THE IMPORTANCE OF THE SAFETY ASPECTS DURING THE CONSTRUCTION WORKS FOR THE NEW MAJOR ALPINE TUNNELS RELATED TO THE SAFETY DURING THE REGULAR SERVICE PHASE. PARALLELISMS AND DIFFERENCES

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ABSTRACT: Prevention measures, self-rescue procedures and measures to ensure the self-rescue are the key-points of the safety concept for tunnels during the construction works as well during the regular service phase. Basics of measures and procedures are the same or very similar for both concepts, whereas the investment levels for prevention respective for measures to ensure the self-rescue are instead very different, depending on the phase. The particular example of the Gotthard Base Tunnel confirms the important role of prevention in the construction phase, related to the higher accident risk. Statistics from the construction site Bodio (southern access) demonstrate the necessity of continuous investments for accident prevention.

RÉSUMÉ: Les mesures de prévention, les procédures d’auto sauvetage et les mesures pour assurer l’auto sauvetage sont les éléments de base de concept de sécurité pour les tunnels pendant travaux de construction ainsi que pendant l’utilisation régulière. Les bases des mesures et procédures sont identiques ou très semblables pour les deux concepts. Par contre, les niveaux d’investissement pour la prévention, ainsi que pour les mesures qui assurent l’auto sauvetage sont très différents, selon la phase du concept. L’exemple particulier du tunnel de base du Saint Gotthard confirme le rôle important de la prévention dans la phase de construction, lié au risque majeur d’accidents. Les statistiques venant du chantier de Bodio (accès sud) démontrent la nécessité de l’investissement continu en prévention d’accidents.

1 INTRODUCTION

The Gotthard Base Tunnel will be the world longest railway tunnel, with a length of 57 km. The tunnel is part of the New Alpine Transverse in Switzerland. Fires in railway tunnels are very unusual events: the actual transalpine rail routes through Switzerland, containing over 500 tunnels (total length around 400 km), are more than a hundred years old and tragic accidents related to fires have not been reported. For the public opinion this meant that railway tunnels are “safe”. But after the tragic fatalities of the Mt. Blanc and the Gotthard road tunnels, as well as the one of Kaprun, the public opinion shows special sensitivity to tunnel safety: in general clients and project managers were called upon to undertake every reasonable effort to further increase tunnel safety. A high safety level is a very important premise for the operation of a railway tunnel and as well an economic exigency. In order to plan and realise a safe operating base tunnel, a safety concept serves as a rail-internal instrument for continuous planning and optimisation of safety measures and as a transparent basis for the control by the competent authorities. The analyses in the Gotthard Base Tunnel safety concept demonstrate, that with simple but very effective measures, a very high safety level can be reached, corresponding to the demanded safety requirements. Even if fire events are an exception, accidents in tunnels under construction are more frequent and in some cases critical for the involved staff. Prior to the public submission of the works, a high safety standard has been established for the entire AlpTransit project. In accordance with the SUVA (Swiss National Accident Insurance Fund), a fire/life safety concept has been developed for the construction phase of the Gotthard Base Tunnel. This paper gives an analysis of both concepts (tunnel safety during regular service and during construction works) and shows parallelisms (similitudes) and differences between them.

2 OVERVIEW OF THE PROJECT

The transalpine rail routes through Switzerland are more than a hundred years old. As they no longer meet the requirements of ever-increasing rail-traffic between north and south they are now being rebuilt. The actual Gotthard rail route is in fact a mountain railway: the northern and the southern access ramps – with a maximum speed of 80 km/h and with a maximum decline of up to 2.2% climbs up to about 1,100 m a.s.l., where the old Gotthard rail tunnel is located, approximately 900 m higher as the city of Milan. The Swiss federal railways together with the Lötschberg railways were commissioned for the realisation and the management of the two New Alpine Transverse, Gotthard and Lötschberg. The AlpTransit Gotthard Ltd., founded by Swiss federal railways – with headquarter in the heart of Switzerland in Lucerne – were charged to manage the design and the construction works of the Gotthard route until the begin of the regular service of the new flat railway. The transalpine rail route “Gotthard” will rely the city of Zurich with the city of Milan (see Fig. 1), interesting a catchment’s area of over 20 millions people in Germany, Switzerland and Italy.

The most impressive part of the new traffic route through the Alps is the Base tunnel under the Gotthard, which is planned to handle mixed traffic (high speed passenger trains up to 250 km/h as well as slower freight trains up to 160 km/h). Once complete and operating, the Gotthard base tunnel will be the longest tunnel in the world. It will run through the Alps at approx. 500-550 meters above sea level. It’s highest overburden will be approx. 2,300 m. With a minimum Radius in curves of 5,000 m and with a maximum slope of 0.70% the Gotthard base tunnel will be the first flat railway trough the Alps.

To shorten construction time and for ventilation purposes, the tunnel will be driven from several sites simultaneously. To this end, the tunnel has been divided into five sections. Excavation will take place from the portals as well as from three intermediate attacks in Amsteg, Sedrun and Faido.

Fig. 1: New transalpine rail routes through Switzerland.
At the present time (end of March 2005) the construction works are proceeding ahead at both portals and at the three intermediate accesses (see Fig. 2). 66 km or more than 43% of the total length of tunnels and the galleries are excavated. Some difficult parts of the tunnel have been completed successfully, some others with over 2,000 m of overburden and poor rock mass properties are under excavation right now.

**3 KEY POINTS OF THE SAFETY CONCEPTS**

The progress of technology is providing new instruments to increase the safety level in different aspects of our daily life. In the particular case of tunnels, this progress leads to improvements of efficiency and reliability of certain safety measures. But it does not have a significant influence on basic principles, which we shall call "Key-points", essential for a successful or unsuccessful safety concept.

The "Key-points" are:

1. The prevention measures
2. The Self-rescue procedures
3. The measures to ensure the self-rescue

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**4 SAFETY CONCEPT / TUNNEL SAFETY DURING THE CONSTRUCTION WORKS OF THE GOTTHARD BASE TUNNEL**

**4.1 Prevention measures during the construction works**

1. First instruction and their continuous upgrade:

The concept is structured for a focused and personalized instruction, depending on the role and tasks of the different members of the staff. In addition to the first basic instruction – a must for every member of the staff – special instruction courses have to be solved from specific groups of persons, for example: "scouts", chief and staff of the safety control center.

The first basic instruction consists in some different blocs and has to be solved prior to the begin of activity on site:

- General introduction
- Alarming, use of radio and phone
- First-aid treatment of injured staff members
- Free making of blocked staff members
- Prevention measures
- Use of personnel equipment and oxygen-devices
- Evacuation procedures
- Use of fire extinguishers
- Site visit

Every 6 months a repetition course is planned, including an update about occurred upgrades and adaptations of the different systems on duty.

2. Planning and periodical update of the risk scenarios:

The safety concept for each construction site is based on admitted risk scenarios, depending from the particular work processes, the used materials and machineries. Some risk scenarios require the intervention of external rescue services.

Risk scenarios are permanently checked and debated, as well as updated in accordance with the progress of the construction works and on basis of new experiences or work processes.

Possible risk scenarios and pertinent intervention modalities are object of a monthly coordination meeting between representatives of construction site and external rescue services. A classical example are fire-event scenarios:

- Fire-event at the front (TBM or SPV)
- Fire-event by the application of the waterproof seal
- Fire-event on tunnel-trains

The different strategies for a fire-event require the handling of technical systems as for example the manual fire-alarm, communications, on-the-spot extinguishing installations, ventilation (Fig. 3) as well a deep coordination under the operating units and the correct use of self-rescue devices.

On-site exercises, with simulations of accident conditions permit to verify the planned rescue procedures (costs approx. between CHF 50'000 and CHF 100'000 each exercise).
According to the legal conditions that staff member’s health has to be protected, a safety handbook and a rescue handbook have been worked out for each construction site. Health and comfort of workers are object of the first handbook. The contractors do as much as possible to limit accidents and occupational disease adopting preventive measures. A certain risk cannot be excluded. In the second handbook all measures and procedures for evacuation and rescue of persons for many different risk situations are described. Updates of both handbooks are periodically scheduled, normally every 12 months. More importance is given to the continuous audit of the described procedures.

Monthly meetings with the external fire-brigade, monthly joined inspections (features: the client, the site supervision and the contractor), monthly reporting in the engineers supervising meeting and the control-inspections of SUVA complete the planning and update measures.

3. The STOP-Risk safety campaign:

The "STOP-Risk safety campaign" has been established by AlpTransit Gotthard Ltd. and from SUVA, in cooperation with all contractors working on the different sites of the Gotthard Base Tunnel. A full and strong awaking of involved staff on safety problems is the main target of this action. The STOP-Risk-logo is reproduced on each poster in many sizes together with different icons reminding specific safety subjects (see Fig. 4).

A single object is exposed on site during 2 up to 4 months; at the same time the contractors offer specific information and instruction events to the staff members. The sequence of proposed subjects (for example: fire-extinguishing, use of personal equipment, use of oxygen self-rescuer, go-for-safety) is independently established on each construction site according to the characteristics of works process as well as depending on accident statistics.

4. The personal safety equipment:

The contractors put a personal safety equipment at staff member’s disposal. The equipment includes:

- Working-suit (orange color) with reflecting stripes
- Helmet
- Boots or safety shoes
- Tunnel lamp
- Oxygen self-rescuer
- Badge for the tunnel access control
- Protective glasses and hearing protection

Staff members are obliged to use the equipment as correctly as possible and they have to report any damage to permit a timely replacement.

5. Prevention measures for visitors:

Generally, visitors admitted to enter the tunnel are subjected to the same safety prescriptions as the staff. The same personal safety equipment is put at their disposal. Prior visitation a short introductory safety lesson is given. It is however not possible do give a complete instruction about the use of emergency devices and about the evacuation procedures in case of event. Visitors are not familiar to tunnel conditions: to counterbalance this handicap, the maximum number of visitors per group is restricted, depending on the means of transport and the available extra-places in the safety containers. Visitors have to be taken in the tunnel by a suitable number of site supervision members.

6. The access control system:

The extension and complexity of the construction site, associated to the safety and rescue tasks, required the installation of an automatic access control system to record – in addition to the transit of persons at the tunnel portal – the number of staff members in the different working sections of the tunnel system. The elevated number of working sections, the transportation of staff by tunnel train and the possibility to walk from a working place to another are resulting in a complex access control system.

A further development of an existing system, a kind of prototype, has been installed for example on the construction site of Bodio and Faido: after a first evolution phase with some technical problems, the developed system reaches now a good level of flexibility and reliability.
4.2 Self-rescue procedures during the construction works

Experiences from former events have confirmed, that an intervention of an external fire brigade needs up to 20÷30 min. to reach the fire in the tunnel. This is definitely too late: at this time it is nearby impossible to extinguish the flames, due to high temperatures (up to 1,000°C) and bad visibility conditions (smoke). In case of fire in the tunnel the first minutes are absolutely crucial: after the activation of the fire-alarm by a manual alarm-system or by communication-system (phone or radio) – if the starting-fire cannot be extinguished – self-protection procedures have to be adopted. For every member of the staff in the tunnel a personal self-rescue-device is provided to permit, in case of fire, to reach the nearest safety container. A fire-protected pressurized-air supply system provides overpressure in the safety containers, where extra self-rescue-devices for the evacuation of the tunnel are available. After the evacuation or after reaching the safety containers a reduction or a reversion of the ventilation flow prevents the propagation of smoke in the neighboring tube and cuts the oxygen supply in the burning tube. First-aid treatment of injured staff members and the intervention of the fire-brigade to rescue blocked staff are the last steps of the procedures in case of fire during the construction works.

A permanent occupied safety control center (see Fig. 5) is in charge for the monitoring and coordination of rescue-operations in case of fire. First instructions of the staff and their continuous upgrade are absolutely necessary (instruction is provided from fire-brigade instructors). Exercises are scheduled to check the correct application of self-protection procedures and to upgrade the experience of the fire-brigade about the progress of the construction works underground (see Fig. 6).

Fig. 5: The safety control center in Bodio

Fig. 6: Exercises with the external fire brigade in Bodio

Thanks to the access control system that has been in operation since the beginning of the main excavation works (since 2002 for the constructions sites Bodio and Faido), the safety control center is able to provide an on-time monitoring of the presence of staff, supervisors and visitors in the underground.

In case of emergency or fire, the safety control personal can immediately identify how many persons are in the danger section of the tunnel and so they can carry out an immediate analysis of the situation. As a result, the self-rescue procedure can be supported and the evacuation modalities can be optimized. Each person entering the tunnel – staff and supervisors – is required to carry on a personal identification card with incorporated microchip. The access control system register all micro-chips entering the tunnel as well further entering the different monitored sections (for example: TBM-zone, cross passages drill & blasting-zone, lining concreting-zone etc.). Visitors are required to subscribe an ID-form: before entering the tunnel a numbered card with incorporated microchip is provided for temporary use.

4.3 Measures to ensure the self-rescue during the construction works

1. The Ventilation system:

The main tasks of the ventilation system during the construction works are to replace exhaust air and to dilute on-site released noxious substances. For example, the adopted system in the section Bodio has been planned to satisfy the requirements for the following construction phases:

- Excavation of the single track tunnels, including the concreting of the invert.
- Sealing and concrete works.
- Concreting of the sidewalks, secondary works and rail equipment works (after the break-through with the northern section Faido).

The ventilation system respects the prescriptions of the Swiss norm SIA 196 as well as the different realization hypothesis (planning, working processes, machineries) on which the demanded amounts of air are estimated. For each person in the tunnel, 1.5 m³/minute are required. This rate is by far granted from the needed amount of air to dilute pollution and exhaust gases of diesel engines.

The ventilation on the site Bodio, essentially based on a circulation system (fresh air into the east tunnel east and exhaust air out of the west tunnel), is boosting fresh air at the front. The system is subsequent upgraded according to the working progress. Re-circulation fans are installed in the first two open cross passages, while the main fans at the portal are reversible. All ventilators are managed from the safety control center.

In case of fire in the tunnel, with subsequent smoke generation, the ventilation system offers a flexible working mode, avoiding smoke propagation from the burning tunnel to the parallel smoke free tunnel, as well as to slow down the propagation along the burning one. External rescue actions occur approaching the fire area from the smoke free tunnel.
2. The personal self-rescue-device:

The personal self-rescue-device, an oxygen self-rescuer, has to be carried from each member of the staff working underground (see Fig. 7 & 8). Lockers are located in the main working places: staff members may deposit their device during the shift. Otherwise, if working isolated, the oxygen self-rescuer must be carried on-the-man. Some technical data of the model Oxy K 50 S:

- Operating period conforms to EN 401: 50 minutes
- Operating period when breathing is steady: 180 minutes
- Weight unopened: 3.0 kg, weight during use: 2.4 kg

3. The safety containers:

Safety containers, representing a safe and clean shelter, are located in the main working places. They can hold the entire staff of a shift (see Fig. 9) as well extra-persons (site supervisors, visitors). Overpressure is assured by a pressurized-air supply-system, inflating fresh air from the outside, preventing smoke propagation in the container. Every safety container is also equipped with a first-aid kit, a stretcher, extra-oxygen self-rescuers and is connected to the phone system.

4. Fire-department pipe-fittings:

Beside fix installed extinguishing equipment along and on the installations, fire-department pipe-fittings are located on the main water-supply-pipe every 160 m along the tunnel to connect fire-brigade water-hoses. The water-pressure of the supply-system takes the least requirements of the fire-brigade into account.

5. The safety control center:

All logistical, executive and safety information from the construction site flow into the safety control center. Alarm announcements are reported by acoustic and visual signals and they can be checked immediately. The most important systems (ventilation, energy-supply, tunnel trains traffic, communications) are managed directly from the safety control center. Qualified staff is on duty around the clock: the coordination of external rescue services and important decisions about immediate measures are established from the safety control center.
5 SAFETY CONCEPT / TUNNEL SAFETY DURING THE REGULAR SERVICE OF THE GOTTHARD BASE TUNNEL

5.1 Prevention measures during the regular service phase

The tunnel system (see Fig. 10) mainly consists of two single track tunnels with two train-crossover sections in the so called multifunctional stations. Along the tunnel, cross passages are located approximately every 310–325 m; the horizontal distance between the tube axes is varying between 40 and 70 m. In front of the tunnel portals turn-out tracks are arranged.

In general every failure of the safety system has to be prevented, otherwise the personnel on the spot (train crew, engine driver) has to deal with it (radio contact to the control center). If unsuccessful, the train has to leave the tunnel or stop at an emergency stop station with highest priority. Assistance from the outside can be expected – depending on the exact position of the train in the tunnel – after 30 minutes at the earliest (e.g. train at emergency stop station with highest priority). In case of an incident the Traffic-Controllers survey the operation in real time. In case of an incident the Traffic-Controllers activate defined and rehearsed procedures using checklists. Always the purpose is to manage the situation quickly, preventing an escalation. It is also important to ensure the operating flow and to achieve a stable operating situation.

5.2 Self-rescue procedures during the regular service phase

In case of a fire on board of a (passenger) train, the procedure of the safety concept depends on the position of the train in the tunnel. Three cases have to be taken into account:

1. The train is running in the last section of the tunnel (after the second multifunctional station): the train has to reach the portal and will stop in the open air. Passengers are able to leave the train.

2. The train is running in the first or in an intermediate section of the tunnel: the train has to reach the next multifunctional station and stops there for the evacuation of passengers (see Fig. 11). The passengers reach the “sheltered area” of the emergency stop Sedrun (see Fig. 11). In the opposite tube for a rescue exclusively by train (multifunctional station Sedrun: no evacuation through the shafts; multifunctional station Faido: no evacuation through the access tunnel).

The safety concept depends on the position of the train in the tunnel.

In case of a fire on board of a (passenger) train, the procedure of evacuation will be applied.

3. A fire event occurs and the train is not able to reach the next multifunctional station or to exit the tunnel. In this case the train will stop at any position in the tunnel and the evacuation occurs. On a 1 m-wide side walk escaping passengers will be able to reach and to enter the next cross passage and reach the safe tube (see Fig. 12). In the opposite tube the speed of the trains running is reduced immediately after alert minimizing the run over risk for escaping people. In this case the process of the external rescue proceeds in the same way as if the train had stopped in an emergency stop station. In any case the train crew has to act quickly and resolutely. Early and clear instructions help to prevent panic situations.

For tunnel safety planning, in first priority preventive measures have been designated and in second priority curative measures have been defined in addition. This principle paid off during decades in railway technique. Should an incident happen in spite of these measures, particular measures facilitating the self- and external rescue will be applied.

The train is running in the first or in an intermediate section of the tunnel (after the second multifunctional station): the train has to reach the portal and will stop in the open air. Passengers are able to leave the train.

Fire-fighting and rescue trains come in action from the south-end as well as from the north-end of the tunnel. The rail-bound rescue is proven and trained for years at the Swiss Federal Railways (Simplon Tunnel 19 km, Gotthard Tunnel 15 km). In order to shorten the time period until the forces are ready, a close co-operation with local intervention forces (fire brigade, ambulance and police) is of great importance. This represents an extraordinary challenge for the upcoming years.

The emergency stop stations (sheltered areas) as well as the lateral and connecting galleries are furnished with fresh air independent of the traffic tunnel system, they are kept smoke-free through overpressure. An evacuation train conducts the passengers outside the tunnel. And this leads to another principle: the rescue from the outside is rail-bound. The evacuation train is either a train emptied in the tunnel or a train already in the tunnel. Fire-fighting and rescue trains come in action from the south-end as well as from the north-end of the tunnel. The rail-bound rescue is proven and trained for years at the Swiss Federal Railways (Simplon Tunnel 19 km, Gotthard Tunnel 15 km). In order to shorten the time period until the forces are ready, a close co-operation with local intervention forces (fire brigade, ambulance and police) is of great importance. This represents an extraordinary challenge for the upcoming years.

In case of a fire on board of a (passenger) train, the procedure of evacuation will be applied.
5.3 Measures to ensure the self-rescue during the regular service phase

1. The Ventilation system:

In February 2002 the Swiss Federal Office of Transportation requested to upgrade the ventilation system of the Gotthard Base Tunnel to permit the extraction of smoke at 7 different locations in both underground emergency stations, in order to ensure sufficient air quality, temperature and visibility conditions in case of a fire break-out and the necessary evacuation of passengers and staff. In the system of the Gotthard Base Tunnel, emergency stations are located in the multifunctional stations, where burning trains will stop in case of fire. To permit an efficient and safe evacuation of the passengers, it is required to extract exhausted air (smoke) near to the fire and to supply fresh air with overpressure in the escape ways and in the opposite tube (see Fig. 5). Main fans (redundant, 2 x 2.6 MW for extraction and 2 x 0.5 MW for fresh air) will be installed in the ventilation plant located near the portal of the intermediate access of Faido as well as in the ventilation plant in the cavern on shaft top in Sedrun. The amount of air blown in and exhausted will be about 200 m³/s and 250 m³/s respectively. In each emergency station seven fire dampers, located on the top of the lining, and six emergency sliding doors will complete the ventilation system.

The technical rooms are separated from the railway tunnels: in case of fire, as normally during service, these rooms will be ventilated to maintain the required temperature. Overpressure in case of an accident will prevent the propagation of smoke and air with high temperature in the technical rooms (see Fig. 13).

Subsidiary boosters (6 jet fans, each rated at 40 kW) will be additionally installed near to both tunnel portals in Bodio and in Erstfeld to maintain the difference of pressure between the tubes (see Fig. 5). This is very important, if a burning train will stop close to the portal.

2. Fire-protection measures.

In February 2003 a special task force has been created to study the problem of availability of the tunnel during and after an event, and to ensure the full respect of the extremely severe requirements set by the AlpTransit Gotthard Ltd. in case of a fire accident. For the evaluation of the design of the tunnel-structures a fire-power of 250 MW (freight train) respective of 40 MW (passenger train; only 20 MW for the design of the ventilation) has been supposed. The first question to be answered by the fire-protection working group was about the fire scenario to take into account.

At European level, different temperature-time-diagrams have been developed: the Hydrocarbon (HC, about 1,100°C), the increased Hydrocarbon (HCM, about 1,300°C) and the ISO (max 1,000°C). But a new temperature-time-diagram has been adopted for the AlpTransit-projects, to considerate the particular fire-event scenarios and the effective design of the Gotthard Base Tunnel (see Fig. 15). Experiences from former events have confirmed, that not only the first 90 min or the first hours have to be observed (peak of the temperature), but also the cooling phase.

![Fig. 13: MFS Sedrun: fresh and exhaust air systems (main fans)](image1)

Fig. 13: MFS Sedrun: fresh and exhaust air systems (main fans)

Subsidiary boosters (6 jet fans, each rated at 40 kW) will be additionally installed near to both tunnel portals in Bodio and in Erstfeld to maintain the difference of pressure between the tubes (see Fig. 14). This is very important, if a burning train will stop close to the portal.

![Fig. 14: Additional boosters (portal Erstfeld)](image2)

Fig. 14: Additional boosters (portal Erstfeld)

2 kg PP-fibres: 4 cm chips
3 kg PP-fibres: 1 cm chips
1 kg PP-fibres: 6 cm chips

![Fig. 15: Different temperature-time-diagrams](image3)

Fig. 15: Different temperature-time-diagrams

After the choice of adequate fire scenarios for the Gotthard-Base Tunnel several studies about the propagation of high temperature and the behaviour of air flow in case of incident have been undertaken, some tests with fire-protected concrete have been done in order to decide about the adequate constructive measures to be adopted (see Fig. 16). In particular polypropylene-fibres with variable length between 6 and 18 mm have been added to concrete specimen – prefabricated with the use of on construction site produced aggregates – to observe the occurring damages with the application of the AlpTransit fire-diagram, in order to find out the optimal design. In consideration of fluidity and workability of concrete, 2 kg/m³ and an upper length limit of the fibres of 12 mm resulted to be ideal.

![Fig. 16: Fire-Protection tests, specimens](image4)
On July 2004 the board of AlpTransit Gotthard Ltd. accepted the constructive measures elaborated by the working group: the application of sensible sections of the tunnel system with 2 kg/m² PP-fibres-added, fire-protected concrete lining and post-application of fire-protecting shotcrete (thickness: 3 up to 7 cm) on the completed lining in the cut & cover section. The lining of shaft II (exhaust air) has also been protected with PP-fibres-added shotcrete.

First concreting experiences in the section Bodio (steel reinforced lining in a geological disturbed zone) show good results using 6 mm-long PP-fibres. A first attempt using 2 mm-long fibres was unsuccessful, cause of insufficient fluidity and workability of concrete. A new lower limit of the fibres length of 6 mm has now to be respected for further concreting with fire-protection.

6 PARALLELISMES (SIMILITUDES) AND DIFFERENCES BETWEEN BOTH SAFETY CONCEPTS

1. Parallelisms.

Under strict application of the three “Key-points” both safety concepts show a very similar structure, established with an intensive planning phase, many years prior to their application. In case of accident or fire event only a self-rescue procedure is applicable to ensure a safe and successful evacuation. An on-time rescue mission from outside is delayed cause of activation time and the long distance to be covered. In both cases 30 up to 45 minutes are required. In both concepts the procedures for the evacuation are very simple, preventing or according to a possible panic situation. They are definitively supported by the ventilation and/or an oxygen-device to prevent smoke-intoxication and to permit to attempt a safe place (the other tube or a safety container). An evacuation train or an external fire brigade is first handling to ensure personal safety and only after that looking for fire extinguishing or to prevent an extension of damage.

2. Differences.

The safety concept for the construction phase is full dynamic and must be updated periodically. During construction works prevention measures are focused on the involved persons. Especially a continuous instruction and awakening of the staff, as well periodic visits and training exercises with the external rescue services permit to optimize and to adapt the rescue procedures to the tunnel system in progress. The staff has to be prepared to face an accident or a fire event. Measures to ensure a safe evacuation have to be flexible and they are subject to continuous displacements and/or upgrades. Planning does not stop until the end of the works.

The safety concept for the regular service phase, after long planning, can be considered a stationary system. The progress of technology may have an influence on details, but the main building of the concept is fix. During the regular service we have to admit that passengers are unprepared to face an emergency situation and a sufficient instruction of them is illusory. Prevention measures are also concentrated on operational and technical aspects to prevent accidents on or to a running train. Self-rescue procedures are standard and fix, focused particular on very improbable but possible events. No major adaptations or radical changes are expected. Measures to ensure a safe evacuation are also standard and unchanged once they have been defined. They are very expensive and they represent an important amount in the budget.

The safety concepts and measures during operation service are mainly standardized and should be the same or similar for all long tunnels. Construction sites, however, are different one from another. Safety concepts – although based on the same principles – have therefore to be adapted to the real situation on site. In this respect, the proper definition and realization of a safety system during construction can be considered as a much more demanding task, since the damage potential in a long lasting tunnel construction site, with up to thousand persons working underground is comparable to the damage potential during the entire life time of the tunnel in operation.

7 SHORT ANALYSIS OF THE ACCIDENT RATES ON THE CONSTRUCTION SITE BODIO

An important instrument to prevent professional accidents is represented by the statistics of the occurred accidents. The introduction of a simple, immediate and suitable reporting and recording system permits a continuous update of the accident situation on site. Last but not least, statistics are used as basis to establish a specific STOP-Risk subject and for a comparison with the Swiss average accident rates for tunneling, published by SUVA.

Fig. 17 shows the situation for the main construction works on the site Bodio. Since 2002 all accidents, including also light accidents, are recorded in a database.

At the present time the resulting accident rate (approximately 250 = accidents per 1,000 staff members and year) is lightly higher than the Swiss average accident rate 2004/2005 (225). The most accidents occurred are leading to light injuries only; unfortunately it is difficult to single out a specific problem to immediately decrease their number.

The Gotthard Base Tunnel construction sites are very complex and extended: only investments on prevention measures will permit – we hope so – to attempt the AlpTransit Gotthard accident rate target (200, lower than the Swiss average accident rate).
8 FINAL REMARKS

Prevention is essential to get a chance to reduce the number of accidents during the construction works. Every construction site and working area is particular and characterized by specific risks. It is important to try to identify these risks in advance and as quick as possible, permitting to reduce their impact. Statistics are very effective instruments to pursue this purpose. To increase their efficiency the record of "nearby-accidents" should be adopted; to put this into practice is rather complicated. “Go-for-safety”, a particular subject of the STOP-Risk safety campaign – for the first time introduced on the construction site of Bodio and now open-end prosecuted – is a simple but promising art of stimulation for the involved staff: everyone may report observed dangers with specific multiple-choice forms. Anonymity is granted and additional comments may be noted.

Additional investments for construction of the Gotthard Base Tunnel arise mainly through improvements to the project with the objective of increasing acceptance among the public, or adapting the safety standards in the light of new knowledge: CHF 308 millions (4.9%) only for Safety and state-of-the-art technology.

The big effort of AlpTransit Gotthard Ltd. to increase the safety levels of both phases has to be acknowledged, especially the investments for prevention during the construction phase. The construction site of the Gotthard Base Tunnel can be proudly considered a good example. Some of the measures described in this paper take a step forward for the future design of safety concepts for long tunnels. The parallelisms and differences between both safety concepts as well as the short analysis of the accident rates on the construction site Bodio shows the important role of the designer prior and during the construction phase. Flexibility and creativity are required to find out persuasive solutions: every long tunnel is a singular object.

REFERENCES

