

## Ventilation of emergency station in the Koralmtunnel

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### ABSTRACT

Due to the limited capability to maintain a train in movement in the case of a train fire, long railway tunnels are subdivided in shorter tunnel sections by emergency stations. These underground stations must be designed and equipped in a way that the conditions for a fast and safe evacuation of a train are much better than in the tunnel itself. To guarantee a safe haven for the passengers over an extended period of time a ventilation system must be provided to control the smoke produced in a train fire.

The paper presents an innovative concept for such a ventilation system using "bypass channels" at both ends of the emergency station. The concept has been developed for the 33 km long, twin bore Koralmtunnel in Austria and is specially suited for situations where a direct connection to the surface by an airshaft is complex and expensive due to the high overburden.

### 1 INTRODUCTION

Due to its location within the Alps of central Europe, Austria has played an important role for European passenger and goods traffic for centuries. Crossing the Alps has historically been one of the biggest challenges in the construction and maintenance of traffic routes.

Ever since it became a member of the European Community (EC), Austria has had to deal with a significant increase in rail traffic. Due to the entry of several eastern European countries in May, 2004, a significant increase, with an above-average increase in road transport, has been predicted for the future.

This changed political and environmental situation will require a transport system that is suited to the dimensions and characteristics of the European Continent. High speed travel and transport by rail is an environmentally conscious alternative, which, at the same time, enables a longterm sustainable mobility. Railway companies are currently working hard to create a high-speed railway network as part of a Trans European Network (TEN). In this task, they are receiving political support at both national and international levels.

In conformity with European intentions, Austria's government has defined five main railway axes to be improved. One of the key railway connecting lines is the Pontebbana corridor. It represents the easternmost crossing of the Alps and links several Central-eastern European cities and countries, Vienna, southern Austria and northern Italy (see Figure 1).

One of these projects is the Koralm railway in the South of Austria. This new stretch will have a total length of approximately 130 km, and will connect the provincial capitals of Graz and

Klagenfurt. With this new railway line, the travel time between Graz and Klagenfurt will be reduced from the present three hours to a journey of less than one hour. In order to improve this connection, efforts have been focused on several stretches along the line.



**Figure 1: The Pontebbana corridor.**

The Koralmbahn route planning is characterised by large radius curves and reduced gradients which makes it possible to run both fast passenger trains and heavy freight trains. The design speed amounts to  $v_{max} = 250 \text{ km/h}$ ; the maximum gradient will be limited to 10 ‰.

The most prominent tunnel along this stretch will be the Koralm tunnel. It will pass under the Koralm, a mountain range between the provinces of Carinthia (Kärnten) and Styria (Steiermark). The maximum overburden will reach almost 1,200 m. The tunnel will have a length of approximately 32.8 km.

The planning process for the Koralm tunnel started in 1998 and was divided into steps:

- The Route selection procedure: Phase 1 - Tunnel route and variant selection; Phase 2 - Route optimisation and planning.
- Preparation and completion of an environmental impact assessment.

- At present, proceedings for building permission and detailed investigation works for the Koralm Tunnel are in progress including a system of investigation tunnels having an overall length of 11 km (see Figure 2).

Depending on results of the preliminary investigation and processing by the authorities, construction work on the Koralm tunnel could start in the year 2008/2009 and result in a scheduled completion in 2016.

## 2 TUNNEL SYSTEM

The Koralm tunnel (see Figure 2) is classified in the category of "very long railway tunnels". With respect to the UIC-Kodex [1] and in compliance with Austrian regulations [2], [3], the system design comprises a double tube tunnel. The cross sectional area of each tube will be 52 m<sup>2</sup>. The tubes are connected by cross-passages at a separation distance of 500 m. The cross-passages are designed as escape routes and provide additional space for the technical infrastructure of the tunnel. The cross-passages are sealed at each end by fire rated doors. The highest-point of the tunnel is close to the middle point. The difference in height between the highest point and the east-portal is approximately 40 m (gradient 0.3%) and to the west-portal 100 m (gradient 0.544%).

Due to the distance to the middle of the tunnel, an emergency station will be provided. The emergency station (see Figure 4) consists of two escape walkways each having a total length of 400 m. These escape walkways run alongside the track for the length of the emergency station. The emergency station also consists of an emergency refuge area connected to the walkways by eight escape routes at a separation distance of 50 m. The emergency refuge area has a floor area of 2000 m<sup>2</sup> and provides a safe refuge for at least 1000 Persons over an extended period of time.

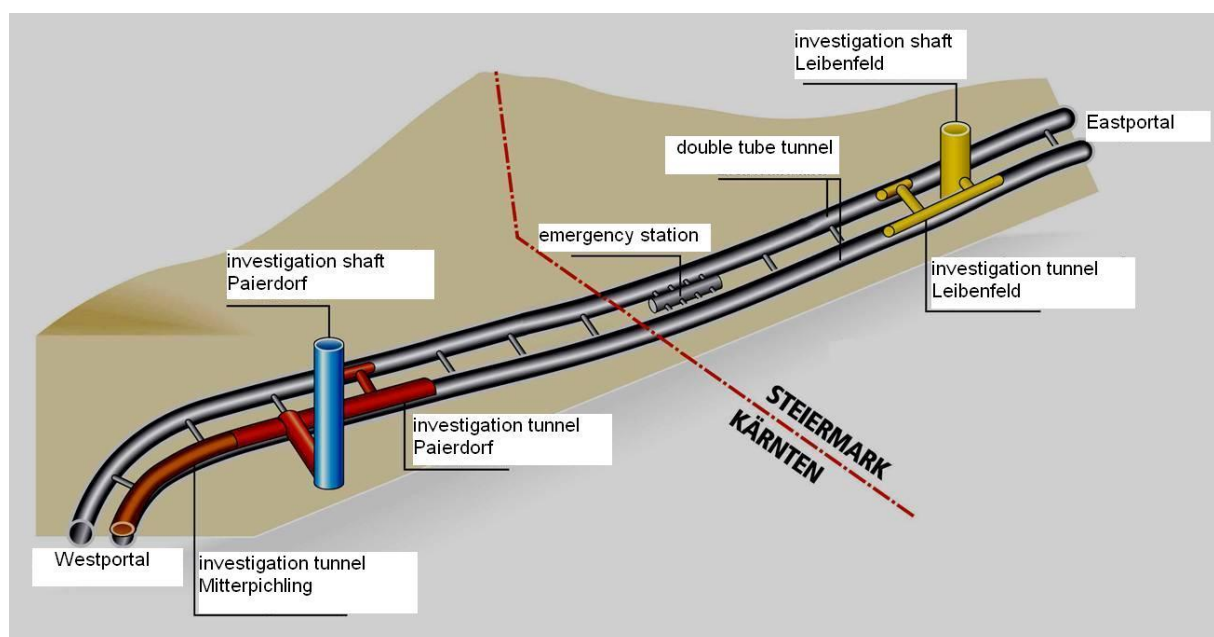


Figure 2: Tunnel system with investigation shafts and the investigation tunnels.

An underground interchange (cross-over tube section), which would connect the two train tunnel tubes, is not necessary for this system's traffic requirements. As a result the safety advantage of separate tubes is maintained.

### 3 VENTILATION CONCEPT

#### 3.1 Design criteria

In addition to the passive safety measure of separated tunnels, the Koralm tunnel will have a ventilation system (emergency ventilation). The emergency ventilation concept is based on fire scenarios of a railway passenger car which may be stopped alongside the emergency station or somewhere within the incident tube. The passengers will then be evacuated into the emergency refuge area within the emergency station or through the cross-passages into the non-incident tube.

In case of fire the ventilation system will facilitate escape and rescue and will mitigate possible damage. According to the safety concept for the tunnel, the following areas are required to be safe over a sufficient period of time:

- Emergency refuge area in the emergency station.
- Non-incident tube.

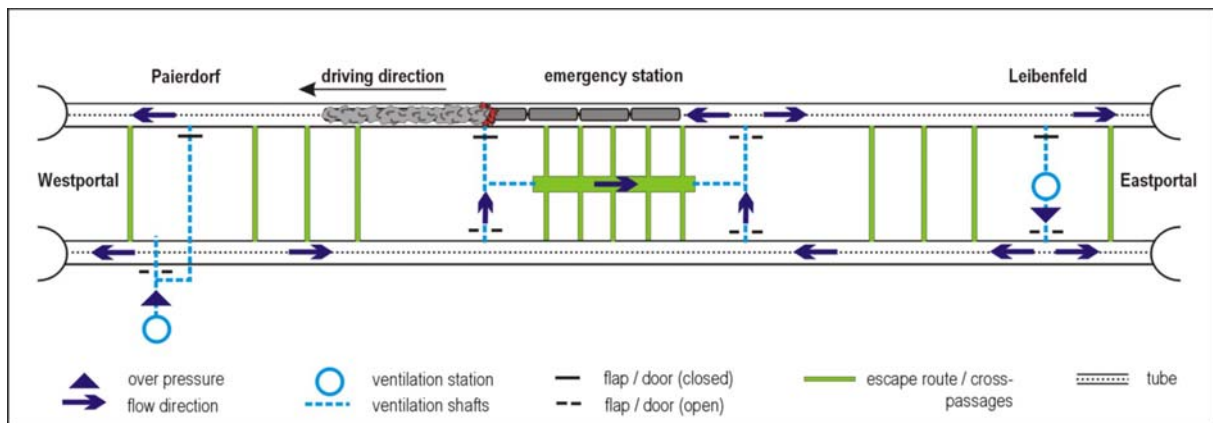
The ventilation system is a safety feature, which has to provide on one hand tenable conditions for occupants and emergency personnel in the safe areas and on the other it provides a contingency measure in the event of the possible failure of the passive fire protection features (eg. fire rated door blocked, open or damaged). The present design of the ventilation system is based on a minimum air velocity of 2 m/s through open doors (emergency refuge and cross-passages), even in the case that all doors of the emergency refuge are simultaneously open. The design target of 2 m/s covers a wide spread of fire-sizes including a heat release rate of 25 MW which is more or less typical for a railway passenger car.

Based on the safety concept, influencing the propagation of smoke within the incident tube and preventing backlayering in the incident tube, are both not primary safety objectives. Nevertheless, the secondary effect of smoke reduction in the incident tube created by the ventilation system was taken into consideration during the evaluation of various options for the ventilation systems.

Additionally, the emergency ventilation system can be used for service and maintenance activities within the tubes. The ventilation system is not intended for use during normal operation of the tunnel.

### 3.2 Ventilation system

Due to the high overburden (1200 m) at the emergency station a vertical airshaft for smoke extraction is complex and expensive. The ventilation concept thus is alternatively based on pressurising the non-incident tube. Fresh air is brought into the tunnel by large axial fans. The concept also includes connection of the emergency refuge to the pressurized tube via bypass and ventilation ducts. The two required ventilation stations will be located at the top of the investigation shafts at Paierdorf and Leibenfeld. At present each ventilation station will be equipped with three axial fans with a total flow capacity of 315 m<sup>3</sup>/s per station. The two tubes will be connected with the ventilation station by ventilation shafts. Controlling the airflow requires two control flaps at each ventilation station (see Figure 3).



**Figure 3: Tunnel ventilation system in a case of fire. The incident train remains stopped alongside the emergency station.**

### 3.3 Overpressure in the non-incident tube

In an emergency, the two safe areas (emergency refuge and non-incident tube) are separated, both aerodynamically and physically, from the incident tube. In the case of open escape doors (during escape), or doors which may fail to close or in the case of failure of some other component of the fire compartment, the overpressure from the non-incident tube will counteract smoke migration into the safe areas. The fresh air, delivered by the axial fans, passes from the pressurized non-incident tube into the incident tube. The expected air velocity at door openings varies between 2 m/s and 10 m/s depending on the door's location and number of open doors.

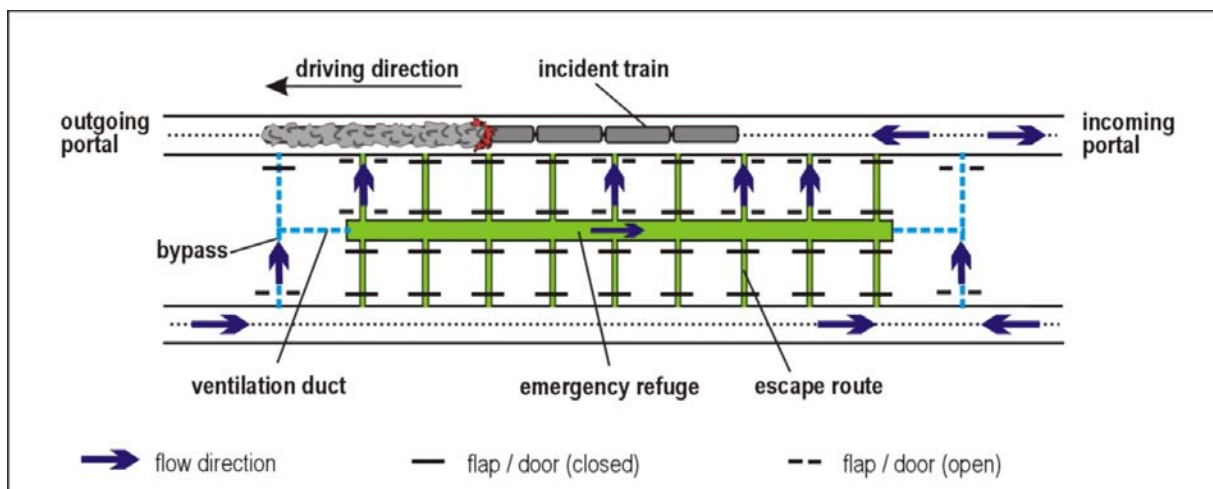
Due to the short distances between the ventilation stations and their respective portals (3.2 km to the east-portal and 3.7 km to the west-portal), an essential amount of the air flows directly out of these portals. The over-pressure in the non-incident tube prevents smoke migration into the non-incident tube from a burning train car which may be close the portal in the incident tube. Therefore, additional ventilation measures close to the portals are not needed.

The pressure difference between the two tubes along the tunnel is typically in the range of 80 to 140 Pa. The force needed to open escape doors against these pressure differentials will be in a range that the assistance of an opening aid (motorized or pneumatic opening device) will be needed.

## 4 VENTILATION OF EMERGENCY STATION

### 4.1 Ventilation of emergency refuge

The objectives in ventilating the emergency refuge are pressurization to prevent smoke movement into the emergency refuge and fresh air supply for the occupants until the rescue is complete. The solution consists of connecting the emergency refuge at each end to the pressurized tube (non-incident tube) via a bypass and a ventilation duct (see Figure 4). The pressurization of the emergency refuge will be established by controlling the four necessary ventilation flaps. The air always flows from the pressurized non-incident tube to the refuge area. In case of open doors the design target of a minimum air-velocity of 2 m/s through the open doors will be fulfilled. The installation of additional locally operated ventilators and fire dampers (e.g. at the escape routes of the emergency station) is not necessary.



**Figure 4: Ventilation concept in the case of fire where the incident train remains stopped alongside the emergency station.**

### 4.2 Manipulation of air flow in the incident tube

Besides prevention (by overpressure) of smoke entry into the safe areas, the bypass solution provides a secondary but significant advantage. Control of the flaps will influence the airflow and movement of smoke in the incident tube in the event of the incident train remaining stopped alongside the emergency station (see Figure 4). The main issue for consideration is

to influence the smoke propagation at the escape walkway alongside the incident train and ventilating the tube section where following trains may be forced to remain a certain time.

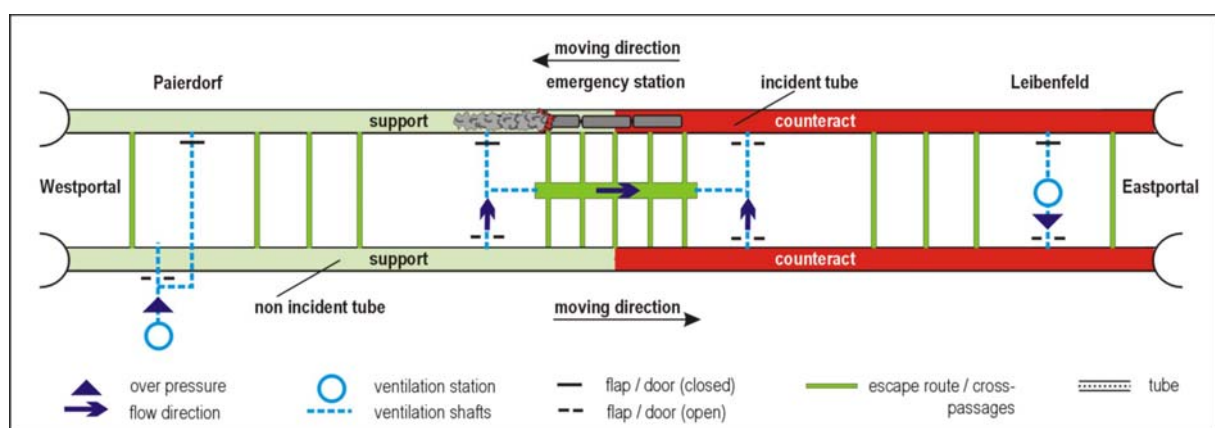
Opening the flap linked to the non-incident tube generates a flow of air into the incident tube. The entering airflow is divided into two streams. One stream heads to the train's incoming portal, the other stream flows towards the opposite outgoing portal.

Control of the flaps ensures that the airflow direction at the escape walkway will always be against the rear of the incident train. Thus the airflow induced by the train's piston effect and by the emergency ventilation system will have the same direction. The initial smoke movement generated by the incoming train will be stabilized by the ventilation system. The smoke in the tube will therefore be diluted (at present design 75 m<sup>3</sup>/s of fresh air - value valid for neutral boundary conditions with out any outside influences like barometric pressure differences) and forced toward the outgoing portal. The escape conditions will be substantially improved in the zone between the fire and the rear of the train.

The other portion of the supply airflow forces fresh air towards the train's incoming portal. This airflow reduces the danger to other trains which may have entered the incident tube before closing the tube for regular train traffic. A possible "smoke trail", deposited by the burning train, will be transported out the incoming portal.

## 5 INFLUENCE OF TRAIN MOVEMENT

1-D airflow simulations which were performed with the simulation program SES show that the ventilation system (overpressure concept) is very robust and stable against the influences of wind pressure at the portals, to geothermal induced buoyancy or barometric pressure differences. For this reason, tenable conditions within the emergency refuge and the non-incident tube are assured.



**Figure 5: Ventilation of the emergency station influenced by train movement depending on the tunnel section where the train is driving.**

Due to the significant influence of the piston-effect other train traffic within the tunnel during an incident (e.g. trains leaving the incident or non-incident tubes; or rescue trains entering the non-incident tube) can have great influence on the airflow in the bypass and thus on the ventilation of the emergency station. Concerning train movement the ventilation system has the following aerodynamic characteristics (see Figure 5):

- *non-incident tube, section between the incoming portal and the emergency station:* train movement supports the emergency ventilation by increasing the airflow in the bypass.
- *non-incident tube, section between the emergency station and the outgoing portal:* train movement counteracts the emergency ventilation by decreasing the airflow in the bypass.
- *incident tube:* in the incident tube the inverted situation is true. But after the incident train has come to a stop along side the emergency station, the trains which follow in the incident tube will have to be stopped in a short period of time. Therefore, these trains will have no significant influence on the ventilation system. The trains ahead of the incident train support the airflow from the non-incident tube into the incident tube via the bypass, which is favourable.

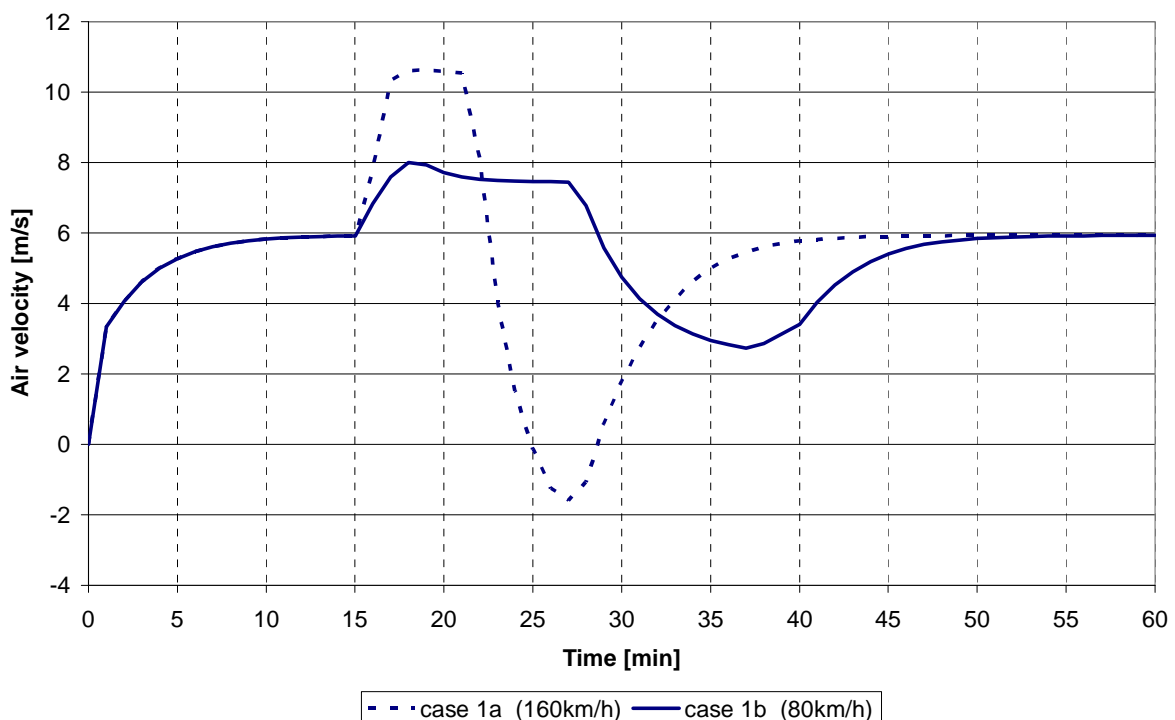
**Table 1: Scenarios used in the 1-D airflow simulations.**

case	description	train velocity	remarks
1a	t=0 min: ventilation starts, air velocity in both tubes v=0 m/s.  t=15 min: train enters the non incident tube	160 km/h	
1b	t=0 min: ventilation starts, air velocity in both tubes v=0 m/s.  t=15 min: train enters the non incident tube	80 km/h	
2	t=0 min: ventilation starts, air velocity in both tubes v=5m/s. No train movement after incident.	no train	reference case
3	t=0 min: ventilation starts, air velocity in both tubes v=5m/s; train 1 enters the non incident tube on a speed of 80 km/h and is heading to the outgoing portal.  t=12.5 min: train 1 reaches the emergency station and continues moving to the outgoing portal; train 2 enters the non incident tube with a speed of 80 km/h and is heading to the outgoing portal.  t=25 min: train 1 leaves the tunnel; train 2 reaches the middle of the tunnel (emergency station) and continues moving to the outgoing portal.  t=37 min: train 2 leaves the tunnel.	80 km/h	
4	t=0 min: ventilation starts, air velocity in both tubes v=5m/s, train 1 is at the emergency station and is heading to the outgoing portal with a speed of 80 km/h.	80 km/h	worst case

Additional 1-D airflow simulations, including modelling the train traffic and the ventilation system, were performed. The evaluation of the system behaviour in terms of ventilating the emergency station was conducted by analysing the airflow (magnitude and direction) within the bypass duct, which is directly connected (open flap) to the incident tube.

In a first step (cases 1a and 1b) the principal influence of train velocity was studied for two simple cases (see Table 1), regarding the safety concept's requirement that in the non incident tube the use of a rescue train has to be possible. The scenarios for the two simulated cases include the movement of a 400 m passenger train (rescue train) within the non incident tube at the two speed levels of 160 km/h and 80 km/h. In the simulation the ventilation system was activated at time  $t=0$  min. After reaching the stationary flow regime the train was entering the incident tube at simulation time  $t=15$  min (see Figure 6). Depending on the trains speed the opposite portal was reached at different point of time. It could be found that:

- for a speed of 160 km/h a temporary change of the flow direction in the open bypass duct occurs. This means that air could be drawn from the incident tube into the non-incident tube and into the emergency refuge, which is not acceptable.
- if the speed is reduced to 80 km/h, a temporary change in flow direction in the bypass duct will not occur, resulting in an airflow into the incident tube at all times, which is desired.

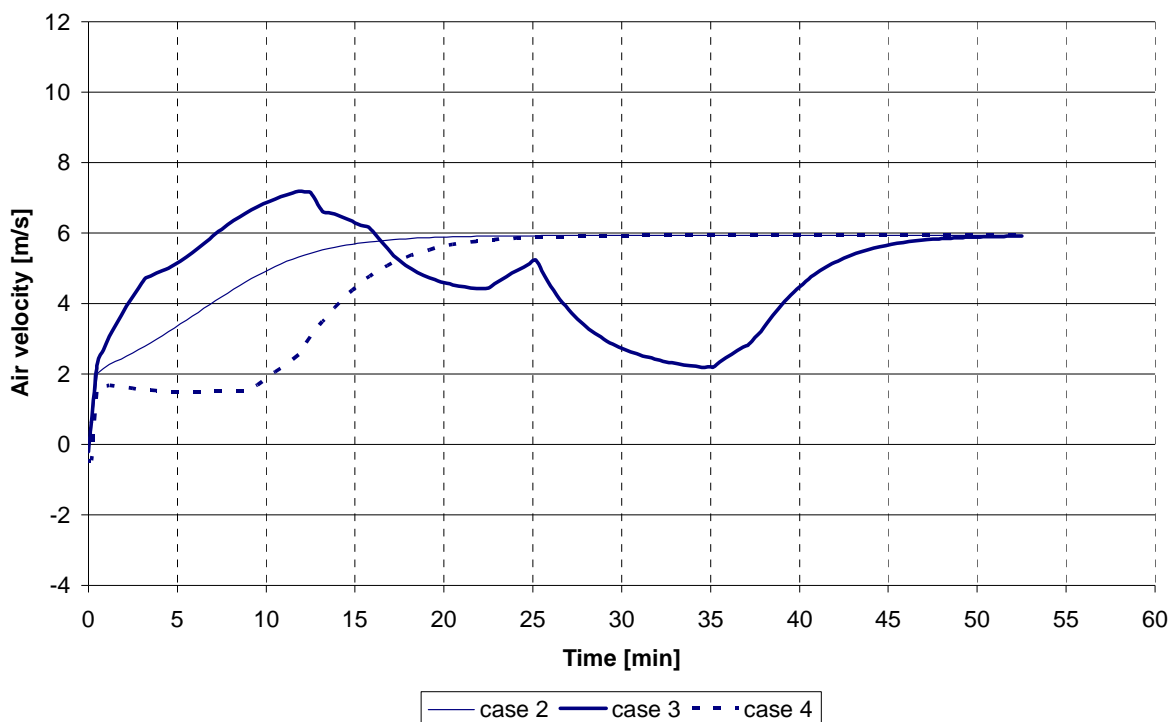


**Figure 6: Air velocity in the bypass duct (cross section area 25 m<sup>2</sup>) under the influence of a moving passenger train (rescue train) in the non-incident tube (case 1a and 1b).**

In a second step, some more complex scenarios (case 2, 3 and 4) were simulated (see Table 1), to understand in more detail the transient behaviour of the ventilation system (e.g. in which time frame can the ventilation system achieve the design targets?) and to look at a worst case scenario. A worst case scenario is a train movement in the non incident tube in the section between the emergency station and the outgoing portal (see Figure 5 - counteract section). In the additional three cases the train speed was limited to 80 km/h and at simulation time  $t=0$  min in both tubes an airflow (5 m/s) was already developed due to regular train traffic. It could be found (see Figure 7) that:

- for all scenarios the airflow in the bypass was directed at any time from the non incident to the incident tube. Even in case 4 (worst case) the velocity magnitude ( $v \approx 2$  m/s) was in an acceptable range.
- the impact of overpressure will be established within the first minutes after activating the ventilation system and after achieving the train speed limit.
- there is a significant influence on the velocity magnitude within the bypass whether the train moves in the support section or in the counteract section.

Based on the simulations performed, it can be concluded that the clearance of trains from or the movement of rescue trains in the non incident tube is possible without affecting the capability of the ventilation system in maintaining safe conditions within the emergency refuge if a speed limit is imposed. The actual speed limit depends on a variety of parameters and has to be defined in the ongoing design process in compliance with the final design of the ventilation system and the demands of the safety concept.



**Figure 7: Air velocity in the bypass duct (cross section area 25 m<sup>2</sup>), cases 2, 3 and 4.**

## 6 SUMMARY AND CONCLUSION

- The overpressure / bypass solution presented is a safe and reliable ventilation system for very long tunnels where vertical ventilation shafts are, due to high overburdens, complex and expensive.
- The emergency refuge and the non-incident tube are made safe using a ventilation system that is robust with respect to outside influences (e.g. barometric pressure differences and wind). Smoke movement into the emergency refuge can be prevented. In addition, the section where other trains may follow in the incident tube and stop is ventilated with fresh air.
- Other train traffic in the tubes is still possible during an incident with reduced speed. At reduced speed the aerodynamic effects do not compromise the safety goals of the ventilation system. The actual speed limit during an emergency has to be defined in the ongoing design process and in compliance with the final design of the ventilation system and the demands of the safety concept.
- The ventilation system is robust and easy to control. All that needs to be known is which tube is affected and the direction of the incident train.
- The pressure difference between the non-incident tube and the incident tube is even sufficient in the zone near the portals to keep the non incident tube free of smoke. Additional ventilation measures are not necessary.
- An aerodynamic connection of the two tubes occurs only in the case when the flaps in the bypass are open. The rejection of the underground interchange solution by the design team helps to keep the aerodynamic conditions simple (separation of the two tubes).
- The investigation shafts that already exist at Paierdorf and Leibenfeld can also be used for the location of the ventilation system.

## REFERENCES

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