STANDARDIZING THE TECHNICAL AND STRUCTURAL SPECIFICATION OF DOORS IN TUNNELS

D. Zierl, K. Liebwald, L. Rossbacher, M. Ebner,
ÖBB-Infrastruktur AG, Engineering Services

ABSTRACT

In the past few years the technical and safety needs for railway tunnel systems designed for a cross travel speed of more than 160 km/h caused a steady increase of tunnel facilities. In addition to the structural engineering experience required, a more sophisticated approach of planning the highly complex tunnel equipment is needed. This also to comply with the permanent on-going change in the legal framework.

Experience in the operation has shown that due to the high complexity the tunnel facilities not always work in the way expected (e.g. failure indication) and that facilities in tunnels are often not designed in consideration with other interacting facilities (e.g. tunnel doors and tunnel ventilation). It becomes apparent, that in the future an integrated design of the tunnel facilities is mandatory. This to take part already in the design phase of a tunnel. Various issues with doors in recently opened tunnel-systems forced an evaluation, that subsequently led to a review of the specifications of tunnel facilities, especially doors.

1. INTRODUCTION

To understand related to tunnel facilities, in this case with doors, following questions have to be discussed:

- Why are these facilities in tunnels?
- How did the current requirement of each specific facility come up?

The answer to the first question can be found in the increased inquiry of safety in tunnels on one hand, and in the increased number of various facilities that are believed to be essential in a tunnel on the other hand (e.g. telecom equipment).

The object of this paper is to give an insight in the complex correlations between the different parts of tunnel facilities on the example emergency exit doors.

There are no precise technical regulations, which define uniform specifications of doors in tunnels. Hence the technical solutions are based on project-related individual solutions.

A future goal is to develop a guideline for the design of emergency exit doors to unify their design and simplify maintenance.

Therein it also has to be taken into account, which system of ventilation for operational, maintenance and emergency situations, is or will be installed, because the issues “doors in tunnels” and “tunnel ventilation” interact very closely. The newly obtained findings and experiences show that to reduce the costs of maintenance and the times of interruption of operation, it is necessary to establish a uniform standard for all the different facilities and equipment in tunnels.

It appears that due to the high aerodynamic impact of passing trains, resulting in suction and compression, complications with the fastening devices for the doors in the cross passages and emergency exits already occurred after a short time of operation.

A study was commissioned, which should investigate and record the impacts in means of strain on the doors with measurement devices.

2. REQUIREMENTS ON DOORS IN TUNNELS ACCORDING TO INTERNATIONAL AND NATIONAL REGULATIONS

In international and national regulations set out requirements to ensure the safety of the passengers and staff in case of emergency depend on the design of the tunnel (length of the tunnel, number of tubes, number of tracks) .

To satisfy these measures, additional rooms have to be created, which imply doors with various requirements. In a first step the requirements on doors based on the international and national regulations have to be assessed to understand how the current problems in existing tunnels have arisen.

2.1. Technical Specifications for Interoperability, Safety in railway tunnels (TSI-SRT)

[1] The TSI SRT 2008 represents a European standard of how to deal with safety issues in railway tunnels. The regulations in the TSI are binding and apply to new, renewed and upgraded tunnels. The purpose is to define a coherent set of tunnel specific measures for the infrastructure, energy, rolling stock, control-command and signalling and operation subsystems, thus delivering an optimal level of safety in tunnels in the most cost-efficient way.

One of the measures required by the TSIis the installation of evacuation facilities. So called *safety areas* shall guarantee the evacuation, maintain survivable conditions, allow people to move to the surface without having to re-enter the affected tunnel tube. For this reason it is necessary to separate the affected tunnel tube from the safe area, which can be accomplished either as a cross passage or an emergency exit. The most efficient way of creating a space, where survivable conditions can be maintained is to shield it with a door, which can withhold the exposure of fire (smoke, heat) from entering.

Chapter *4.2.1.1. Prevent unauthorised access to emergency exits and technical rooms* regulates, that doors of technical rooms have to be locked to keep unauthorised person off from entering. Furthermore it regulates, that emergency exits should be locked for security purposes, but shall always be possible to open frominside.

Chapter *4.2.1.2. Fire reaction of building materials* request, that non-structural panels and other equipment (including doors in tunnels) shall fulfil the requirements of classification B of Commission Decision 2000/147/EC. According to TSI SRT 2008, the structural fire protection of the HC curve (Eureka curve) has to match. This curve was applied to the calculations of tunnel doors. In the TSI SRT 2014 this requirement is eliminated and doors can be calculated specifically.

Paragraph *4.2.1.5.2 Access to the safe area* regulates the minimum clear opening of doors giving access from escape walkways to the *safe area,* which shall be at least 1,4 m wide and 2,0 m high. Also multiple doors next to each other which are less wide are allowed, as long as the flow capacity of people is demonstrated to be equivalent or higher.

2.2. Guideline of Austrian Federal Fire Service Association for protection requirements for the construction and operation of railway tunnels

[2] The Austrian Federal Fire Service Association published a guideline for protection requirements in railway tunnels. This national guideline is much more specific regarding means of structural demands for safety in railway tunnels. It describes the structural and operational safety measures to preserve the self-rescue possibility of passengers and railway personnel, but also to enable the rescue forces to operate in case of emergency.

The following chapters of the ÖBFV-RL A-12 address doors in tunnels.

Chapter *2.1 principles* in the paragraph *preservation of the functionality* requests the escape route illumination, emergency communication devices, energy supplies and the opening mechanism of emergency exits in the affected tube to preserve their functionality for a minimum duration of 90 minutes (E90 due to ÖNORM DIN 4102).

Chapter *2.3 emergency exits, emergency stair cases, rescue tunnels* in the paragraph *locks* requests that between track tubes and between emergency exits respectively rescue tunnels locks of a minimum length of 12,0 m have to be installed. Moreover it is demanded that the doors have to be sealed against fire according to T90 (now EI2 90-C). Doors of emergency exits must open in the direction of escape and the wings of the door must have a minimum width of 1,0 m.

Chapter *2.3 emergency exits, emergency stair cases, rescue tunnels* in the paragraph *object protection* requests that doors of emergency exits have to be equipped with panic locks (horizontal bar). These doors have to open from the inside of the affected tube with just moderate effort.

3. DYNAMIC MEASUREMENTS OF EMERGENCY ESCAPE DOORS

The first issues with emergency escape doors in tunnels occurred in recently opened tunnel-systems for the expanded railway lines between Vienna and St.Pölten as well as between Kundl-Radfeld and Baumkirchen , where the trains travel up to 230 km/h. Both lines include a number of tunnels with different tunnel lengths and tunnel constructions.

It was decided to run further investigations to assess the exposures and the critical parts of the doors in tunnels in the course of the *Innovationsmessfahrten 2012* on above named railway lines. Summaries of the result of these measurements will be presented in this chapter.

3.1. Measurements during the *Innovationsmessfahrten* 2012

In 2012 measurements on two selected emergency exit doors in the newly built railway lines have been performed in the course of the *Innovationsmessfahrten*. The focus was to measure the pressures and deformations in the doors, the forces in bolts and the strain in the door hinges.This was done in the *Wienerwaldtunnel* and *Stierschweiffeldtunnel* accomplished by special trains equipped with several measurement devices. .

The emergency escape doors were constructed as double wing door constructions, where one wing is “standing” and one wing is denoted as “moving door”. Both wings are capable of being opened in escape direction with a maximum width of the door (both the wings) of about 2 m.

The **Figure 1** details, the way the door is fixed to the building.

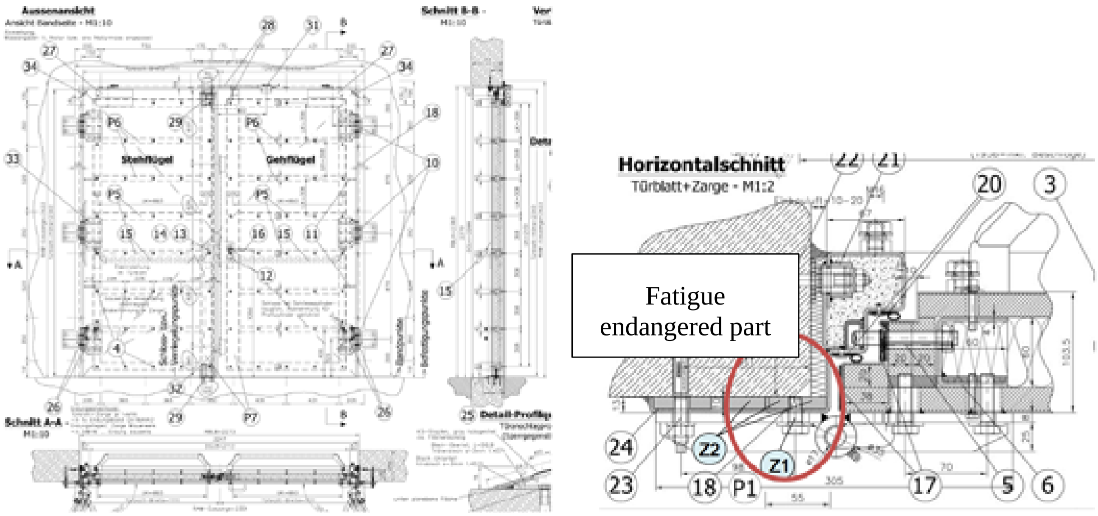

Figure 1: Blue prints of the emergency exit door, Detail of the attachment of the hinges to the door frames. [3]

The measurements during the *Innovationsmessfahrten 2012* were done with twelve measurement sensors (air pressure sensor, displacement sensor, force sensor, strain gauge and photo sensor) to measure the impacts of a variation of passing trains on specified parts of the investigated doors. **Figure 2** shows the alignment of the measurement.

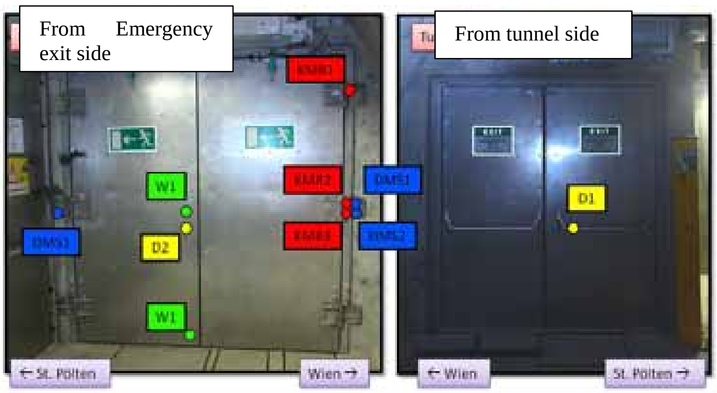

Figure 2: Arrangement of the sensors in the Wienerwaldtunnel [3]

The difference in the air pressure in the tunnel and inside the escaping room due to passing trains was measured by air pressure sensors. Pressure sensor D1 measured the barometric pressure in the tunnel perpendicular to the door, while Pressure sensor D2 observed the air pressure inside the escape room.

The deformation of the doorblade was gauged by a laser displacement sensor. In the 1st phase solely the deformation in the middle of the door W1 was measured. The sensor was placed in middle height in the middle of the doorblade of the “standing door”. In the 2nd phase the displacement measurements were enhanced and another laser displacement sensor was added to measure the movement of the door close to the floor. The forces in the fatigue relevant bolts were measured with three ring force sensors (KMR 1, KMR 2, and KMR 3). For triggering the start of the measurement record, there were mounted tow light barriers (LS1, LS 2).

3.1.1. Summary of the results of the Innovationsmessfahrten in the Wienerwaldtunnel

[3] The Wienerwaldtunnel is a double tube, single-track tunnel with a length of 13 km and a cross-section area of 51 m². The two tubes are connected every 500 m with cross passages and separated by escape doors cross passages.

The results of the measurements show, that the maximum compression and suction impacts on the doors are greatly depending on the direction of the train passing the tunnel. Trains travelling with 235 km/h cause a maximum air compression of 3,7 kN/m² and a maximum intake pressure of -3,1 kN/m². The greatest difference between the measured maximum compression and measured intake pressure caused by a passing train was 5,3 kN/m².

Figure 3 shows the maximum compression and intake pressure impacts of passing *Railjet* trains. The 2 purple lines in the graph represent the design value of the maximum compression/suction values (±4 kN/m²) without considering a dynamic factor $\varphi_{dyn} = 2{,}0$.

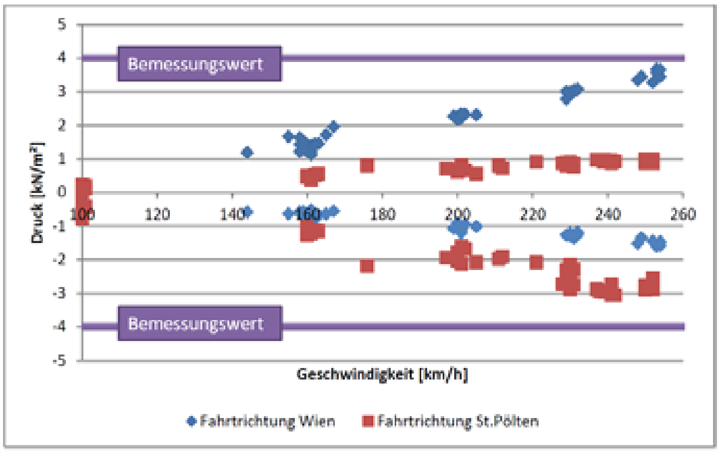

Figure 3: Maximum compression/suction impacts compared to the design values, Wienerwaldtunnel. [3]

The maximum movement was measured at the lower edge of the door blade of the emergency exit doors with around ±3 mm. The distortion (the difference of the movement in the middle and at the edges of the doorblade) was around ±1,5 mm.

Additionally the influence of the tightening torque of the screws in the door hinges on the stresses of the screws was investigated. According to the manufacturers the tightening torque should be around 30 Nm. By means of force sensors it could be assessed, that by reducing the tightening torque the dynamic forces in the screws are doubling.

Figure 4 shows the maximum values of compression in the tunnel due to passing *Railjet* trains. It obvious, that the compression respectively the suction impact on the door is highly depending on the direction of travel.

The impact of this suction is superposed with the impact of the compression resulting from the portal entry wave. That's the reason why the maximum value of suction of a train heading to Vienna is lower than one heading to St. Pölten.

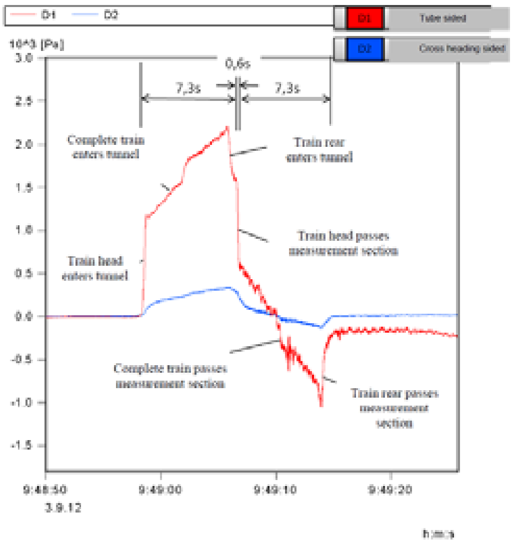

Figure 4: Maximum values of Compression in the tunnel (sensor D1and D2) [3]

3.1.2. Summary of the results of the Innovationsmessfahrten in the Stierschweiffeldtunnel

[4] The *Stierschweiffeldtunnel* is a single tube, double track tunnel with a length of 3 km and a cross-section area of 76 m². The investigated emergency escape doors separate the tunnel tube from the emergency exit.

The analysis of the measurements shows, that the maximum measured compression/suction values cluster around 2,1 kN/m² respectively -3,2 kN/m². It turned out, that no matter on which track the train is travelling, the compression/suction impact on the doors is more or less the same.

Figure 5 shows the maximum compression and intake pressure impacts due to passing *Railjet* trains. The design value of ±4 kN/m² was not exceeded.

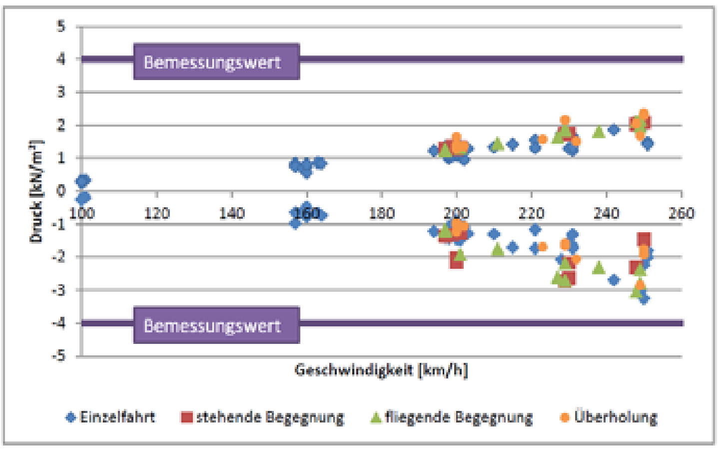

Figure 5: Maximum compression/suction impacts compared to the design values, Stierschweiffeldtunnel. [4]

4. EXAMPLES OF ISSUES WITH DOORS IN TUNNELS

An evaluation of the maintenance records of the emergency exit doors in the first year of operation showed, that doors were occasionally opened by passing trains. An examination of the affected doors showed that the fastening systems are suffering from fatigue damage, because of the load changes caused by passing trains.

The malfunction of a subsystem like the emergency exit doors subsequently causes a reduction of possible train operations of the line.

4.1. Contamination of the closing mechanism of emergency exit doors with magnetic dust caused by abrasion.

In the first year of operation a malfunction of the closing mechanism of emergency exit doors was observed. As already mentioned before, some of the emergency exit doors opened by passing trains. This unwanted opening immediately starts the emergency ventilation program, and also sends a message to the facility service center.

Investigation showed, that the closing mechanism of the doors couldn't lock the doors properly. The emergency exit doors have three locking pins, which are connected with a locking bar and can be moved by operating panic bar. This bar was contaminated with magnetic brake dust of the trains and caused an adherence of the locking mechanism (**Figure 6**).

Figure 6: From left to right: contaminated locking pin, brake dust behind the coverage, magnet placed on coverage [5]

4.2. Interactions between tunnel doors and tunnel ventilation systems

It has become apparent, that not only the choice of the type of door (Swing door, double swing door, sliding door, etc.) is of importance, but also the verification of requirements really necessary and if they areaccomplishable.

Therefore it also has to be taken into account, which system of ventilation for operational, maintenance and emergency situations, is or will be installed, because the issues "doors in tunnels" and "tunnel ventilation" interact very closely.

5. PROSPECT AND GOALS FOR FUTURE TUNNEL PROJECTS

Given the various interactions of the individual tunnel facilities a working group was established to evaluate the specifications of tunnel facilities, especially doors, in already operating tunnel-systems. This working group is composed of representatives of the departments project management, construction management, maintenance of tunnel constructions and emergency management to exchange experiences and expertise.

The group's objective is to develop a technical regulation, which defines the uniform specifications of tunnel facilities e.g. of the doors in tunnels. Furthermore a specification sheet will be created, describing the essential operational procedures and service intervals for the maintenance.

It is expected that these will make a valuable contribution to reduce the costs of maintenance and the times of interruption of operation.

6. REFERENCES

[1] Official Journal of the European Union, Technical Specifications for Interoperability - Safety in railway tunnels, 7. März 2008

[2] Österreichischer Bundesfeuerwehrverband, Richtlinie ÖFV-RL A-12 Bau und Betrieb von neuen Eisenbahntunneln bei Haupt- und Nebenbahnen - Anforderungen des Brand- und Katastrophenschutzes, 28. Februar 2000

[3] RED Bernard GmbH, Bericht Messtechnische Untersuchung „Fluchttüren“ – Innovationsmessfahrten 2012, Wien, 19. März 2013

[4] RED Bernard GmbH, Bericht Dynamische Messung an einer Fluchttüre im SSFT unter Betrieb, Wien, am 13. Dez. 2013

[5] Klaus Liebwald, Ludwig Rossbacher