ADDITIONAL SAFETY EQUIPMENT OF THE BOSRUCKTUNNEL

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ABSTRACT

After the tragic accident and fires that occurred in the past few years in long bidirectional tunnels, ÖSAG has worked out a plan to improve safety in Austrian tunnels.

The Bosruck Tunnel was the first of the long bidirectional tunnels that has been provided with an additional safety equipment in the last year. In substance, the improvement consists in the installation of escape routes and the update of the ventilation system.

Moreover, the SOS niches have been transformed into protected accessible niches and phosphorescent reflectors as well as orientation lights have been installed.

As a result of the investigations carried out by a group of experts the tunnel has been recoated, so-called “rumble stripes” have been milled into the road surface and the lighting has been improved.

INTRODUCTION

Pursuing the aim of raising tunnel safety the Österreichische Autobahnen- und Schnellstraßen-Aktiengesellschaft (ÖSAG) is providing the old long bidirectional tunnels with a wide range of additional facilities.

In a first step the 5.5 km long Bosruck Tunnel on the A9 Pyhrn Autobahn, opened in 1983, has gradually been provided with an additional safety equipment. The work began in April 2001 and was completed in December 2001. The work in the main tunnel has been done between September 10 and mid-November 2001 by night with traffic lights in operation at the portals in order not to obstruct road traffic.

The Bosruck Tunnel is divided into three parts:

- The 5500 m long eastern bidirectional tube (main tunnel)
- A parallel running gallery at the western side which is divided into the northern ventilation gallery (1387.5 m in length), the drainage gallery (2727 m in length) and the southern ventilation gallery (1356 m in length)
- The two parallel running tubes are linked with crosscuts every 400 m. In the area of the drainage gallery these crosscuts are on the same level as the two tubes whereas in the area of the ventilation galleries they are on a higher level and therefore connected with the tubes by means of a special construction (i.e. a shaft with a ladder inside)

Being provided with a parallel gallery linked with the main tunnel by crosscuts the Bosruck Tunnel differs substantially from other bidirectional tunnels in so far as in case of fire tunnel users have the possibility to flee through the emergency exits into the crosscuts and wait for the rescue service. But they also may save themselves by fleeing into or through the parallel tube.
1. **Measures that have been taken**

1.1 **Parallel gallery**

To make the parallel gallery passable along its whole length the following measures had to be taken:

- Raising the road surface of the ventilation galleries
- Removal of rock broken apart and installation of a reinforced shotcrete shell in the drainage gallery
- Installation of an emergency lighting running along the whole length of the tunnel
- Laying of 20 kV-cables to supply two transformers
- Installation of a radio facility

![III.1: Parallel gallery with cable system](image)

1.2 **Crosscuts**

The crosscuts have been transformed into waiting areas which required the following work to be done:

- Installation of a T90 door to separate the crosscut from the main tunnel
- Installation of an emergency lighting
- Installation of information boards with emergency phones, first-aid boxes fire-extinguishers and safety advice
- Installation of places to sit down
- Installation of video cameras switched on automatically when the door is opened
- Installation of a loudspeaker system
- Installation of hooks going in rails to elevate and let down injured people and heavy loads within the shafts
- Installation of a ventilation system

![III.2: Equipment of the waiting areas](image)
The crosscuts that have been transformed in waiting areas are separated from the main tunnel, the ventilation galleries and the drainage gallery by tight doors. It is important that, in comparison with the main tunnel, there will always be an over-pressure. On the other hand, the over-pressure is to be kept on a relatively low level to permit the doors to be opened. In case of fire-alarm the ventilation system blows approximately 2 to 3 m³/s of fresh air into the crosscuts, regardless of whether there is high or low pressure in the ventilation galleries.

The construction of the 14 crosscuts differs because the floor level of the main tunnel and the ventilation galleries differs from that of the drainage gallery. In case of fire-alarm the ventilation valves which are closed by magnetic mechanisms are opened by springiness or gravity and the ventilation system is put into operation. A kickback valve prevents the air from flowing back into the ventilation gallery. When the main ventilation units are not in operation the pressure of the waiting areas is kept at approximately 70 Pa. Thus, the air flows back into the ventilation gallery. In case of higher pressures caused by air intake into the ventilation gallery a second kickback valve leading to the main tunnel is opened because of over-pressure (from 100 Pa onward) and pressure in the waiting areas is reduced.

When the emergency exit is opened pressure diminishes, the kickback valves shut and fresh air is blown through the open door and prevents smoke from flowing into the waiting area. All kickback valves are moved mechanically by springiness or gravity. Between the drainage gallery and the ventilation galleries tight doors are installed. In case of fire alarm valves movable by springiness or gravity are opened by means of a solenoid switch in order to take in fresh air into the drainage gallery.

Thus, air flows from the waiting rooms into the main tunnel only when there is an over-pressure of more than 100 Pa or when the emergency exits of the main tunnel are opened. In case of fire-alarm all magnetically moved valves are opened and all ventilation units start to operate. Hence, the air circulates flowing from the ventilation/drainage galleries to the waiting areas and back to the ventilation/drainage galleries. Because the volume of air is 100,000 m³ a rise in temperature or a significant rise of harmful substances is not to be expected.

The Austrian Guideline Code for the Planning, Construction and Maintenance of Roads (RVS) provides over-pressures of 50 Pa and an air speed of 0.75 m/s with open valves in order to keep the staircases of buildings free from smoke. In tunnels, because of the higher volume of smoke and the stronger fluctuation of pressure a maximum difference of 100 Pa is approved in order to raise air speed to up to 1.5 m/s with open emergency exits in the main tunnel.

The kickback valves installed between the main tunnel und the waiting areas have to meet special standards and are fireproof according to the category F30.

1.3 High-voltage supply

In the crosscuts 5 and 10 two additional transformers were installed in order to supply with power the motors of the waste air blinds, the ventilation unit of the waiting areas and the emergency lighting in the ventilation galleries and the drainage gallery. The two transformer units consist of a 10 kV-control system with 4 switchboards and a 400kVA-distributor. These units are supplied by transformers at the portals by means of a high voltage cable system including holding devices which has been installed in the ventilation galleries and the drainage gallery.

1.4 Waste air blinds

After the fire disasters in some European tunnels we had to reflect on how to increase the safety of tunnel users. To reach this aim, above all as far as bidirectional tunnels are concerned, it was necessary to update the facilities that remove the smoke. The Bosruck
Tunnel was provided previously with waste air openings of the first generation installed every 12 m in the intermediate ceiling of the tunnel. These waste air openings had fixed vents which, in case of fire, could not be opened or shut completely. Thus, in case of fire, the smoke intake within the section could not be modified. Therefore, wide waste air blinds which can be moved separately by a motor have been installed. The motors are installed in the fresh air intake ducts and connected with the cable system by means of light wave cables. The cables in the intake ducts run in ducts made appropriately for this purpose. In case of fire one or more waste air blinds in the area of the source of fire are opened whereas the others remain closed in order to guarantee an effective removal of smoke. Investigations have shown that the waste air blinds should be more or less of the same extent as the surface of the waste air duct which in this case is approximately 9 m². Totally, 51 waste air blinds, one every 100 m, which had to meet the following standards have been installed in the intermediate ceiling:

- Every single part of the blinds (i.e. frames, lamellas, bearing axels, rod linkages etc.) are made of stainless steel material no. 1.4571
- The blinds resist temperatures ranging from $-25^\circ$ C to $+40^\circ$C, in case of fire the valves must be fail save for two hours time with temperatures up to 400°C.
- The valves resist pressure fluctuations of $\pm 2500$ N/m² caused by the percussive power of the passing vehicles.
- The leak rate is less than 0,15 m³/m²/s with pressure fluctuations of 2500 N/m²

1.5 Modification of the SOS niches

The emergency call niches set up on the side of the carriageway with driving direction to Linz were modified in safe accessible niches and have been provided with separate fresh air intake ducts. In addition to that, the niches have been provided with emergency call boxes. The tunnel users had to make their emergency calls previously on the pavement with the traffic passing by. The modification of the emergency call niches and other measures that have been taken i.e. the provision of the niches with fire emergency masks and the updating of the emergency call system represent an important step to raise the safety of the tunnel users. The technical plants in the niches are isolated from the main tunnel and the emergency call unit in order to protect them against fire.
Fresh air supplied by two compressors (one at each portal) is blown in by means of 6/4” polyethylene pipes laid under the pavement. The compressors have a power of 18.5 kW, the volume of fresh air supplied is 2.31 m³/min with 12.7 bar. The SOS niches are provided with fresh air intake ducts installed in a height of approximately 1.70 m by means of which the ventilation is accomplished. They are switched on automatically or by a hand lever. In case of a break of the main distribution conduct a safety device keeps the pressure at 1.8 – 2 bar.

Abb4. SOS niche and fresh air intake ducts

1.6 Indication of escape routes

According to the Austrian Guideline Code (RVS) 9.282, point 9.4.2 special lightings which help to find the next emergency exit indicating the direction and distance have been installed between the SOS niches.

In order to make the emergency exits to be found more easily the contours of the doors have been set off by not soiling phosphorescent plastic tubes fixed on the wall between the main tunnel and the crosscuts along the contours of the doors by means of spacers.

1.7 Phosphorescent reflectors on the kerb

The sides of the carriageways have been specially marked by means of phosphorescent reflectors. The reflectors are fixed on both sides on the emergency pavements and are lighted by means of light emitting diodes (LED) on the front and on the back (red on the right side, white on the left side). They are supplied with power by cables running under the pavement.

At the entrance area of the tunnel they are installed every 15 m and in the inner part every 25 m.

Investigations have shown that drivers keep more distance from the car ahead and the oncoming cars when LED-markings are installed.

Ill. 5: LED – reflectors on the kerb
1.8 Breakdown bays

To make the breakdown and turning bays to be found more easily from greater distances, they have been painted in a lighter colour and were provided with Metal Halide Lamps of a different colour, which produces a halation effect that breaks the monotony of the tunnel lighting and makes the bays more visible. In addition to that, the respective distances from the portals are indicated.

Ill. 6: Breakdown bay with emergency exit leading to the waiting area

2. Additional measures

In addition to the measures explained above the following safety measures have been taken as a result of investigations carried out by a group of experts set up by the former Minister of Innovation, Technology and Transport, Monika Forstinger:

2.1 Coating

The whole tunnel has been recoated. After the grounding had been prepared a water-soluble epoxy-painting colour (“magnolia”) which is resistant against all types of emissions and salt and has a light-reflecting-power of 78% was coated on up to a height of 4,5 m.

2.2 Lighting of the main tunnel

The power of the lighting has been raised installing 150W-High Pressure Sodium Lamps instead of 100W-lamps. In addition to that, the walls are lighted more efficiently by means of reflectors. These measures did substantially improve the whole lighting of the tunnel.

2.3 Rumble stripes

In the area of the middle traffic-line millings 8-10 mm in depth and 30 cm in width have been cut every 30 cm. Investigations have shown that these millings produce good effects. Passing over these stripes the car gets into strong vibration and, in addition to that, the strong rumbling noise calls the attention of the driver to the danger.

The work was finished in December 2001
The total amount of costs is EUR 8,3 million