 DOI: 10.3217/978-3-85125-883-7-24

EGRESS-DOORS IN ÖBB RAILWAY TUNNELS – BASICS, DECISIONS, RECOMMENDATIONS

[1]Helmut Steiner, [2]Michael Bacher

[1]ÖBB Infrastructure plc, A; [2]Graz University of Technology, A

ABSTRACT

Increasing demands on a modern public transport infrastructure result in ever more extensive and complex projects including long tunnels. This usually also entails increased expenditure on rail technology equipment (including control and instrumentation systems and sensors). The aim of the overall rail tunnel system must be to ensure that railway operations must be safe, punctual and, as far as possible, uninterrupted. Aspects of maintenance, servicing and renewal must never be forgotten in this context.

Emergency exit doors represent an important element in a rail tunnel, especially in the event of an incident for people fleeing and seeking for safe areas. It is of great importance and in many aspects a great challenge to define reasonable requirements for egress doors with regard to statics, serviceability, fire protection, operability, among others. Such requirements are finally often associated with compromises.

Keywords: Egress-door, tunnel-door, emergency exit door, swinging door, double-action swinging door, sliding door, railway tunnel, tunnel safety

1. INTRODUCTION

Modern transport infrastructure is playing an increasingly important role in the area of conflict between constantly increasing mobility needs, the associated traffic volume and the fight against the global climate crisis. This requires efficient, fast and convenient connections between urban areas, coupled with high frequency. Only rail-based systems can provide these options to the required extent (e.g. transport capacity) and in accordance with today's general conditions and targets (e.g. reduction of CO2 emissions).

The existing topography in Central Europe (e.g. the Alpine arc), settlement structures, environmental considerations, require underground and tunnel systems to an ever increasing extent. In this context, safe operation and, in case of incidents, safe escape of the passengers are of eminent importance. Escape routes must be adapted to the tunnel system (e.g. single- or double-tube or double-track line) and the external boundary conditions (e.g. topography and geology) and can therefore vary considerably. In tunnels, emergency exit doors are an essential component to ensure a safe fire protection separation of the different areas such as tunnel, cross passage, emergency exit, etc. The long tunnel projects currently under construction in the ÖBB network, such as the Semmering Base Tunnel (SBT) and the Koralmtunnel (KAT), as well as the transnational Brenner Base Tunnel (BBT), require a large number of such doors.

In Austria, in a double-tube tunnel system, cross passages are built in general at intervals of around 500 m, connecting the two tubes. These not only provide the escape route, but also serve technical rooms with various technical equipment like electrical power supply, telecommunications, etc. In order to protect these areas from high pressure fluctuations and dust loads due to the train service, the aspect of leakage must also be taken into account.

2. BOUNDARY CONDITIONS / REQUIREMENTS

Doors let people in, but they also lock them out. They create safety, security, protection against weather, wild animals, uninvited guests and much more. Doors have been around since people began building shelters of all kinds, for different reasons and with different materials. Especially in railroad tunnels of high-performance tracks, the requirements for emergency exit doors are multi-layered and diverse in nature. These doors can therefore in no way be described as "off-the-shelf product", but are "special units" of great complexity and high quality.

Requirements for emergency exit doors arise on the one hand from static and dynamic aspects, mainly resulting from the pressure effects of fast-moving trains. On the other hand, since they also serve as partitions for fire compartments, corresponding fire resistance classes must be specified. In order to meet these two requirements, very stable, solid and therefore heavy constructions are required. In the interest of easy escape, however, low opening forces are defined by standards and regulations. The high door weight in combination with easy usability almost automatically results in a motor-assisted or motor-driven door, which on the other hand must be equipped with additional safety elements to avoid escaping passengers being crushed or pinched.

In total, this results in a very complex, high-tech component that should be available with a high degree of reliability and availability in conjunction with the lowest possible expenses for maintenance [1, 2].

3. ASPECTS - DECISIONS

Table 1 provides an overview of possible aspects that influence the project-related decision when selecting an emergency exit door. The order in which the topics and keywords are listed does not represent a ranking or evaluation, nor does it claim to be complete.

Table 1: Aspects of emergency exit doors

General	• RAMS – Reliability, Availability, Maintainability, Safety • Life Cycle Costs (LCC) • Live Cycle Management (LCM) • Quality - e.g. steel grade, coating thicknesses • Pressure-, smoke-, dust-proof
Type	• Swinging door • Double-action swinging door • Sliding door - articulated sliding door, sectional sliding door • Special door – e.g. pressure-neutral door, telescopic sliding door
Structural analysis	• Boundary conditions - e.g. tunnel cross-section, train speed, railway system, train split • Design – structural- and fatigue safety • Durability
Fire	• Functional integrity • Fire resistance class • Heating curve - e.g. unit temperature-time curve
Geometry	• Shell geometry, shell clearance • Clearance and height • Assembly conditions • Space requirements for open door
Operation	• Operating and opening elements

	• Operating and opening forces • Labelling, symbols, lighting, colour • Safety devices
SCADA / sensors	• Remote control • Status indication
Tender process	• Type of tender process • Prequalification (suitability, selection criteria) • Best bidder and quality criteria • Validation of required criteria

3.1. Type of doors

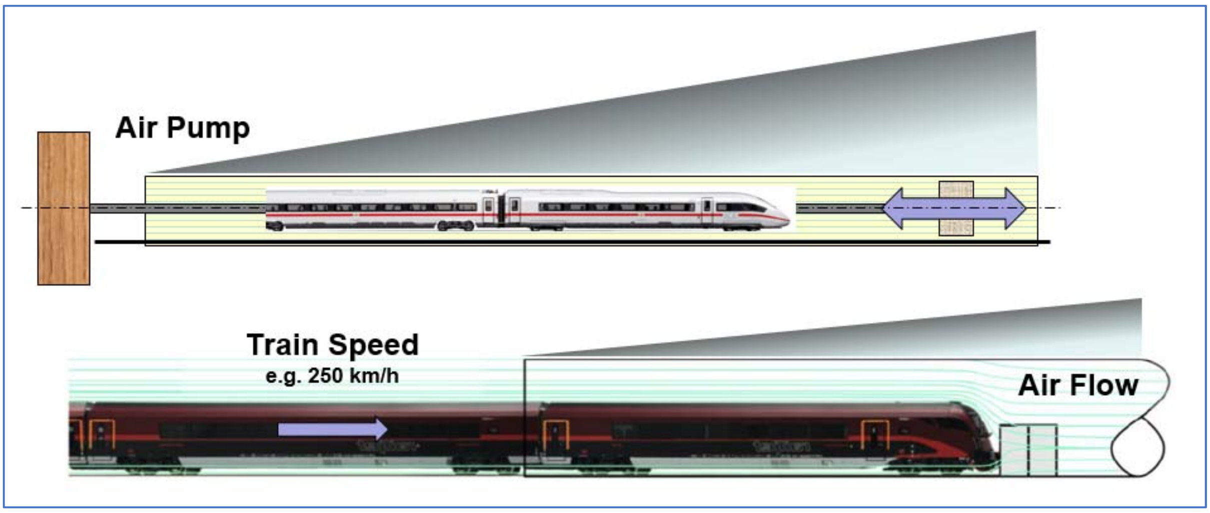
Currently, different types of doors are used by railroad operators in Europe. For example, double-action doors are used in Germany and sliding doors in Switzerland. Each type has advantages as well as disadvantages, which depend on the specific application and the boundary conditions. The basic principle is: keep it as simple as possible. Doors should have as few sources of error as possible, but at the same time offer high availability and lower maintenance and service costs [6].

The ventilation system plays a decisive role in the selection of the door type, because in event of an incident, the escape routes must be kept smoke-free. By generating a positive pressure gradient between the escape route and the location of the incident, fresh air flows from the safety tube into the event tube, avoiding any penetration of smoke into the escape route. However, this pressure difference has a big influence on the door opening forces. Especially in the case of swing and double-action doors additional components such as overpressure relief flaps or mechanical door opening aids are indispensable.

Last but not least, the geometry of the escape route as well as the installation situation also influence the decision as to which door type is finally selected.

3.2. Aspects of structural analysis

High speed trains in a railway tunnel cause multiple phenomena and thus also affect the various installations in the tunnel. One of them is the piston effect which generates an air flow in the tunnel. The other one is the sonic boom at the exit portal, generated by train induced pressure waves (Figure 1).



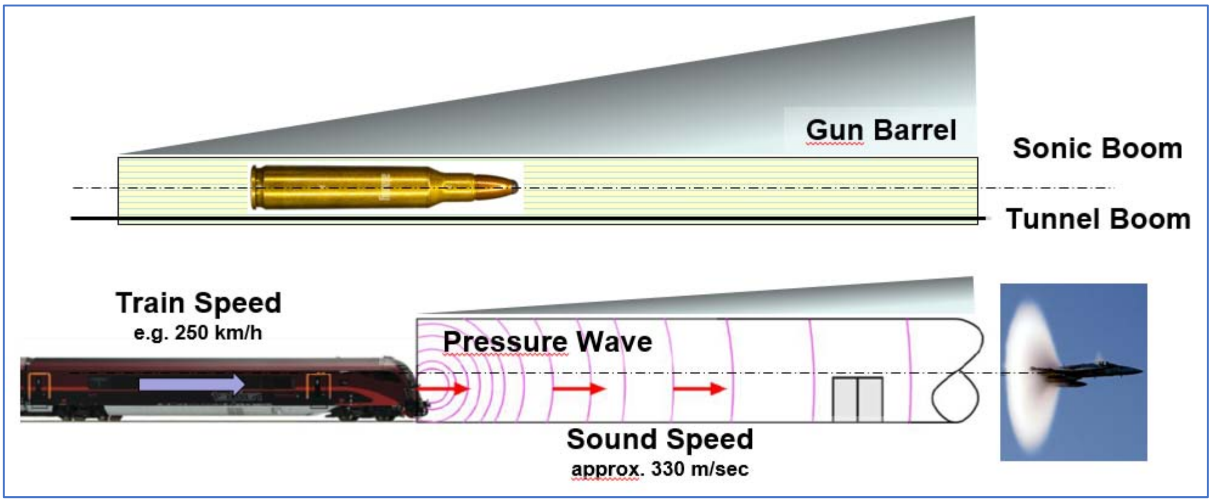


Figure 1: Air flow and pressure wave phenoma in a railway tunnel

It is important to distinguish in which way pressure can be balanced in a tunnel. In the case of an emergency exit door, were no pressure balance between inside and outside take place, very high-pressure differences occur within milliseconds when a high-speed train enters, passes through and exits the tunnel. These pressure differences lead to dynamic loads on the emergency exit doors. Figure 2 shows a typical pressure load profile in a tunnel resulting from a ÖBB RailJet train.

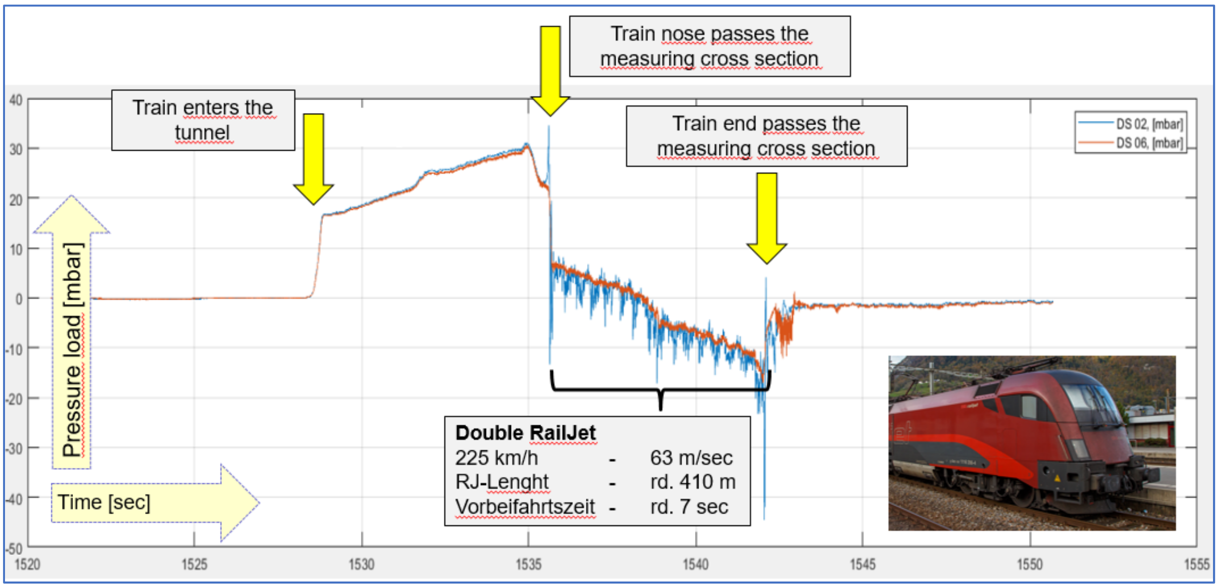


Figure 2: InSitu measured pressure curve of a double RailJet

With the help of in-situ measurements in railway tunnels (e.g. Unterinntal, west route) on various components (e.g. sole drainage lid, emergency exit doors, telecom cable brackets), the loads that actually occur could be determined. The results of these measurements serve as the basis for the design of the components and their mounting [8, 9].

Using numerical simulations on an idealized model tunnel, the influence of the tunnel length (including the reflection of the pressure waves at the portals), the clear cross-section and the train speed were examined and subjected to an overall assessment [4].

3.3. Fire resistance

Every building structure as well as every underground system must be divided into fire compartments in order to provide safe areas for escaping persons in the event of an incident. In the case of the Koralm Tunnel the two tunnels are connected with cross passages at intervals of about 500 m. In case of an incident, passengers can escape from the emergency tube via the cross-passages into the opposite safe tube. According to the safety plan fire resistance must be provided over a time span of 180 min. This is done by the two wall slabs – including the escape doors, which separate the cross passage from both tunnel tubes (Figure 3).

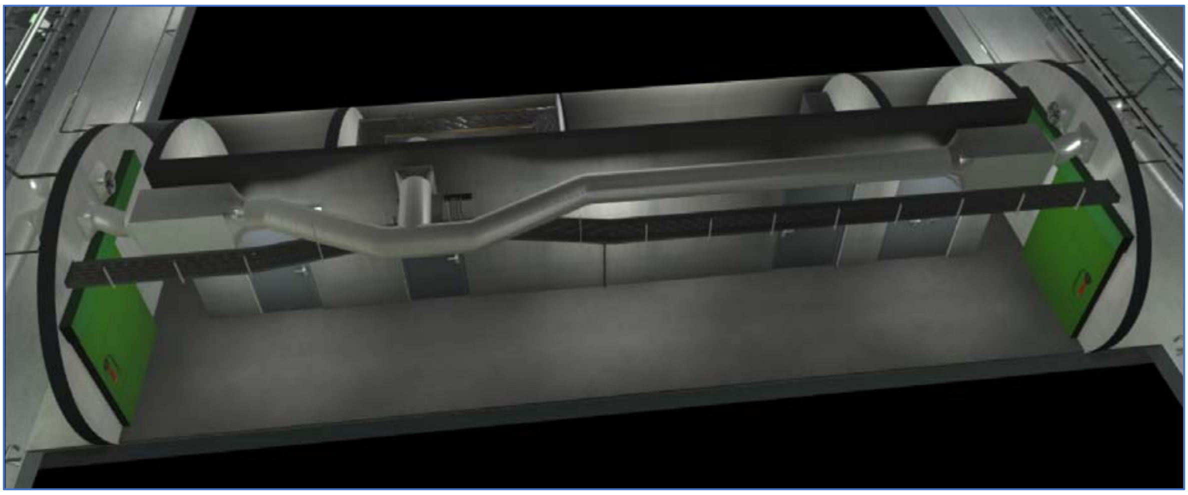


Figure 3: 3D view of a koralmtunnel crosscut / shown in green the emergency exit doors / the clossing on both sides to the running tunnels

The fire classification is based on test criteria which include a temperature-time curve. Since various temperature-time curves for such classifications exist, it is essential to select the appropriate curve for the specific application. Figure 4 shows various curves widely used for different applications in tunnels. The so called RWS curve is sometimes used in road tunnel applications while the ISO standard temperature versus time curve (ISO 834 or EN 1991-1-2) is often used for 'standard' fire testing applications.

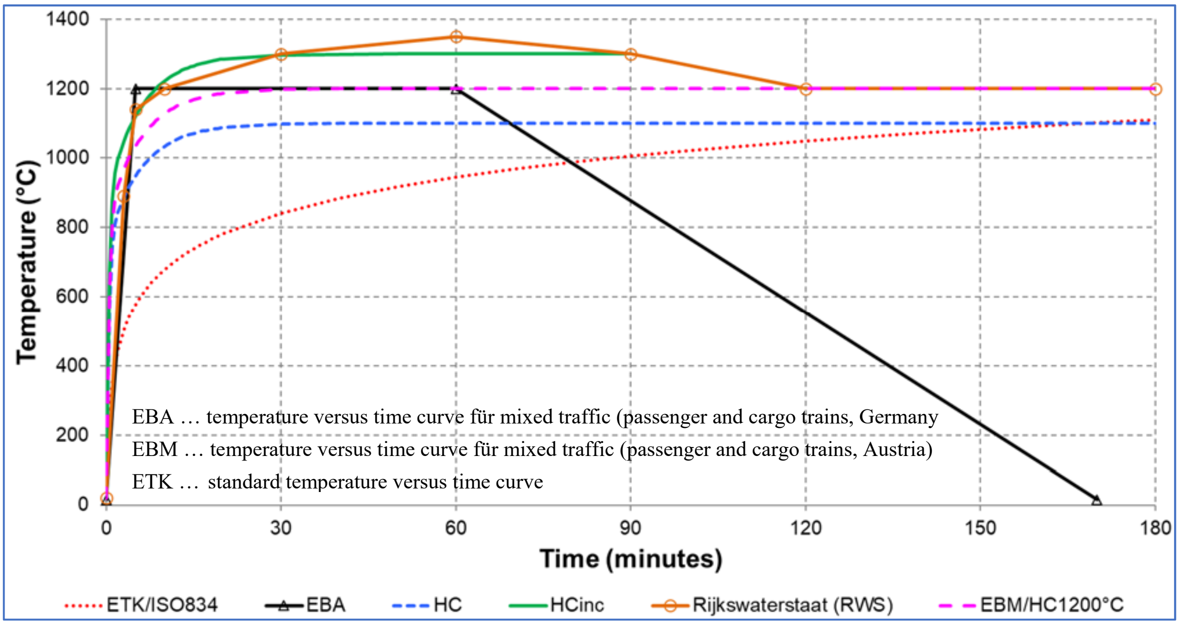


Figure 4: Comparison of different temperature-time curves

In order to be able to select the most appropriate temperature-time curve for the specific project, detailed analyses (e.g. CFD simulation with different fire loads, geometries, boundary conditions) were carried out e.g. for the Koralm railway line [5]. Figure 5 shows the results from a 100 MW (75 MW convective heat) fire event concerning a train stopping very close to cross passage door.

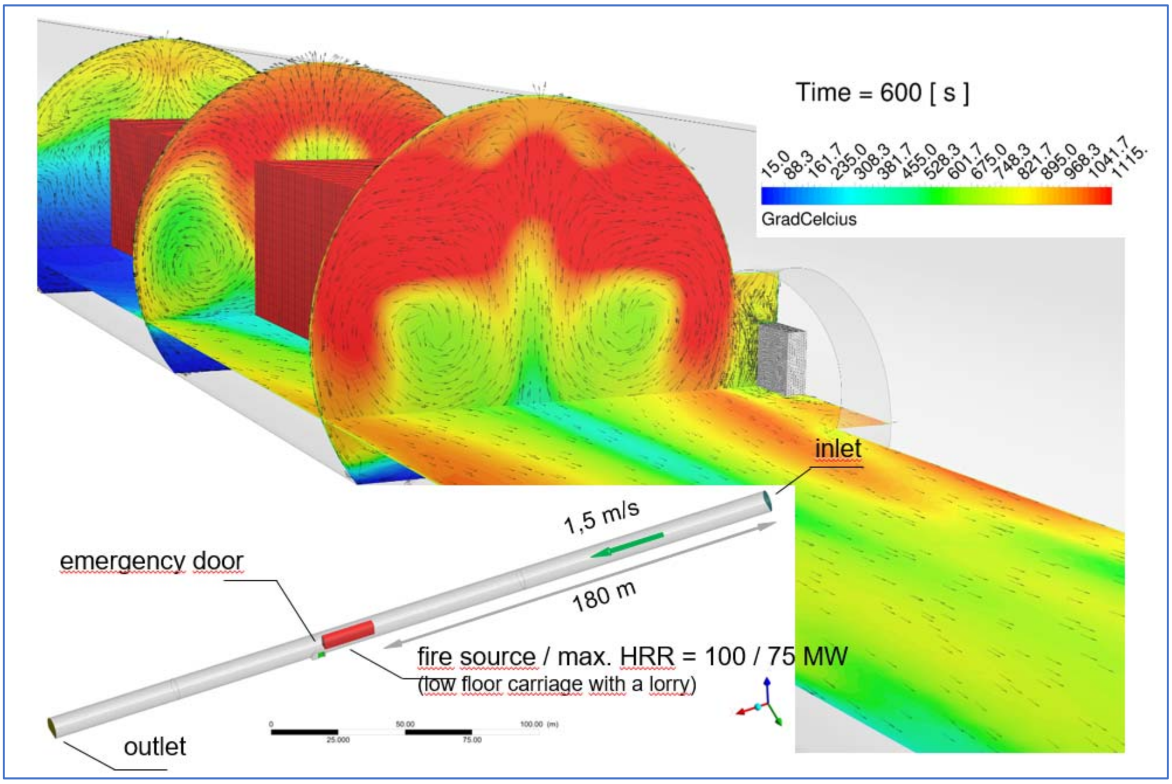


Figure 5: CFD simulation - 75 MW HRR after 600 sec.

From the results in connection with existing technical literature, it was concluded that the application of the unit temperature versus time curve is sufficient and correct in this case.

3.4. Clearance of the passageway

It is very important to provide sufficiently dimensioned passageways. The dimensions of the cross section of the passageways was determined with the help of egress simulations. The critical input parameters are the type of trains and the associated maximum number of escaping passengers (Double RailJet - approx. 1,000 persons), the width of the escape route in the tunnel (pavement width for the KAT is between 1.8 and 2.1 m), the stop position of the train in the tunnel (directly in front of a cross- passage or between two cross-passages) and the escape route length (distance between two cross-passages). For the KAT, the following minimum clearance of the passageways through the door were obtained (see table 2).

Table 2: Emergency exit doors - clearance of the passageway

location	type of door	clear width	clear height
outside the emergency stop escape routes every 500 m	sliding door	1.6 m	2.2 m
within the emergency stop escape routes every 50 m	sectional sliding door	1.4 m	

3.5. **Opening force**

To ensure that the emergency exit door can also be opened easily by physically impaired persons, children, etc. in the event of an incident, the corresponding maximum opening forces (100 Newton) must be observed. The doors are intended to be used for a period of at least 30 to 50 years (depending on train frequency and train mix). During this period, soiling and abrasion occur, which leads to an increase in the opening forces over the service life. Therefore, it makes sense to define a lower limit value (e.g. 80 N) for the new egress door. By mechanizing the door, which can be achieved by e.g. completely motorized opening and closing process, the maximum opening forces can be guaranteed over the life cycle of the door. However, in the case of mechanized doors, it is necessary to take measures against crushing, shearing, impact and retraction.

4. TENDER PROCESS

In order to ensure that the desired product can be produced, delivered and installed on time in the required quality, sufficient time for tests must be calculated already for the tendering and contract awarding process.

Since large projects such as the Koralmtunnel require a large number of emergency exit doors (approx. 200 pieces), order and production delays can take on proportions that jeopardize the entire project process.

An EU-wide published multi-stage award procedure with the stages - Prequalification, Bidding, Negotiation and Clarification, Last and Final/Best Offer - offers the best chances of obtaining the defined product in terms of quality as well as price.

However, it must not be forgotten that a large number of accompanying services, supplies and construction work are still required and that these costs must not be forgotten in the project budget.

In this connection it must be mentioned that suppliers of suitable emergency exit doors can be found only in very limited numbers in Europe.

5. REALISTIC STEADY-LOAD TEST

Commissioning the planned, designed and finally built emergency exit door is an essential point. Above all, the checks should be carried out under boundary conditions that are as close to reality as possible.

A very special issue is the steady-load test, which is necessary to simulate the dynamic pressure effects caused by fast-moving trains in the railway tunnel. In Switzerland and Germany, a test procedure was established at testing institutes in which the pressure load is applied to the door by means of air.

However, since the real load changes occur in fractions of a second and not in seconds, this method was discarded for the Koralm tunnel project. It has been replaced by a more realistic process utilizing a servo-hydraulic load-controlled loading device simulating the pressure waves. Figure 6 depicts the pressure load in the Wienerwald Tunnel as a result of a train passing through.

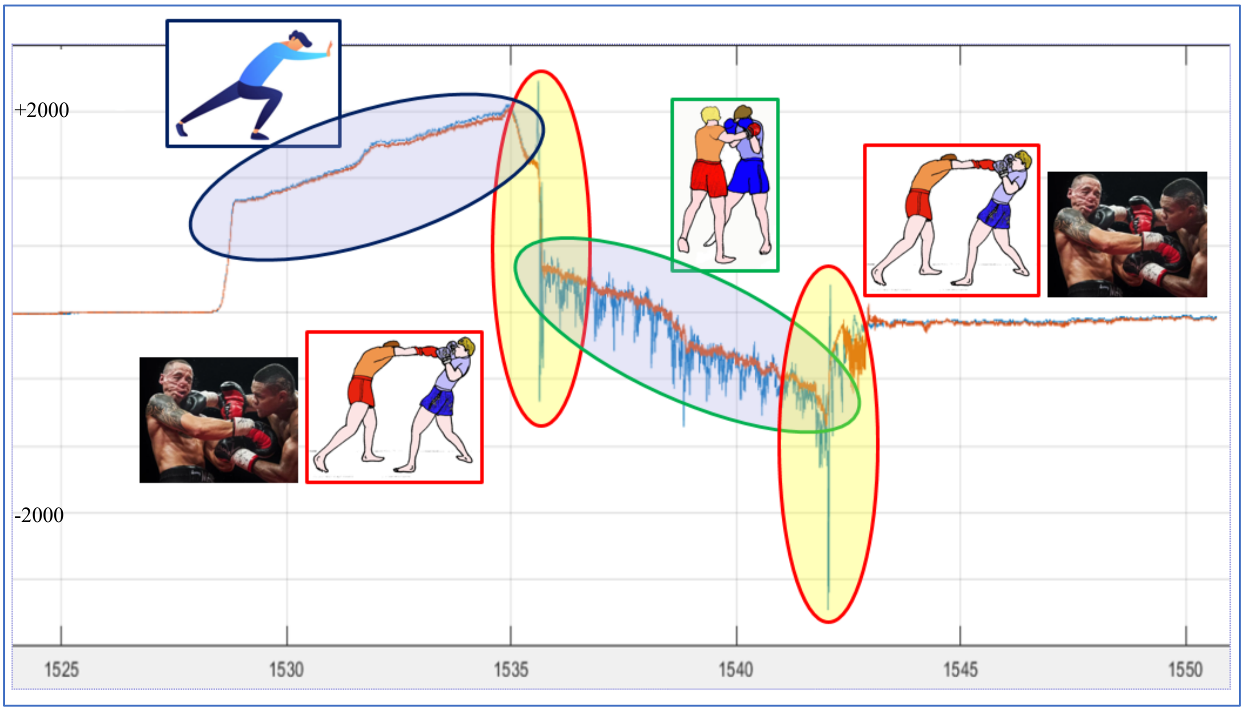


Figure 6: Pressure curve impact analogies (x-axis = time [sec]; y-axis = pressure load [Pa])

In order to uniform the load on the door leaf, an appropriately designed load transmission construction is essential.

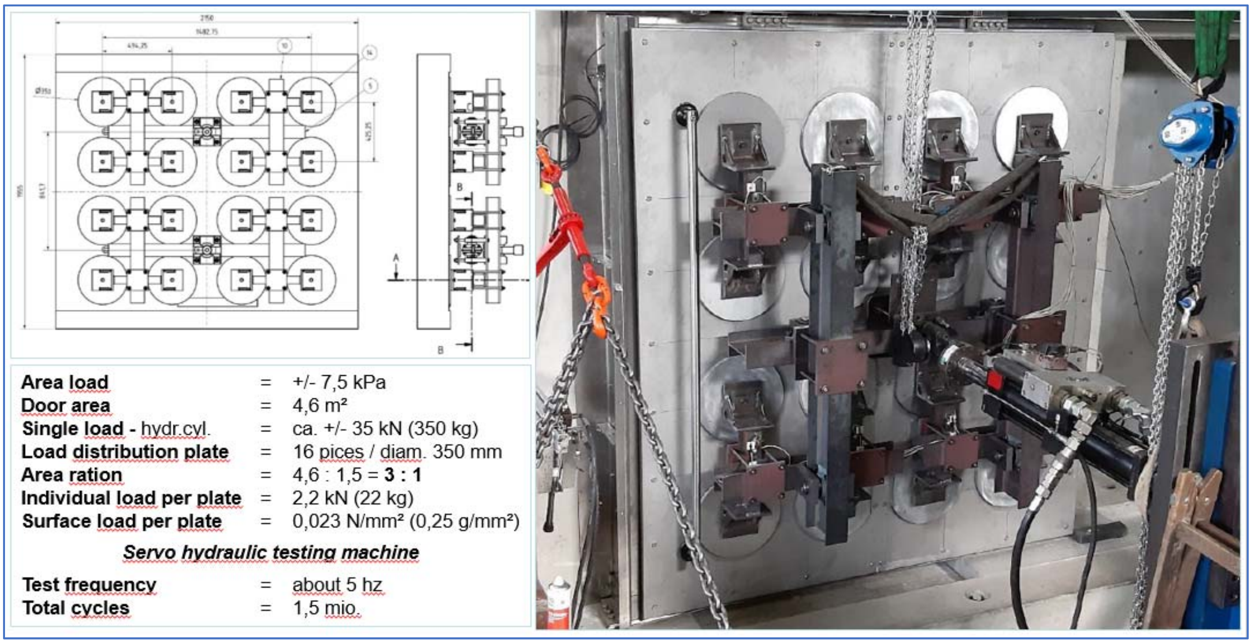


Figure 7: Test set up: concrete frame, sliding door, load transmission construction (servo-hydraulic testing device)

For the testing of the different types of emergency exit doors for the Koralmtunnel, a special test arrangement was developed, evaluated and extensively tested for its practical suitability. The test results were in line with the objectives [3, 7]. Figure 7 shows the load transmission equipment for the tests.

6. SUMMARY AND CONCLUSION

This paper is intended to provide an overview of the different aspects that can influence decisions regarding emergency exit doors in a railway tunnel. Every decision is in the most cases a compromise and depends on the particular boundary conditions of the project and can vary from project to project.

It is important to rank and weight the different aspects and thus to make the decision-making process comprehensible and transparent for third parties and outsiders. A good basis for a profound decision-making process can be an overall project assessment that begins at a very early stage of the project. In this context, a building information modelling (BIM) process can make an important contribution.

7. REFERENCES

[1] Fabbri Davide, Strass Christian, Peggs Simon; Safety doors in world´s longest tunnel under the Gotthard: Outstanding requirements and performance. Feedback from the bidding phase and results from the testing phase on selected prototypes; Proc. of the 33rd ITA AITES World Tunnel Congress; Prague; 5.-10. May 2007

[2] Peggs Simon, Pochop Frank; Anforderungen und ganzheitliche Projektabwicklung am Beispiel Gotthard-Basistunnel; Rosenheimer Tür- und Tortage 2008

[3] Steiner Helmut, Kari Hannes, Reiterer Michael; Erste Schritte zur Entwicklung von “neuen” ÖBB-Tunneltüren; STCE - Dynamik Tage Wien 2016; Tagungsband

[4] Steiner Helmut, Kari Hannes, Reiterer Michael; Baudynamische Analysen bei der Entwicklung von Tunneltüren für die ÖBB: Simulationsberechnungen der Druck- und Sogbelastungen, Stoßspektren, Eigenfrequenzen, Ermüdungsbemessung; STUVA Conference 2017; Forschung + Praxis 49

[5] Steiner Helmut, Beyer Michael, Sturm Peter-Johann; Requirements for escape doors in the tunnels of the Koralm railway line – special focus on the thermal loads during fire; 9th Int. Conv. „Tunnel Safety and Ventilation“ 2018, Graz, proceedings ISBN 978-3-85125-606-2

[6] Baltzer Wolfgang, Brungsberg Torsten, Riepe Werner; Anforderungen an die Ausbildung von Notausgangstüren in Straßentunneln: Barrierefreiheit, Druck-/Sogbelastungen, Geometrie, Ausführungsbeispiele; STUVA Conference 2019; Forschung + Praxis 53

[7] Steiner Helmut, Reiterer Michael; Experimentelle Untersuchung der Dauerhaftigkeit von Tunneltüren für schnellbefahrene Bahntunnel der ÖBB; STCE - Dynamik Tage Wien 2021; Tagungsband

[8] Schellander Janez, Reiterer Michael, Steiner Helmut; Messtechnische Untersuchungen von druckwellen- und strömungsinduzierten aerodynamischen Belastungen in Hochgeschwindigkeitstunneln; 17. D-A-CH-Tagung 2021 Luzern

[9] Reiterer Michael, Schellander Janez, Steiner Helmut; Bahntechnische Einbauten in schnellbefahrenen Eisenbahntunneln der ÖBB – Realitätsnahe Belastungsansätze in Theorie und Praxis, Laborversuche und In-situ-Messungen, STUVA Converence 2021; Forschung + Praxis 56