ABSTRACT
Mountains in Slovenia, in the Region Kars, in the direction to the Adriatic Sea are serious obstacle for the railway’s traffic. By the new planed railway so are provided a few tunnels all together long about 20 km. Because of safety measures all the tunnels longer than 1000 m they must have a rescue tunnel too. In the rescue tunnel in the case of fire in the main (railway) tunnel it must be higher air pressure as in the main tunnel. In the article the basic information and solutions about this problem are given. All the solutions are in according with "Richtlinie Anforderungen des Brand – und Katastrophenschutzes an den Bau und Betrieb von Eisenbahntunneln", BRD, 1997

1. INTRODUCTION
On Fig 1.1 the situation is shown. Between Divaca und Koper (Slovenia) there is a new railway with tunnels, about 20.000 long.

Fig. 1.1: Tunnels and Rescue Tunnels, location and length.
Tab. 1.2: Tunnels and their length

<table>
<thead>
<tr>
<th>MAIN TUNNEL</th>
<th>RESC. TUNNEL</th>
<th>LENGTH m</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>RT1</td>
<td>6.845</td>
</tr>
<tr>
<td>T2</td>
<td>RT2</td>
<td>5.985</td>
</tr>
<tr>
<td>T7</td>
<td>RT7</td>
<td>1.105</td>
</tr>
<tr>
<td>T8</td>
<td>RT8</td>
<td>3.745</td>
</tr>
</tbody>
</table>

2. BASIC PRINCIPLES
On Fig. 2.1 the basic principle of the rescue tunnel is shown. Between main tunnel and rescue tunnel they are rescue connections, closed with dour, every 500 m. The length of rescue tunnel is equal as main tunnel (see Fig 1.1 and Table 1.1).

Fig. 2.1: Rescue tunnel and Rescue sections
The fans inside of rescue section are not active; the fans outside of rescue section are blowing the air from both sides (both portals) to the middles of rescue tunnel.

2.1 Rescue section

Fig. 2.1: Rescue section
2.2 Air velocity

![Diagram of air flow through a tunnel with variables labeled](image)

Fig. 2.2.1: Air velocity

Main characteristics of the fans are (see also Fig. 2.2.1):

- $V = 20 \text{ m}^3/\text{s}$
- $D = 900 \text{ mm}$
- $n = 1520 \text{ n}^{-1}$
- $P = 520 \text{ N}$
- $N = 22 \text{ kW}$

The basic data:
- $h = 3 \text{ m}$
- $v_0 = 31 \text{ m/s}$
- $V = 20 \text{ m}^2/\text{s}$
- $a = 8^\circ$
- $n = 1$
- $K = 6$

With using equations for induction is:

$$L_x = \frac{h}{\tan \alpha} = \frac{3}{\tan 8^\circ} = 21 \text{ m}$$

$$v_x = \sqrt{2} \frac{K n V}{L_x \left[ n \left( \frac{\pi d^2}{4} \right) \right]} = \sqrt{2} \frac{6.20}{21 \sqrt{1 \left( \frac{\pi 0.9^2}{4} \right)}} = 9.40 \text{ m/s}$$

Average air velocity

$$v = \frac{9.40}{2} = 4.70 \text{ m/s}$$

and air flow rate

$$V = v \cdot A = 4.70 \cdot 13 = 61 \text{ m}^3/\text{s}$$

At air velocity 4.70 m/s is the pressure drop

$$\Delta p = 0.02 \cdot \frac{1000 \cdot 1.20 \cdot 4.70^2}{4.30 \cdot 2} + 5 \frac{1.20 \cdot 4.70^2}{2} = 128 \text{ N/m}^2 = 128 \text{ Pa}$$
So the air velocity at 1000 m is

\[ v = \sqrt{\frac{2.128 \cdot \frac{1}{1.20} \cdot \frac{0.020 \cdot 1000}{4.70} + 5}{0.020 \cdot 1000}} = 4.80 \text{ m/s} \]

and at 500 m

\[ v = \sqrt{\frac{2.128 \cdot \frac{1}{1.20} \cdot \frac{0.020 \cdot 500}{4.70} + 5}{0.020 \cdot 500}} = 5.45 \text{ m/s} \]

2.3 Overpressure in the rescue section
Theoretically we may say, that instead of air flow in the opposite direction is a wall. So is:

\[ I = m \cdot v = V \cdot \rho \cdot v \quad [\text{kg m/s}] \]

\[ P = I_2 - I_1 \]

and in according with Fig. 2.3.1:

\[ P = 0 - I_2 = - V \cdot \rho \cdot v \]

Fig. 2.3.1: Impulse and forces

\[ P = 61 \cdot 1.20 \cdot 5.45 = 398 \text{ N} \]

So the overpressure is

\[ p = \frac{P}{A} = \frac{398}{13} = 30 \text{ N/m}^2 = 30 \text{ Pa} \]

If the cross connections are closed, the overpressure at point D is

\[ p_D = 30 \text{ Pa} \]

Airflow from one direction is 61 m³/s. So the air velocity in the connections is

\[ v = \frac{61}{(2.50 \cdot 3.10) + \frac{2.50 \cdot 3.10}{2}} = 5.20 \text{ m/s (18.50 km/h)} \]

At the point A under pressure till point B, where is \( p_B = 0 \), is
Approximately we may say that the pressure from point B to point D rises linearly. Distance between two cross connections is about 500 m, from the middle (point D) to point B, where the pressure is 0.00 Pa, the distance is 230 m, all together 730 m.

So is

$$p_c = \frac{30}{730} \times 230 = 10 \text{ Pa}$$

---

**3. RESCUE TUNNELS**

On Fig. 3.1 the rescue tunnel 1 is shown. Along tunnel they are 7 rescue sections: from RS 1 to RS 7. On the north part of rescue tunnel is a wall as protection against the wind. Similarly are the rescue tunnels RT 7 and RT 8 shown on Fig. 3.2 and Fig. 3.3.
4. CONCLUSION
From figures and calculations, made for the case of fire in the main railway tunnel for one rescue section we can see that all of them are useful for all the rescue tunnels, from T1 to T8. In any case the air overpressure is attained, at the middle of the rescue section and at the end. To obtain the air overpressure is possible also when one of the fans in the rescue section failed.

5. REFERENCES
Pischinger, R. The influence of Air Polution on the Visual Range in Road Tunnels 2\textsuperscript{nd} International Symposium on Ventilation of Road Tunnels, 1976
Pischinger, R. Sichtweitbestimmung in Strassentunneln Bundesministerium für Bauten und Technik, Wien, 1977
Pischinger, R. Aerodynamics and Ventilation of Vehicle Tunnels 6\textsuperscript{th} International Symposium, Durham, 1989
Pucher, K. Abbremsung der Luftbewegung bei Brand im Tunnel Österreichische Ingenieur Zeitschrift, 3/1979
Modic, J. Analysis of Rescue Tunnels on Railway Divaca – Koper FS-UL, Ljubljana, 2001