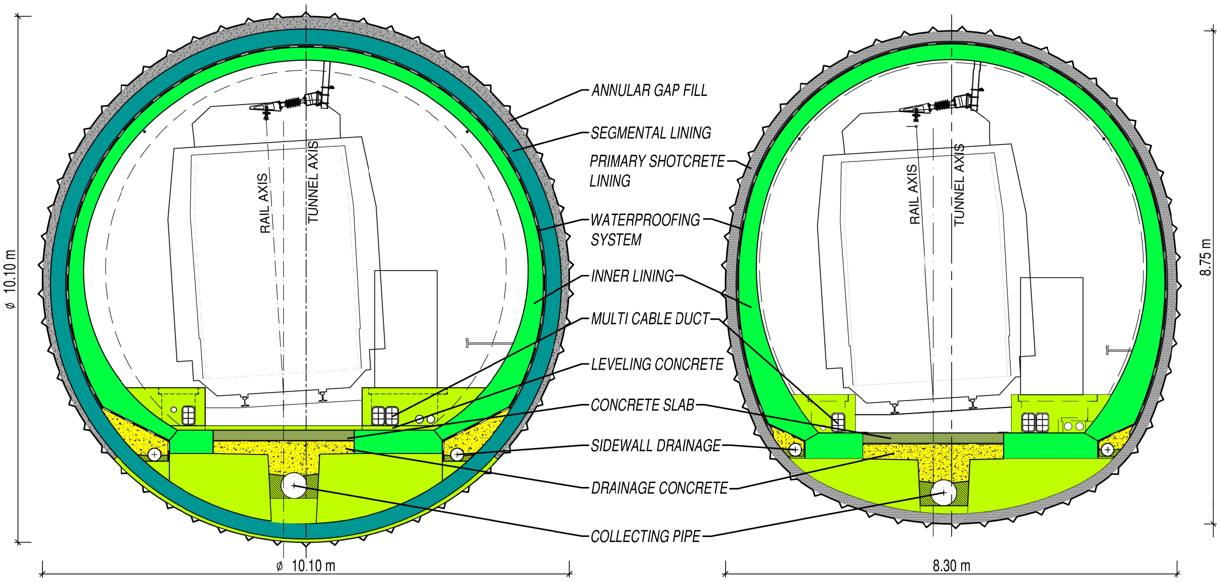

Figure 3: Regular cross sections for TBM and NATM (source: OEBB/PGST)

4.2 UNDERGROUND EMERGENCY STATION AND VENTILATION SHAFTS

As required by Austrian and European law and due to the length of the tunnel an underground emergency station is required within the tunnel. The overall rescue concept is based on self-rescue into a safe area, followed by the rescue by others (emergency team). In case of a fire on the train the main target is either to reach the portals and leave the tunnel before stoppage or to stop in the emergency station.

The emergency station has a length of approximately one kilometre and is located at the toe of the two permanent ventilation shafts. For accommodation of installations and areas required by the safety concept tunnels, caverns and passages of various sizes are foreseen. The centre of the emergency station is dominated by the rescue tunnel, which is located in between the two running tunnels with connections to the running tubes by short escape passages and two regular cross passages. In addition, ventilation tunnels are placed in between the rescue tunnel and the main tubes to provide a smoke free environment in connection with the ventilation shafts (see Figure 4.).

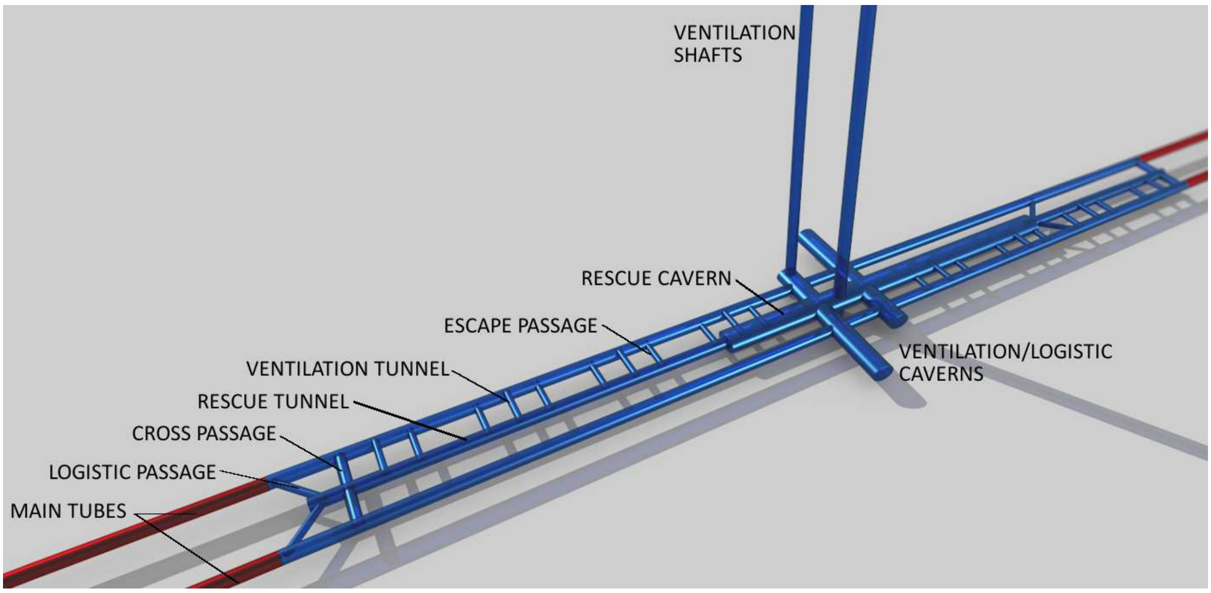

Figure 4: Scheme of emergency station (source: OEBB/PGST)

The depth of the ventilation shafts is about 420 metres with diameters of 12 metres in maximum. In the final configuration the shafts will be equipped with ventilation and inspection equipment and on the top of the shafts a complex ventilation building housing the ventilators, electrical equipment and the control and telecommunication units will be built.

5. SELECTED DETAILS

5.1 TBM SYSTEM

The tender documents provided minimum requirements regarding various aspects of the TBM system. Such requirements for the TBM system included minimum dimensions for the boring diameter and the annular gap as well as the TBM type (shield or double shield), power and thrust properties or equipment for certain measures for ground improvement or exploration purposes. Such measures included installations for pre-drilling ahead of the cutter head as well as for injection measures or installation of face bolts as well as for the application of a pipe roof.

The contractor decided for two single shield TBMs with a shied length of app. 10 m and a boring diameter of 10.14 m. The number of disk cutters installed in the cutter head exceeds the number of 50. Figure 5 shows the assembly works of the first TBM in the main cavern of the emergency station.

Figure 5: TBM Installation (source: PGST)

5.2 SEGMENTAL LINING

For the segmental lining a minimum thickness of 30 centimetres and a parallel 6+0 system with planar joints and a taper based on the minimum radius for the correction of the TBM drive was requested by the tender documents. Three different types for regular and high loads as well as for the intersections with the cross passages were foreseen. In addition the tender specifications provided also information regarding the structural design of the segments including analyses details such as bedding conditions, various loads and affiliated loading combinations and fabrication tolerances.

The detailed design for the segmental lining was in the sphere of the contractor based on these requirements and boundary conditions, checked by the client only. The contractor decided for segments with a width of 2 metres. The annular gap between the segments and the underground is filled by mortar in the invert and pea gravel or mortar in the sidewalls and crown. Figure 6 shows the stacks of two sets of the segmental lining rings each placed on the site installation area.

Figure 6: Segmental lining (source: PGST)

5.3 CONSTRUCTION LOGISTICS

Due to the tight time schedule parallel excavation works are required in all three underground construction lots. At the main portals access to the tunnels is given at the East portal only. Further access is only given via the permanent or temporary access shafts and tunnels.

Four of six shafts in total will be completely backfilled after the end of the construction period, only the two ventilation shafts will be used for operational purposes. The depth of the shafts ranges between 100 metres and 420 metres, diameters range between 7 metres and 14 metres. Two shafts will be excavated underground via a 1.2 kilometres long access tunnel. For accommodation of the installations for the hoisting operations during construction a complex system of tunnels and caverns is foreseen at the top of the underground shafts. At the shaft bases of the temporary shafts large underground caverns are located to provide sufficient site installation area for machinery assembly and material handling underground as well (see Figure 7). Apart from two caverns, which will house permanent cross passages, all other caverns will be backfilled after the end of the construction phase.

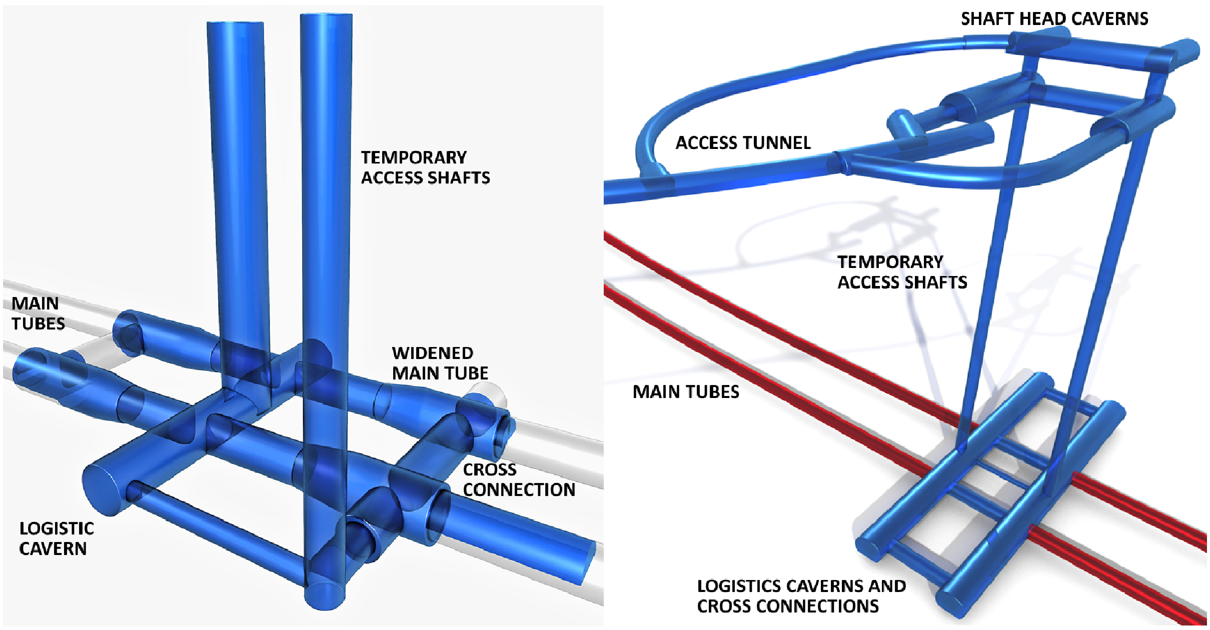

Figure 7: Scheme of cavern systems at temporary shafts (source: OEBB)

The rescue tunnel in the emergency station was built as a large cavern over a certain length to provide sufficient space for site installations, supply and TBM assembly during construction. Two additional caverns were carried out perpendicular to the running tubes, which are also required for the site installation purposes underground. A vertical supply and discharge operation via shafts always creates a potential bottleneck in case of break down or maintenance breaks of the hoisting installations, therefore the majority of required site installations had to be moved underground

The production of the segmental lining takes place in a precast concrete plant located approximately 25 km from the construction site. The transport is carried out by trucks which have to follow restricted routes using temporary construction roads thus avoiding residential areas. In order to compensate for driving bans for trucks on weekends and public holidays sufficient space for the placement of segments was foreseen on the site installation area on the surface as well.

The excavated material is transported to a new landfill site approximately two kilometres from the site installation area of the central construction lot by conveyor belts (see Figure 8) thus providing a continuous discharge of the excavated material. The excavated material of the neighbouring construction lots in the eastern and western parts have to carry out the transports to the landfill site by trucks using newly built construction roads bypassing residential areas. The total volume of the landfill site is approximately 4 million cubic metres.

Figure 8: Conveyor belts leading to landfill site (source: OEBB/Ebner)

6. CURRENT STATUS

Currently the construction in all four lots of the Semmering Base Tunnel project is in full progress.

The tunnel excavation at the eastern construction lot in Gloggnitz, which started by the end of 2015 has reached a length of about 3.2 kilometres for both tubes, with the cross passages following accordingly. The intermediate access tunnel, the shaft head caverns as well as the shafts are finished and the cavern excavation at the toe of the shafts is underway. The start of the NATM excavation works of the main tunnels is scheduled for late 2019. The excavation works at this construction lot are to be completed by the end of 2022.

In the central construction lot the ventilation shafts as well as the caverns and tunnels in the area of the underground emergency station are finished and the NATM headings of the main tunnel tubes towards the West are excavated for a length of approximately 1.5 kilometres. The first single shield TBM excavated approximately a length of 1.3 kilometres, whereat the assembly of the second TBM is finished and the excavation works are due to start in the first quarter of 2019 for a period of two years. The NATM works for the main tunnels in the opposite direction are planned to be finished by 2021 as well.

In the western construction lot the running tunnels are excavated already over a length of around 750 metres after the two temporary shafts and the cavern excavation were finished. The excavation works for the main tunnel tubes are foreseen to reach the mined portal in Muerzzuschlag by 2022.

The excavation works in all three underground construction lots will be followed by the lining installation and the backfilling of the shafts and the access tunnel. The finishing works of tracks and electrical installations as well as signalling will be carried out in a combined contract for the entire tunnel system including the cut and cover and open cut section at the western portal. Tendering for this final step of the construction works is planned for 2020.

The overall schedule of the project with a partially overlapping of the civil construction and final installation phase and a planned final opening for operation at the end of 2026 is on target.

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