Safety measures for the Wolfsgruben tunnel

Integrated track design in tunnels with special reference to safety considerations

In the wake of recent disasters due to fires in tunnels, safety in tunnels is a highly topical issue. The new Wolfsgruben tunnel in St. Anton am Arlberg has been designed so as to allow existing local firefighting vehicles direct access along the railway tunnel. In this context, the article describes the safety and civil engineering measures in the Wolfsgruben tunnel.

The 60 km long, single-track mountain railway over the Arlberg range was opened to traffic in 1884. Only the 10 km Arlberg tunnel between St. Anton and Langen am Arlberg was constructed as a double-track section from the beginning. Due to the increasing volume of traffic, it was finally decided about 15 years ago to increase the capacity of the Arlberg line. This was to be achieved mainly by extending the double-track section on both sides of the Arlberg range, in the Stanzer and Klosterle valley sections. Thanks to the double-track upgrade between Langen and Klosterle on the Vorarlberg side, as well as the relocation of St. Anton station and an adjacent section of line totalling 4 km, and in conjunction with already upgraded sections in the Stanzer valley, a 23 km double-track section has now been created, representing more than one third of the total length of the Arlberg line. Both upgraded sections mentioned include the construction of new double-track tunnels: the 1800 m Wolfsgruben tunnel on the Tyrol side and the 2400 m Blisadona tunnel on the Vorarlberg side. St. Anton and Langen am Arlberg stations respectively lie between these new tunnels and the Arlberg tunnel (see Figs. 1 and 2).

The close juxtaposition of these tunnels, especially taken together with the recent fire disasters in the Mont Blanc and the Tauern road tunnels which have strongly influenced public opinion, and with the great public interest in the 2001 alpine skiing world cup competition which took place immediately after the opening of the Wolfsgruben tunnel, led the Austrian Federal Railways to give special attention to safety aspects of the Wolfsgruben tunnel.

In this context, the following aspects were taken into account:

- Safety policies of railway companies and rescue services,
- Definition of a realistic accident scenario,
- Resulting planning in terms of safety measures, based on self-rescue by passengers as well as adequate access for rescue services,
- Evaluation of the planned measures in order to ensure their compatibility, taking into account the whole chain of tunnels.

The safety philosophies of railway companies and fire services are fundamentally different. It is the purpose of all railway safety installations to prevent unusual incidents. All safety installations operate in accordance with the “fail-safe” principle. The basic safety philosophy of railways is to take appropriate measures in order to avoid accidents. By contrast, fire brigades and rescue organisations set out from the assumption that an accident or a fire has occurred. They see themselves as lifesavers and rescuers and as controllers and extinguishers of fires. Their contribution to risk reduction is limited to minimising the effects of an incident.

These differing perspectives complement each other very well. However, because the emergency services have no responsibility for the cost of an infrastructure project, there is a risk of excessive investment in safety and of insufficient compatibility between preventive measures and measures to reduce the effects of incidents.

The basis of tunnel safety planning has thus always been the extremely unlikely scenario of a passenger train being stuck in the tunnel and then catching fire. A comprehensive package of measures has been developed to deal with this scenario, with a view to their applicability also to other less spectacular accident scenarios.

As indicated in reports on tunnel fires and confirmed by tunnel fire tests in Norway in 1992 in the course of the EUREKA project [1], [2], about 15 minutes elapse between the outbreak of a fire and the tunnel being entirely filled with smoke at the source of
the fire. The most effective action is therefore the rapid evacuation of the stranded train.

Safety approach for the Wolfsgruben tunnel

Construction details have therefore been designed so as to give passengers a good chance of escape from the dangerous part of the tunnel within 15 minutes, thus enabling their self-rescue in good time. Wide "cess" walkways, lighting for orienta-
station to the tunnel mouth as well as rapid access within the tunnel. In addition, for the first time in Austria, the track in the Wolfsgruben tunnel has been designed to enable drive-in access for road vehicles, as shown in Fig. 4. The technical solutions for this slab track construction to enable access by road vehicles, together with the technical and organisational precautions taken in order to segregate the emergency operation of rescue teams on the track from normal track operations, are described in the following sections.

Technical and organisational precautions

In recent years, slab track has been increasingly adopted by Austrian Federal Railways, primarily to ensure stable track alignment and to minimise maintenance costs. On the Austrian Federal Railways, slab track is used mainly in new tunnels. However, the smooth concrete surfaces in the tunnel and the lack of sound deadening on the undersides of carriages led to increasing complaints from passengers. Sleeping car passengers have found this noise nuisance particularly disturbing. Extensive research has led to the development of acoustic panels to reduce noise reflection from the smooth concrete surface to the undersides of carriages. Tunnels which had already been completed have been upgraded with these acoustic panels. Because of the construction of numerous tunnels on new lines and not least as a result of recent tunnel disasters, rail tunnel safety has also been subjected to intensive research, and solutions have been developed to increase the level of safety.

The Zammer tunnel

In 1992, in the course of the project approval procedure for the Zammer tunnel (Innsbruck - Landeck line), only walkable ccesses with a minimum width of 1.20 m, emergency niches with a maximum spacing of 50 m as well as a continuous handrail were specified. Radiating cable equipment offered new opportunities for emergency radio applications. Fire services were expected to be equipped with road-rail vehicles. Because the operating licence was not issued with the legal construction permit required by railway regulations, joint measures have been established in coordination with local authorities and their experts and in close contact with the fire services, in order to upgrade the Zammer tunnel in terms of safety. In 2000 these measures finally led to the successful completion of the operating licensing procedure required by railway regulations.

The additional measures include a fire hydrant duct mounted on the lower part of the right hand side wall of the tunnel as well as a reservoir with a volume of 108 m³ at the eastern portal, orientation lighting and escape route signs installed in the tunnel, rescue areas and communications facilities (emergency operations rooms) provided at the tunnel mouths, and finally a re-railing (emergency operations rooms) provided at the tunnel mouths, and finally a re-railing device for the road-rail fire engine as well as an electrically locked entry barrier.

Wolfsgruben tunnel

For the Wolfsgruben tunnel, all these measures were already incorporated during the project planning stage (see Fig. 5):

• Escape gallery (L = 180 m): Due to the time-critical construction schedule for its
implementation, the Wolfsgruben tunnel had to be driven via a lateral access gallery. Today, this lateral gallery is available for use as an escape tunnel, joining the main tunnel at approximately mid-length. Thanks to the bigger cross section required by the construction process, it is possible to provide emergency vehicle access to the main tunnel via the escape gallery.

- **Fire door (25 m²):** A smoke-proof door was constructed in the area of the intersection of the main tunnel and the escape gallery, enabling a safe stay of at least 90 minutes. Thus, passengers have to walk 450 m at the most in order to reach safety. The construction of fire doors is especially important in alpine regions, because the distance from the main tunnel into the open air can significantly lengthen the escape route, as shown, for example, by the Blisadona tunnel in Langen with its 420 m long escape gallery.

- **Emergency exit doors:** The emergency exits into the escape gallery and in the area of the fire door are equipped with "panic locks" allowing opening in the escape direction. Opening of track-side doors from outside is prevented by means of an electric lock and is only possible after consultation with and release by the emergency operation centre.

- **Communications rooms:** Communications rooms fitted out with telephone, fax and emergency radio are situated near each tunnel portal and emergency exit in order to enable optimum two-way communication with rescue teams. The emergency operations centre is co-located with the train operations control centre in St. Anton am Arlberg station.

- **Rescue area (1500 m²):** Paved rescue areas covering about 1500 m², equipped with sufficient lighting as well as appropriate barriers to keep them permanently clear of obstructions, face each of the communications/control rooms. These rescue areas provide space for emergency vehicles and for tents for first aid to the injured. In the winter months, these areas must also be kept clear of snow. If at all possible, helicopter landing facilities should be available in the immediate vicinity (see Fig. 6).

- **Water duct for hydrants:** Due to the delayed decision about the need for this, the firefighting water pipe has been installed at a height of about 4.2 m on the lower right wall of the tunnel, as shown in Fig. 7. The hydrant duct consists of insulated pipes which are additionally equipped with a heater band. Hydrants are placed in the emergency niches, with a maximum spacing of 150 m. Moreover, the hydrant system has been designed with shut-off units every 450 m. The hydrant duct is a wet pipe, i.e. it is permanently filled, with a pressure of at least 7 bar. In accordance with a joint decision, the pipe, which is fed from one direction only, must provide water at a rate of 20 litres/second for a period of 90 minutes. A reservoir with a volume of 108 m³ as well as an additional deep well have therefore been set up in the feeding area. In order to achieve maximum availability of the water supply with its electrically operated pumps, an emergency power supply with its own generators was designed. On future new tunnel projects, the water supply to fire hydrants will be incorporated beneath the cesses and water reservoirs will be provided at both tunnel portals. This should prevent any damage in case of future disasters.

- **Emergency niches:** Emergency niches have been incorporated on both sides throughout the tunnel, with a maximum spacing of 50 m. The niches with fire hydrants are also equipped with electric power outlets (Fig. 7).

- **Orientation lighting:** Orientation lighting has been fitted above every emergency niche. Thanks to illuminated push button switches, anybody in the tunnel can switch it on. However, lighting can only be switched off from the emergency control centre.

- **Cesses:** The cess walkway is 1.30 m wide, generally arranged at the same level as the top of the rails, and must be kept free from any further installation which may cause obstruction.

- **Drivability:** To enable road vehicles to
access the tunnel the acoustic panels have been strengthened in accordance with static requirements. Thanks to the rail height of 19 cm, this did not cause any problem. However the design of the sound-absorbing surfaces is critical; while damage cannot be excluded in a disaster situation, during emergency service training care should be taken to protect them.

Between the rails (the four-foot way), the rolling surface for road vehicles is provided by means of drivable absorption panels, while in the six-foot way (between tracks), drivability has been ensured by filling with filtering concrete up to sleeper-top level. In the tunnel portal areas as well as in the area of the intersection with the escape gallery, the six-foot way has been filled further, up to top-of-rail level, to enable those escaping to reach safety without obstacles.

This also makes it easier for emergency vehicles to get onto the tracks or to turn round at specific places in the tunnel. Training exercises have shown that filling with concrete up to top-of-rail level offers significant advantages to emergency vehicles needing to pass each other in the tunnel.

In the next tunnel, in Langen am Arlberg (the Blisadona tunnel), filling will be to top-of-rail level throughout its length. As a result of having the same level over the whole cross section of the tunnel, the possibility of emergency vehicles driving on the cess walkways cannot be excluded, so the cable ducts situated in this area must also be equipped with drivable covers (Figs. 8 and 9).

In the vicinity of switches, because of the continuously varying distance between the individual running rails, special constructions in the form of gratings had to be used. Up to 170 different components per switch had to be produced for this purpose. Moreover, for safety reasons, these components could not exceed 30 kg in weight, in order to enable one person to handle them in case of failure. For switch diagnostic systems, which are particularly sensitive to magnetic disturbance, the grids had to be made of glass-fibre-reinforced plastic (GRP) (Fig. 10).

Wherever escape routes cross the track, the remaining 18 cm gaps between the running rail and the drivable acoustic panel on the one hand, and the cess walkway on the other hand, have been filled with plastic gap fillers (Fig. 11). In the future, this gap will be reduced to 13 cm, thus enabling these plastic components to be dispensed with.

Thanks to the drivability of the whole tunnel area, after intensive negotiations the local fire services agreed that the railway authority could rely on their existing infrastructure. Thus, in contrast with the purchase and maintenance of a dedicated train for tunnel emergencies, including provision of the necessary staff, only small adaptations have been necessary to the equipment of the local fire services.

Construction design

Drivability on prefabricated slab track

The track design in the tunnel, enabling both drivability and noise absorption, is a special feature. Backed-up by comprehensive tests and research, this system, which is based on the BAFS drivable sound-absorbing guard rail system, approved in Germany for operational testing and already used on the new Hanover - Berlin line, and on sound-absorbing track covers, has now been practically implemented in the Wolfgruben tunnel in cooperation with the Rieder and the Rhomberg Bau companies.

Figs. 12 and 13 show two cases of loading of the sound-absorbing track covers with a wheel load of 85 kN. Even with the loading shown in Fig. 13, which rarely occurs in practice, no damage has been observed. Only steering movements under full wheel load produce some damage to the edges. In the access ramp areas, these edges have therefore been additionally protected by means of steel angles. The sound-absorbing track covers are manufactured in two separate
layers with supporting steel-reinforced concrete plus absorbent porous concrete, and are then laid elastically on the prefabricated track slabs using strips at the outer side of the plate, as shown in Fig. 14. These plates are bolted onto the substructure in order to prevent them from shifting due to vibrations caused by the passage of trains.

Drivability on elastically supported monobloc sleepers

In the sections with the six drivable switches as well as in the intermediate tracks, a slab track design with monobloc sleepers elastically supported in rubber shoes has been chosen and implemented. In order not to alter the elastic properties of track and switches, all drivable parts of the construction design had to be decoupled from the sleepers. Fig. 15 shows the longitudinal section of this design. In the spaces between sleepers, mouldings are placed on iron pins previously set out in lean-mix concrete, are then adjusted and grouted with concrete. The sound-absorbing panels are laid on these mouldings and bolted in place at their joints with the substructure.

External track covers

Areas outside the track are covered with prefabricated components up to a distance of 18 cm from the outer edge of the rail, thus ensuring that the elastically supported sleepers are entirely decoupled.

Summary

In spite of the extremely short construction schedule, numerous details used for the first time in this project were developed and efficiently implemented in the course of construction, thanks to the close cooperation between the ÖBB project management, the project design engineers and the railway construction contractors under the technical direction of Rhomberg Bau GmbH. The integrated approach of all those involved to meeting the very wide variety of requirements, together with their comprehensive technical and organisational solutions, enabled timely completion ready for the skiing world cup in St. Anton in 2001.