Renovation of Railway Tunnels under Operation

Retrofitting of railway infrastructures, especially of tunnels, is a big challenge as the train operation should not be interrupted during the ongoing works. Rhomberg Bahntechnik and its partners address themselves to the development of advanced solutions based on long term experiences in the railway world.

Introduction

It is quite a while since the first railway lines have been constructed, and hardly anyone is able to imagine our life without these lifelines which enabled the growth and the welfare during decades. But it is a fact that railway lines, planned and constructed in the prime-age of railways, suffered a bit from the burden of more than 100 years of operation. More and more they need renewal.

On the one hand certain civil works for renovation have to be done. On the other hand busy lines often reached their limits of capacity. Especially tunnels and bridges mark a bottle neck for enabling old lines to serve also for the next decades. A similar problem is given in urban areas, where old metro lines almost reached their lifetime and have to be renovated without the chance of “just closing the lines for a while” due to massive disturbances on the daily life of a bigger city.

So we have to face a necessary “renovation under operation”, which causes certain requirements and gives special conditions which have to be considered:

- Location (e.g. mountainous environment, subway in a city-centre, etc.)
- Capacity of the line, number of trains per day (and the respective time-frame for possible working activities, giving the total time for access)
- Extent of works (tunnel, track, catenary, cables, signalling, etc.)
- Additional features to be considered and installed (e.g. safety concept and installations)
- Number of tracks in one tunnel and the derived effects of a line-construction-site
- Size of cross section clearance profile
- Length and condition of access to site and places of required works
- Legal restrictions and requirements (labour, pollution, checks before start of operation, etc.)

All these special conditions, the variation of factors and their interdependency require experienced generalists to be able to guarantee successful construction works without endangering labour force or risking train delays.

Special conditions of old tunnels

It is obvious that the techniques to construct tunnels have changed quite a lot during the last 100 years. Especially the inner shells have been built without anchoring just by lining up stones and bricks to tunnel arches to sustain the rock pressure and possible deformations.

In many cases also pressures in the bottom area of the tunnel were assumed. Consequently the realized bearing structure of the tunnel base must be analysed carefully.

The form, thickness and extent of the bricking change often over the length of a certain tunnel, depending on local rock conditions. The negative effect for us is that we have to make assumptions and control measures to get information about the respective conditions. A deciding question is: Should we rely on very old drawings or do we spend an extra effort to determine the actual conditions?

The main reasons for renovating old railway tunnels are:

- Loose stonework and cavities
- Change of tunnel alignment due to changing ground properties
- Water leakage or penetration
- Dimensioning of the drainage
- Dirt (grime, oil, etc.)
- Non-adequate clearance profile
- Poor track conditions or new track standards
- Unfulfilled safety requirements

Difficulties in these old tunnels in lines under operation:

- Lack of information
- Starting from wall thickness and ground conditions and ending with reliability of existing data for survey.
- Little information about previously conducted construction measures.
- Fragile, partly destroyed rock and brickwork structures.
- After decades of operation and movement of mountains and underground there is almost no reliable information available with regards the
cavities behind the tunnels and the quality of stonework itself.

- Limited access
The distance from the portal to the site itself also limits the time for possible works - not only regarding the material but also the available working time for the staff.

- Location of tunnel and site installation
Old tunnels to be refurbished are mostly either in exposed or in densely populated regions, making it almost impossible to establish a major site installation adjacent to the site itself.

- Free space to work
Most of the old tunnels have been designed to ensure the passage with a minimum cross-section (often also designed for a much lower speed), giving limited space for work and movement (see Fig. 1).

- Necessary coordination for enabling operation
An important factor which limits considerably the time of work is the fact that construction measures during a possession have to be finished or left in safe conditions before restarting train operation. Further on power supply or signalling have to be launched according to a certain procedure. These factors may reduce the net time for working to less than 4 hours.

The demands on the renovated tunnel depend on the respective requirements and standards. The works may vary from some measures to strengthen the brickwork up to a complete refurbishment and renovation of a tunnel, including inner shell and enabling of access by regular road vehicles (see Fig. 2).

Renovation under operation

Renovation of single track tunnels

In general working activities just can be executed during track possessions. Usually there is no chance to store material or equipment adjacent to the track due to lack of space and/or safety requirements. An additional access does usually not exist. Normally all materials have to be transported and built in during the limited break. The distance for transport of labour and material is a decisive and limiting factor. Additionally the track has to be prepared for the following traffic, considering a start up phase and the fulfilment of safety requirements or sufficient setting of the respective construction materials (e.g. concrete).
Further on the complete clearance of the site must be guaranteed or special measures equivalent to the final installations ensuring the full availability of the line have to be taken (Fig. 3). These tunnels require a minimum of set-up time to achieve efficient work rates.

Renovation of double track tunnels

On the one hand double track lines may make the access easier by using the adjacent track. On the other hand one track has to be kept clear for regular operation of trains. This causes a strong safety problem. Sometimes special measures must be taken, because old tunnels have a distance between the centreline of the tracks of 3.50 m or less (Fig. 4). Without any doubt this type of work requires also special qualities and experience of the staff and the site management.

A choice of solutions

Taking into account the items mentioned the number of adequate solutions is limited. By keeping the general approach, a mostly mechanized rail bound solution with independent work fronts has to be developed.

The complete works – from the very beginning to the finished renovation – have to cover the following crucial topics:

▷ Build up of reliable data about the existing conditions.
▷ Establishing an actual net for survey – adapted to the planned measures (e.g. a tunnel profile requires less accuracy than track geometry).
▷ Enabling a safe work environment for the staff.

Fig. 4: Train passing in a narrow double track tunnel

▷ Rail bound and quickly available machinery for a wide range of activities.
▷ Flexible logistics and reliable material transport, taking into account the volume for the referring shift.
▷ Reduction of dust and dirt to a minimum, ensuring safe operation.
▷ Procedure with a minimum of idling.
▷ Whereas possible: Decoupled arrangements of working activities by establishing solutions with part-time character which can remain for a longer period.
▷ Trained and experienced staff.

Case study: Arlberg-Tunnel

History and technical background

The 2-track Arlberg-Tunnel, located between St. Anton and Langen, is a part of the busy trunk line connecting the western part of Austria with the nation’s capital, Vienna. At about 1,300 m above sea level, the tunnel has a total length of 10.6 km. The tunnel was constructed from 1879 to 1884, using the "Old Austrian Tunnelling Method". The tunnel walls are made of broken stonework with a thickness of 0.5 to 2.0 m. Almost 5,000 m of the tunnel are equipped with bottom slab because of high rock pressure.

Track centreline distance is 3.50 m, and the train operation speed is 100 km/h. Certain intents for renovating the inner shell by means of an impermeable gunite layer to protect the stonework have been made in the area of the western portal during the 80’s and 90’s of the last century.

As the tunnel was used for many years by steam locomotives, the inside of the whole tunnel is covered by a thick grime layer. It is worth mentioning that since 1978 there is a 14 km long road tunnel crossing the Arlberg in parallel to the railway tunnel. Due to several accidents in alpine road tunnels during the last years, a new safety concept has been worked out, using the railway tunnel for access and causeway in cases of emergency. As seen in Fig. 5, this is managed by 6 interconnecting tunnels in distances of 1'700 metres. In the future it is planned to shorten up distances up to 425 metres.

Scope of works in the Arlberg railway tunnel

▷ Widening of tunnel profile on 6 places where the causeways are connected to the Arlberg road tunnel (a project which is executed by Rhomberg in a joint venture)
▷ Replacing of the surface of the inner shell in affected areas
  - Removal of about 60,000 m² of existing gunite layer
  - New shotcrete sealing of about 40,000 m²
Chosen solutions
Rhomberg Bahntechnik and its partners designed a working train based on conventional wagons, able to be split to work on different places of the tunnel at the same time (Fig. 9). Connected wagons have a common energy and air supplies, additional aggregates are installed in case of malfunction to keep redundancy. The wagons were equipped with walls to separate the working areas from the adjacent track under train operation. A detailed survey has been done before starting the working activities on the train and the referring tunnel sections were determined after establishing a new alignment.

Reconstruction and cleaning of the surface
First the existing gunite has to be removed. Therefore a high-pressure water-jet (1,500 bar) was used, producing a clean and rough surface with good adhesion for the new shotcrete. Another advantage of this procedure is the reduction of vibrations. A special fleece is fixed and covered by a 2 cm gunite layer. Then a plastic reinforcement will be tapped by another 3 cm of shotcrete (Fig. 10). The cleaning is executed by water-jetting, using a reduced pressure of about 400 bar.

Tunnel widening
To guarantee the clearance profile “Rola 240” for piggy-pack, the clearance must be widened up to 12-15 cm, taking into account the new track alignment. Also...
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existing niches have to be widened. Therefore a wagon has been adapted and equipped with a wheel saw which is cutting precisely the required profile in the tunnel wall in proper intervals. The wall cut in this manner is prepared for breaking out the remained noses quickly by small chipping hammers. In this way the tunnel clearance can be widened without significant vibrations which could damage the old tunnel structure (Fig. 11).

Removing the existing ballast track

In the further progress of the project the existing ballast tracks will be replaced by a modern slab track system to enhance the quality and durability of the railway section and consequently to reduce the future maintenance effort considerably.

In the first phase of the replacement process the old ballast track will be removed: As trains are working on the adjacent track during the whole time of construction, this will be conducted by using a special track removal machine designed by Rhomberg Bahntechnik Group. The machine is able to remove track entire panels as well as to dismantle and load them onto the wagons. Furthermore the machine removes the old ballast by a special conveyor system and stores them on the referring wagons.

Installing of the new slab track

In the second phase the slab track system ÖBB-Porr will be installed: The core elements of the system are the pre-cast concrete track panels. After a basic layer with stirrup reinforcement has been built on the tunnel base, the track panels will be brought into the tunnel and positioned roughly. The final position of the panels will be determined by special adjustment devices. The track panels will be fixed permanently on the basic layer by casting concrete into the apertures and underfilling the track panels.

Construction of spring-mass-systems

Close to the portals there will be applied spring-mass-systems on elastic supports. Their weight is about 4.4 tons per meter. The spring-mass-system is based on elements type ÖBB-Porr, the area of turnouts is designed with single supports.

In the zone of spring-mass-systems the sole has to be adapted to the required thickness of the concrete layer. A removal of up to 40 cm will be done during possessions. This will be done by blasting and excavating (also rests of old material) and a basic concrete layer will be levelled.

Water supply line

Most of the line with a diameter of 200 mm will be positioned in between the two tracks. Taps for emergency use are located every 150 m.

Surface to be used by road vehicles

Similar to other tunnels in Austria, the Arlberg tunnel will be equipped with elements able to allow road vehicle traffic: The prefabricated elements are positioned on a rubber suspension layer and fixed by dowels. The gap in between the element and the rail will be closed by a filler.

All works will be finished in 2009.

Summary

The retrofitting of railway infrastructure – particularly of civil engineering works as well as of the tracks themselves – is one of the biggest challenges to keep railway lines efficient. Wherever railway transport on existing lines cannot be interrupted by construction works innovative concepts allowing construction in close neighbourhood of the working tracks are necessary. Rhomberg Bahntechnik and its partners address themselves to the development of practice oriented solutions based on long term experiences.

Fig. 10: Fixing the plastic reinforcement

Fig. 11: Wagons equipped with special steered wheel-saws to cut the profile