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SAFETY DOORS IN THE WORLD'S LONGEST TUNNEL UNDER THE GOTTTHARD

Outstanding requirements and performance

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by

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Safety doors in the world’s longest tunnel under the Gotthard: outstanding requirements and performance. Feed-back from the bidding phase and results from the testing phase on selected prototypes

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ABSTRACT: The 57 km Gotthard Base Tunnel (GBT) will be the world’s longest railway tunnel. The tunnel is the central part of the new transalpine rail line in Switzerland. The two single-track tubes are linked by 178 cross passages approximately every 325 m, and two multifunctional stations with an emergency stop station for each tube located one-third and two-thirds along the base tunnel. During regular operation, high speed passenger trains with a top speed of 250 km/h as well as slower freight trains (160 km/h) will run through the tunnel. In the worst case scenario e.g. a fire on a passenger train, the doors of the cross passages and those of the emergency stations will be essential elements of the safety concept. This paper gives a short presentation of the safety concept in the case of fire on a passenger train and an overview of the most important requirements of the different door-types. It also includes the state of progress of the special procedure for the commissioning and feed-back from the tests on selected prototypes.

1 INTRODUCTION

A high safety level is a very important premise for the operation of a railway tunnel and as well an economic exigency. After tragic fatalities in existing long traffic tunnels public opinion is especially sensitive to tunnel safety: clients and project managers were called upon to undertake every reasonable effort to increase tunnel safety. In order to ensure long service (long durability, no revision of the doors in the first 20 years after the installation), the required fire protection (90 minutes at a temperature of 1,000°C) and efficiency in the case of evacuation, very high and stringent regulations have been set for the delivery of doors for the cross passages of the Gotthard Base Tunnel.

Based on former experience, especially on the commissioning of the doors for the Lötschberg Base Tunnel (34.6 km long, also part of the New Alpine Transverses in Switzerland) and in consideration of the unique, extremely harsh conditions of the Gotthard Base Tunnel, the development of a special technical solution is essential; these doors will not be a “standard” product.

The client – AlpTransit Gotthard Ltd. – decided to adopt a special procedure for the commissioning as well as for the evaluation by means of prototypes. A selective bidding procedure with pre-qualification was started on January 2005.

The Joint-Venture Gotthard Base Tunnel South has been charged to carry out the bidding procedure.

2 HIGHLIGHTS OF THE SAFETY CONCEPT

2.1 Safety Requirements

A fire on board a passenger train in the Gotthard Base Tunnel is the “worst case”: the probability of such an incident is very low. However, the following requirements have to be met in the case of an accident:

1. Availability during an event. In the case of fire on board a passenger train, the safety of passengers has first priority. In order to ensure this, the availability of the tunnel has to be maintained as long possible, as passengers should be able to reach a safe place. This is a must! In consideration of the fire/life safety system this means: The tunnel has to maintain operation for 90 minutes after an alarm.
2. Availability after an event. In the case of fire, the interruption of tunnel traffic has to be as short as possible. After evacuation, the reopening of the railway line has first priority. In order to ensure this, constructive fire-protection measures have to be taken:
- To exclude major damages or collapse of the safe tube,
- To reduce resulting damages, time and costs for the repair of the burned tube.

2.2 Overview of the fire/life safety system

The tunnel system (Fig. 1) 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 325 m; the horizontal distance between the tube axes varies between 40 and 70 m.

Figure 1. Gotthard Base Tunnel (GBT), the tunnel system [7].

In the case of a fire on board 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 stop outside the tunnel.
2. The train is running in the first or in a intermediate section of the tunnel: the train has to reach the next multifunctional station and stop there to let passengers be evacuated (Fig. 2). After the fire-alarm, prior to the arrival of the train, the lights of the emergency station will be turned on, the sliding-doors of the escape ways will be automatically opened and the ventilation system will start the extraction of exhaust air from the traffic tube trough the middle of the seven fire dampers. The passengers reach the “sheltered area” of the emergency stop station within 3 to 5 minutes.

After evacuation from the train – without using stairways or elevators – passengers will wait at the emergency stop station of the opposite tube for evacuation by train.

Figure 2. GBT, evacuation in an emergency stop station [7].

3. Fire occurs on board a train and it 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 evacuation will have to take place there.

On a 1 m-wide side walk escaping passengers will be able to reach the next cross passage through which they will reach the safe tube (Fig. 3). In the opposite tube the speed of the trains is immediately reduced after the alert. 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.

Figure 3. GBT, Evacuation through a cross passage [7].

For case nr. 3, object of the present paper, doors will provide fire-protection of the escape way and the technical equipment inside the cross passages. The ventilation system will ensure overpressure conditions in the safe tube to avoid smoke entering the safe tube.
3 REQUIREMENTS FOR THE DOORS

3.1 Main requirements

According to the stringent requirements of the safety concept and for durability of the tunnel system, very high requirements have been set for the doors of the cross passages. The most important ones are:

- Resistance in case of fire: 90 minutes with Alp-Transit temperature-time-diagram (Fig. 4), maximal average inside temperature of the door-panels of 200°C.

![Figure 4. goods train fire curve ATG (direct flame application).](image)

- Resistance for high pressure/suction loading due to the passage of trains: ±10 kPa in each running tube, resulting pressure difference on the door of 20 kPa.

- Serviceability: a conceptual solution for the guarantee of operational safety and impervious sealing is especially requested. A maximal necessary force for manual door opening of 100 N (mechanical support driving mechanism permitted) and serviceability in case of interruption of energy supply, as well as a max. air-leakage rate through the door sealing of 50 m³/h (according to the ventilation system) are fundamental requirements.

- Durability: 100 years for the structure, minimum 20 years for electronic devices and for replaceable parts.

3.2 Other requirements

A 16 page long list of requirements, properties and conditions divided into 45 relevant themes, including the main requirements. Every single requested property or prescribed condition has to be fulfilled: some of them are now the object of direct verification with selected tests on prototypes doors. All others have to be certified or plausibly described in the offer.

4 THE BIDDING PROCEDURE

4.1 The lots

For the commissioning of the doors of the cross passages AlpTransit Gotthard Ltd. decided on the procurement of 2 separates lots:

- Lot A “Doors for the cross passages of the GBT” for the development, staggered fabrication, delivery and possible installation of steel doors in the tunnel
- Lot P “Tests and verifications of prototype steel doors for the cross passages of the GBT” for the examination of the proposed solutions of lot A.

4.2 Selective bidding procedure for Lot A

The suitability of the contractor had to be determined by a selective procedure based on weighted suitability criteria in accordance with the Swiss Federal Law on Government Procurements (BoeB). For this reason, the selection procedure for Lot A is currently carried out according to the following 9 stages (at the time of the submission of the paper to the editor, stage 5 has been reached):

1. Invitation to tender / Invitation to participate at the prequalification. On January 10th 2005.

2. Prequalification of applicants according to the weighted suitability criteria. Reduction of the number of bidders to a maximum of 8. AlpTransit Gotthard’s decision was published on June 9th: 2005, the applicants were admitted to the next stage.

3. Bidding phase. From Mai to September 2005: five bids were handed in.

4. Choice of offers based on the additional criteria: reduction of bidders to a maximum of 4. Based on the evaluation of the Engineers-JV, on December 7th 2005 AlpTransit Gotthard Ltd. called all 5 bidders for prototyping and testing. Facilities for testing the prototypes are carried out by an accredited testing institution chosen by AlpTransit Gotthard Ltd. This stage started on March 2006 and is in progress at the present time (September 2006).

5. After testing phase: discussions with the individual bidders for the improvement of the technical solution based on the results of the examination. Expected in Winter 2006/2007.

6. Revision of the submission documents.


8. Revised evaluation of offers and supplements based on the additional criteria.

4.3 Suitability criteria for Lot A

Suitability criteria were used at stage 2 to evaluate the basic qualifications of a contractor or a bidding consortium to carry out the project. Only suitable bidders were invited to submit an offer. The following suitability criteria were applied:

- Criterion 1: Experience with the production of doors with high technical requirements and with the installation of doors under difficult conditions (weighting: 60%, minimum score 3).
- Criterion 2: Sufficient personnel and technical capacity to fulfill the scheduling and qualitative requirements (weighting 20%, minimum score 3).
- Criterion 3: Sufficient financial capacity for the execution of the job (weighting 20%, minimum score 3).

4.4 Additional criteria for Lot A

To evaluate the offer of a contractor or a bidding consortium, the following additional criteria were applied at stage 4 and will be applied again at stage 8:

- Criterion 1: concerning a plausible declaration that the required quality, serviceability and durability will be guaranteed (weighting 30%, minimum score 3 / score scale: 1 to 5, scale division 0.5), i.e.:
  - Fulfillment of fire resistance requirements (partial weighting 10%).
  - Fulfillment of the requirements for high pressure/suction loading due to the passage of trains (partial weighting 10%).
  - Fulfillment of the requirements for serviceability, especially: conceptual solution for the guarantee of operational safety and impervious sealing (protection from dust and noise) (partial weighting 5%).
  - Fulfillment of the requirements for durability (life expectancy) (partial weighting 5%).
- Criterion 2: Price level (weighting 30%, minimum score 3).
- Criterion 3: Appropriateness of the installation concept (weighting 20%, minimum score 3), i.e.:
  - Appropriateness of the underground installation concept. Conceptual solution to guarantee simple and timely installation deadlines (partial weighting 5%).
  - Appropriateness of the underground storage concept (partial weighting 5%).
  - Appropriateness of the packing concept (partial weighting 5%).
  - Appropriateness of the underground transport concept (partial weighting 5%).
- Criterion 4: Guarantee of meeting deadlines (weighting 10%, minimum score 3), i.e.:
  - Reliability of the planned underground installation schedules (partial weighting 4%).
  - Flexibility of the delivery of the doors (high availability and large capacity during production, adjustment of the production schedule as a function of modified deadlines in the tunnel lots) (partial weighting 3%).
  - Plausibility of the tendered services (production and delivery times) (partial weighting 3%).
- Criterion 5: Guarantee of appropriate maintenance (weighting 10%, minimum score 3), i.e.:
  - Maintenance concept. Conceptual solution to guarantee simple and timely maintenance during the construction phases and in service (partial weighting 5%).
  - Possibility for replacements (partial weighting 5%).

5 TESTS ON SELECTED PROTOTYPES

5.1 Installation tests under tunnel conditions

To observe and evaluate the installation of the prototype doors – manufactured and mounted by the bidder of the separate Lot A – the contractor of Lot P (the joint-venture PQ: VSH Sargans & Berner Fachhochschule Biel) has been commissioned for the establishment of the conditions corresponding to the simulated tunnel conditions (Fig. 5 and 6).
5.2 Functionality tests under tunnel conditions

For the verification of the prototype doors according to the prescribed requirements (i.e.: observance of the maximum permissible weight and dimensions for transport, door operation and opening, duration of the opening and closing operations, maximum necessary force for manual door opening of 100 N, verification of the door surveillance apparatus, verification of the function and storage capacity of the mechanical support driving mechanism) the contractor of Lot P has been commissioned for the establishment of the conditions corresponding to the simulated tunnel conditions:

- Execution of opening and closing operations with an overpressure of 0.5 kPa, performed by a robotic arm (Fig. 7), under similar tunnel climatic conditions (temperature and humidity).
- Verification of the air-leakage rate through the door sealing (max. 50 m³/h during 24 hours, difference of pressure inside/outside of 100 Pa). The fulfillment of this condition is very important to allow the cooling effect inside the cross passage by the ventilation system (air recirculation). Operational equipment requires a max. air temperature during service of 35°C.

5.3 Endurance test under tunnel conditions

For the verification of the prototype doors according to the prescribed pressure and suction loading during train passage and simulation of single pressure shocks (resulting pressure loading of 20 kPa and suction loading of 10 kPa, 500’000 loading cycles, 1 cycle every 2 seconds, 1 cycle = 1 pressure + 1 suction loading, functionality tests every 100’000 loading cycles and at the end of the endurance test) the contractor of Lot P has been commissioned to design and assemble a testing facility (Fig. 8, the so called “Mjölnir”), to simulate the tunnel conditions:

- Loading by air pressure (no mechanical contacts between testing equipment and prototype doors), verification of the behaviour of the doors including the sealing.
- Very quick increase of the loading (shocks).

5.4 Fire tests under tunnel conditions

For the verification of the high fire protection resistance prototype doors the contractor of Lot P has been commissioned to design and assemble a testing facility (Fig. 9), corresponding to the simulated tunnel conditions in the case of a fire in front of the door:

- Freight train fire (250 MW, max. air temperature 1'000°C after the first few minutes, 90 minutes resistance required, see Fig. 4). After a major fire in the tunnel the functionality of the door is no longer required and a replacement is necessary.
- Overpressure on the side of the cross passage of about 100 Pa (reduced amount vs. real conditions) to simulate the air-leakage through the sealing to the “burning tube” during the fire, avoiding smoke and significant heat propagation in the cross passage. Overpressure is assured by the ventilation system in emergency mode.
A maximum average temperature of the inside face of the door during the fire load of 200°C is a must. A single sensor on the inside face of the door should not measure more than 240°C. These requirements are a condition to limit the inside air temperature of the cross passage at 45-50°C, permitting the functionality of the electrical equipment during a fire.

During an evacuation the functionality of the doors of the cross passage has to be assured up to an air temperature of 90°C in the “burning tube”. This requirement can be tested in a preliminary phase of the fire test.

6 FIRST FEED-BACK FROM THE TESTS

At the present time (September 2006) the installation test, the functionality tests and the endurance tests have been completed. In October 2006 the fire tests will be carried out and the final reports of the tests should be completed before the end of the year. According to the bidding procedure, and respecting the copyright of the prototype doors disclosure of the results of the tests is not yet permitted.

First feed-back from the tests confirm the correct decision of the AlpTransit Gotthard Ltd. and of the engineers for a selective bidding procedure, with separate procurement of an independent certified contractor for the design and assembling of the testing equipment as well as for test processing. The extreme loading in the Gotthard Base Tunnel, endurance test and the verification of the air-leakage rate through the door sealing represent a real challenge for each bidder. After the completion of the tests, the following revision of the submission documents and technical / financial revision of the offers, based on the very interesting and significant results of the tests, will represent the next important challenge for the choice of a central element of the fire/live safety system of the Gotthard Base Tunnel.

7 CONCLUSIONS

The Gotthard Base Tunnel (GBT) will be the world’s longest railway tunnel, with a length of 57 km. It will be unique. This is the reason why no standard solution or products can be adopted to reach the prescribed requirements in the case of an accident. Only “on mass tailored” solutions or products are able to meet all requested properties and prescribed conditions: The know-how of some of the best door manufacturers and the chances given by the new technologies are the mixture for success.