NEW SEMMERING BASE TUNNEL,
PROJECT DESCRIPTION AND VENTILATION CONCEPT

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ABSTRACT
The New Semmering Base Tunnel is one of the most important infrastructural projects in the heart of Europe. The 27.3-kilometer-long, twin-bore tunnel, with an emergency stop in the middle, connects Gloggnitz in Lower Austria with Mürzzuschlag in Styria. The emergency ventilation includes air extraction and supply through a 400-meter-long shaft situated at the emergency station. This article gives an overview of the tunnel project including a description of the ventilation concept.

Keywords: rail tunnel, ventilation requirements

1. INTRODUCTION
The New Semmering Base Tunnel is one of the most important infrastructural projects in the heart of Europe. This twin-bore railway tunnel stands as a long-term investment in Austrian business, creating substantial value and a positive influence on the Austrian employment market for years to come.

The Südbahn southern railway line is the central connecting section of the trans-European, high-speed line from the Baltic to the Adriatic. As a result of the extension and modernization of this Baltic-Adriatic corridor via Warsaw and Vienna, Austria is gaining access to new markets and economic areas. Together with Vienna’s new main railway station, the redevelopment of Graz main railway station and the Koralmbahn section, the New Semmering Base Tunnel ensures that the Südbahn line will remain attractive with a secure future, both for goods and passenger transportation.

The 27.3-kilometer-long tunnel connects Gloggnitz in Lower Austria with Mürzzuschlag in Styria. The route implemented was selected as the best of a total of 13 variations. This involved investigation and consideration of aspects relating to the areas of transport and technology, location and environment along with economic criteria.

In addition to the twin bores, the tunnel construction also comprises:

- architecturally sophisticated entrance designs in Gloggnitz and Mürzzuschlag
- the intermediate construction sites at Göstritz, Fröschnitzgraben and Grautschenhof, which play an important role in the construction phase
- the Longsgraben spoil dump with a capacity of up to 5 million cubic meters for the disposal of excavated material
- temporary roads for construction site access and to reduce the load on public transport during the construction phase
- comprehensive hydro-engineering measures for flood prevention
• an emergency stop around the midpoint of the tunnel
• construction-phase ventilation shafts in Trattenbach and Sommerau, which are necessary for the supply of fresh air during the day
• an auxiliary bore
• and railway power supply lines and substations in Gloggnitz and Langenwang for supplying electricity to the trains in the tunnel

The New Semmering Base Tunnel consists of twin parallel bores each of around 10 meters diameter. The twin bores have a separation of between 40 and 70 meters and are connected at maximum intervals of 500 meters by cross-passages (see Figure 1).

![Figure 1: Schematic of the New Semmering Base Tunnel](image)

Thus the tunnel fulfills the latest requirements for tunnel safety. In the event of a train breakdown, passengers can be evacuated via the cross-passages. In addition, around the midpoint of the tunnel and between the main bores is an emergency stop. Here, in an emergency, passengers can move to a safety area via escape tunnels and be brought out of the tunnel from there (see section 3).

From the point of view of transportation engineering, the New Semmering Base Tunnel constitutes the necessary complementary development of the historical Semmering mountain section.

In contrast with the 42-kilometer-long mountain section, the 27.3-kilometer-long tunnel has a very small gradient of only 0.84%. This means that even the heavy goods trains of up to 1600 tons, which negotiate the southern route daily, can be pulled by a single locomotive. The Base Tunnel allows speeds of up to 250 km/h along the Semmering section. It therefore merges seamlessly with the high speed network for trans-European passenger and goods transportation and offers a modern level of comfort with substantially reduced journey times. The tunnel is a robustly forward-looking complementary development of the UNESCO-World-Heritage Semmering mountain section, which will also continue to operate. Work will begin on building the New Semmering Base Tunnel in 2012 (tunneling will begin in 2014), with completion planned for 2024.

Initially there will be hydro-engineering work for flood prevention on the Schwarza in the area of Gloggnitz. This phase of construction also includes two new railway bridges, a new road bridge and underpass construction for the B27 trunk road. Site clearing and preparation of a construction area in Gloggnitz form the preparatory work for actual tunnel construction. Depending on geological and hydro-geological conditions over three principal phases of construction, a variety of tunneling methods will be applied. In Figure 2 excavation using tunnel boring machines and conventional excavation by diggers and blasting are shown.
In the case of tunneling by boring machine, the cutter head of an approximately 200-meter-long boring machine digs through the rock. The tunnel bore is secured by pre-cast concrete sections, the liner segments. Once installed, they serve to react to the load from the boring machine for the next section of excavation. Very high excavation rates are possible using this tunneling method.

In the case of conventional excavation, also known as the “New Austrian Tunneling Method (NÖT)”, the material is extracted by blasting or by diggers and then dumped, meaning it is brought out of the tunnel by dump trucks. After each stage of blasting, the vault of the tunnel is secured using sprayed concrete, steel reinforcement and tie bars, and in this way, the tunnel grows bit by bit.

Several intermediate construction sites are foreseen in order to comply with the planning to finish work in 2014 (cf. Figure 3).

At the Göstritz intermediate site, in a particularly challenging zone for tunneling, excavation will be conventional, employing a combination of 1000 meters of gallery and around 250-meter-deep shafts in the mountain down to tunnel level.

At the Fröschnitzgraben intermediate site, first of all two shafts will be sunk more than 400 meters deep and up to 22 meters in diameter. The emergency stop will be built at the foot of these shafts. It is then from here that the tunnel boring machines will start work in the direction of Gloggnitz.
At the third intermediate site, Grautshenhof, tunneling will take place via an approximately 1300-meter-long access gallery towards the Fröschnitzgraben intermediate site and Mürzzuschlag.

All shafts and galleries will be closed off after construction of the tunnel, except for one shaft at Fröschnitzgraben, which will be used for ventilation when the tunnel comes into operation.

The Semmering area constitutes a valuable ecological system and its protection has the highest priority. Particular attention was therefore paid to all relevant aspects of the environment during planning for the environmental impact statement, above all the topics of ground, mountain and surface water in this water-rich area.

The following aspects were also investigated:

- climatic and air pollutants
- noise and shocks
- regional development and local land-use planning
- animals and plants and their habitats
- agriculture and forestry and many more

Ahead to the year 2019; construction work on the New Semmering Base Tunnel is progressing according to plan. The heavy machines are still boring, digging and blasting their way through the mountain where, in a few years, goods and passenger trains will pass through Semmering via a state-of-the-art tunnel.

Once tunneling is concluded, the structure will be equipped for forthcoming rail traffic:

The tunnel outer shell is necessary to support and secure the overlying rock. The water-collecting drains lie within the subsequently installed invert concrete.

The next activities are to construct the supports for the tunnel arch concrete, install the longitudinal drainage which collects the water, and line the tunnel bores with arch concrete.

With its various layers, the track superstructure must withstand axle loads of up to 22.5 tons.

Cable ducts in both peripheries carry cables whose total length exceeds a million meters. A total of 54 kilometers of illuminated handrail ensure a sense of orientation. The equally long overhead cables supply the trains with power at 15,000 Volts.

A milestone for construction of the New Semmering Base Tunnel was set in May 2010 when over 10,000 pages of reports and 700 m² of plans were submitted to the relevant authorities. Once the official notifications are issued by the authorities, work will begin on preparatory construction in 2012 and actual tunneling will start in 2014.

Thus, in 2024, the future of rail transport on the southern railway line (Südbahn) will become reality, matched to the requirements of the Baltic-Adriatic axis.

2. SAFETY CONCEPT AND VENTILATION REQUIREMENTS

The Tunnel Safety Concept of the New Semmering Base Tunnel is based on the regulations for Austrian rail tunnels, which are being designed at the moment or have been established in recent years; for more information (cf. [1]). Within the safety concept of the New Semmering Base Tunnel a range of specific protection goals were defined. The protection goals which concern the ventilation concept include:
• The creation of a safe area in the middle of the tunnel system (emergency station).
• Emergency station, non-incident tube and portals are safe areas (cf. [2]) and should remain free of smoke for at least 180 minutes.
• Avoiding further danger to following trains in the incident tube.
• The prevention of the simultaneous entry of smoke into both tubes as a result of a fire in a technical room.

The following main ventilation objectives have been derived based on the protection goals:
• In order to prevent smoke propagation through open cross-passages (tunnel) and escape passages (emergency station) into the safe areas, there must be a sufficiently high over pressure in the non-incident tube and in the refuge room of the emergency station with respect to the incident tube. For hot incidents in the tunnel this objective is implemented by the requirement of a minimum flow velocity through open cross-passages.
• In order to prevent smoke propagation into the non-incident tube at the portal regions, the exit of smoke from the incident tube must be avoided or the outflow velocity from the non-incident tube must be high enough to prevent smoke entry. This objective is implemented by the requirement on the flow velocities in the tunnel tubes.

Further ventilation criteria / requirements include:
• not to exceed the maximum allowable flow velocity through open cross-passages ($v_{\text{max}} = 10 \text{ m/s}$) to prevent a negative impact on the escape procedure,
• low air flow in the incident tube (to prevent a rapid smoke propagation and an impairment of the smoke layering),
• high reliability by low complexity of the ventilation system and its control.

3. VENTILATION CONCEPT

During normal operation, ventilation is achieved by the train-induced piston effect. Hence, no active ventilation is foreseen.

During maintenance work, one tunnel tube will be completely closed. Pollutants produced by working machines, e.g. exhaust emissions from engines, will be sufficiently diluted and transported out of the tunnel system by the extraction fans (250 m$^3$/s).

In the event of a hot train incident, the two design scenarios "Incident in the emergency station" and "Incident outside the emergency station" have to be considered.

Incident in the emergency station

When a fire is suspected due to a report from the driver or irregularities in operation, the emergency station will be prepared for train evacuation (cf. Figure 4):
• doors in the emergency station from the incident tube into the escape area are opened automatically,
• fresh air is fed into the escape area (150 m$^3$/s) and
• air is extracted at the emergency station (250 m$^3$/s).
Three supply- and three extraction fans are foreseen. The actual planning status of the smoke extraction in the emergency station is described in section 4.

**Incident outside the emergency station**

If the incident train stops outside the emergency station:

- the open doors in the emergency station (prepared for the event of an incident in the emergency station) from the incident tube into the escape area are closed,
- fresh air is reduced (100 m³/s) and fed into the non-incident bore and
- air is still extracted at the emergency station (250 m³/s).

Simultaneous air extraction from the incident bore and air supply into the non-incident bore leads to a pressure difference between both tunnel bores (**Figure 5**). Hence, air flow from the non-incident bore into the incident bore through open cross-passages prevents smoke propagation into the safe area.
4. CURRENT STATUS OF THE PROJECT PLANNING

4.1. Smoke extraction in the emergency station

The design of the extraction system was chosen based on project-specific protection goals and ventilation criteria. Two possible smoke extraction systems were investigated with the help of 1D simulations based on a variant study:

- Extraction at the ends of the platform: Two extraction locations at each end of the emergency station,
- Distributed extraction: Five extract locations along the emergency station.

3D simulations showed that the conditions for self- and third-party rescue are much better with a distributed smoke extraction with 5 extraction locations along the emergency station. The main advantages are (cf. Figure 6):

- Much better smoke and temperature stratification on the emergency platform.
- Shorter retention time of the smoke in the emergency station.
- Shorter smoke-filled sections along the emergency station.

Distributed smoke extraction along the emergency station (five extraction points) is applied for the long tunnels crossing the Alps (Lötschberg Base Tunnel, Gotthard Base Tunnel, Brenner Base Tunnel). Hence, this is a state of the art solution.
4.2. Air quantities

There must be a sufficient positive pressure in the safe area in comparison to the incident tube to ensure that smoke cannot cross over when the cross-passages and escape passages are open. The air supply and extraction quantities are designed as follows:

**Extraction quantity (250 m³/s)**

Various aspects had to be taken into account for the determination of the extraction quantity. In case of an incident where a train stops at the emergency station, there should be no airflow back out of the emergency station, even if the portal pressure difference is high or if a fan stops. The extraction quantity is also to be designed to ensure a sufficiently high flow velocity through open cross-passages, even near the outermost cross-passages, so that smoke propagation can be prevented, even under unfavorable conditions. With the help of an event tree analysis it has been shown that the extraction quantity of (250 m³/s) is adequate (cf. [3]).

**Air supply quantity (150 m³/s)**

The main function of the air supply is to prevent smoke entering the safe area in the emergency station. 3D simulations showed that for the distributed extraction along the emergency station (cf. section 4.1) an air quantity of 100 m³/s is close to the lower limit. Either additional structural or ventilation measurements are required for the distributed extraction. To reduce the danger of smoke entering the escape area the air supply quantity was increased compared to the submission project. It could be shown with the help of 3D simulations that the higher sideways flow does not impair the smoke layering in the emergency station when increasing the distance of the escape doors to the emergency platform.

5. REFERENCES

