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Simulation-based design of railway tunnels' safety assets

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INTRODUCTION

In tunnels, the confined spaces are potentially generating very serious effects:

a) the high temperatures can seriously damage the structures;

b) it amplifies the risks of a high concentration of toxic gases in the air during the evacuation and rescue phases.

The key requirement is the minimum air flow needed to keep the emergency exits safe according to:

- Tunnel and safety doors' shape and size,
- Fire position and intensity: freight wagon,
- Longitudinal velocity of natural airflow (wind).

The present work illustrates the results of an extensive Computational Fluid Dynamics (CFD) simulation campaign, focused on the emergency exits in different scenarios.
The goal is finding the most appropriate design requirements for the ventilation systems as the main involved parameters vary

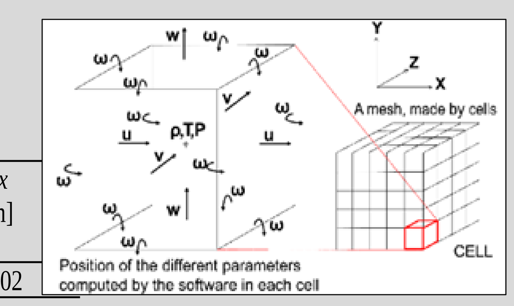
MATERIALS, METHODS & IMPLEMENTATION

Computational Fluid Dynamic (CFD) with the support of Fire Dynamics Simulator (FDS) are methods and tools to solve the Navier-Stokes equations, adapted for fire-driven fluid flow using an appropriate low speed (<0.3 Mach).
The calculated relevant parameters are pressure, temperature, airflow velocity in a 3-dimensional network (mesh) of cubic cells.

The simulated scenarios are:

- 10 m cross-connection between two single-track twin tunnels (A = 32 m^2)
- 18 m connection to a safe chamber in a double-track tunnel (A = 59 m^2)

HRR Q [MW]	Density ρ [kg/m^3]	Specific heat c_p [kJ/kg °K]	Amb. temperature T [°K]	Gravity g [m/s^2]	Typical Diameter D^* [m]	D^*/dx	dx [m]
10	1.204	1.005	293 °K	9.81	2.409	16	0.602



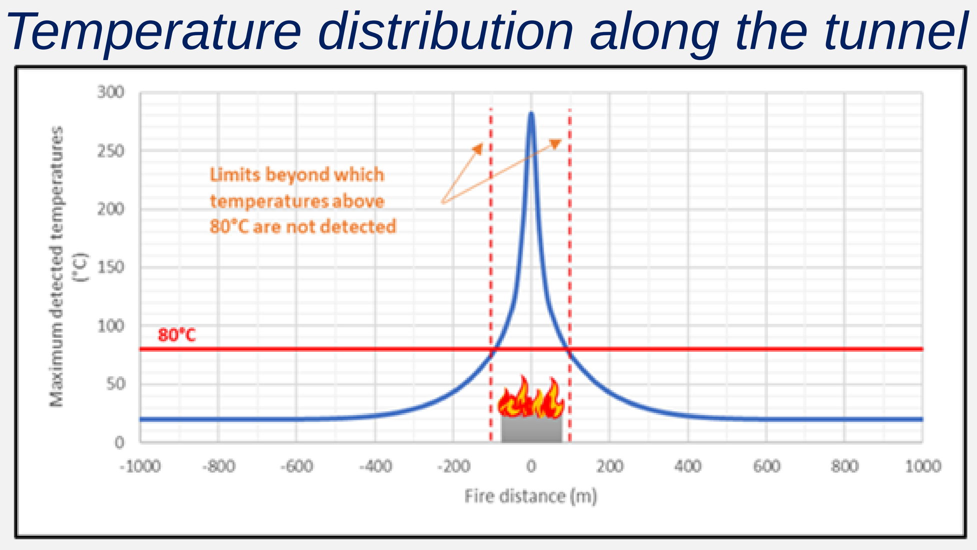
RESULTS

The scenarios are finalized to quantify the required velocity of the ventilation (range: 0.5-7.5 m3/s) to ensure a safe access of passengers to the emergency doors, depending on:

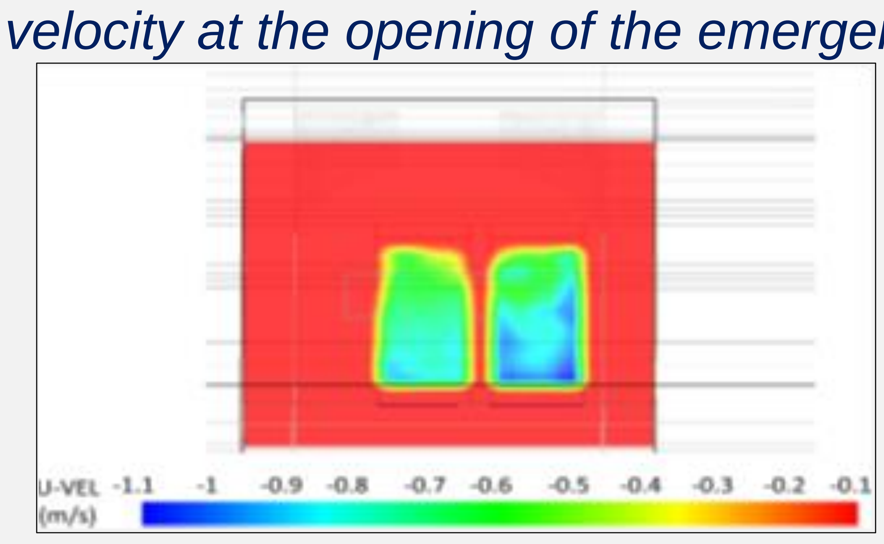
- Position (open/close) of the doors
- Position (0-250 m from the door) of the fire
- Longitudinal velocity (0-10 m/s) of the wind airflow
- Timeframe during which the temperature in front of the emergency door remains <80 °C.

Distance from fire (reference thermocouples) [m]	Time to reach 80°C [s]
20	36
140	597
260	5160
380	Temperature under 80° C

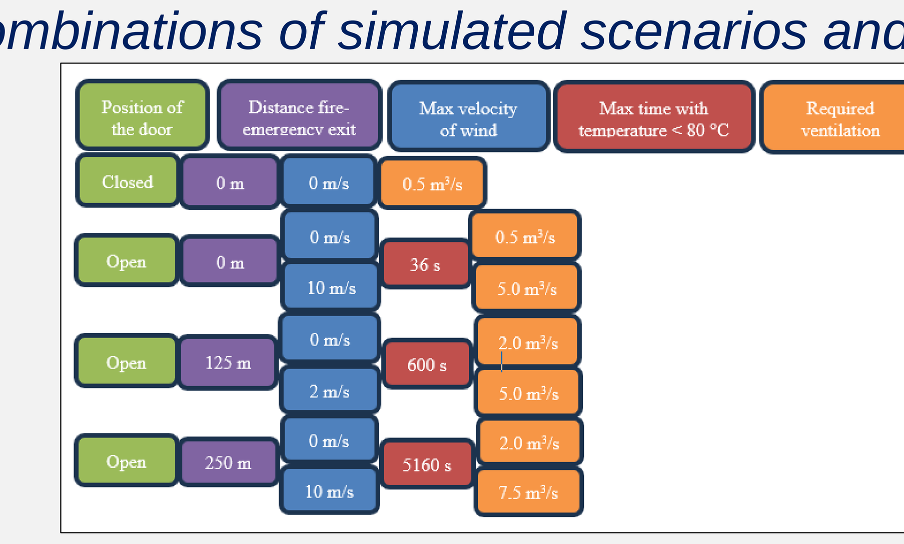
Temperature distribution along the tunnel



Y-Z air velocity at the opening of the emergency doors



Combinations of simulated scenarios and results



In these conditions, the maximum required ventilation airflow is 5 m^3/s, when the wind velocity in the tunnel reaches the maximum value (10 m/s).
All the combinations of opening and closure of the doors have been analyzed. the standard simulated tunnel is considered equipped with pedestrian emergency doors located every 1000 m and, for long tunnels, a larger safety door, accessible by rescue vehicles, every 4000 m.
The simulation process is ready to be extensively employed in a large set of infrastructural and operational situations.

CONCLUSIONS & IMPLEMENTATION PATH

CONCLUSIONS

The **described results** move further towards the closure of the gaps in the regulation framework for the design of ventilation systems protecting the emergency doors during fires in railway tunnels from smoke and other byproducts.
The **most appropriate design requirements** according to the variability of the relevant parameters, have been searched basing on identified critical scenarios.
The **ventilation airflows needed to keep the emergency doors safe** can be identified according to the variability of the identified key parameters: position of fire, wind, single or twin morphologies of the tunnel.

IMPLEMENTATION PATH

The **next identified developments** are a further generalization of results, towards a **design handbook for railway tunnels**.
In this framework, the research items identified as most promising for **further investigation developments** are the **effects of the firepower**, mainly depending on the features of the rolling stock, and the **longitudinal airflows**, only partially manageable by the proposed simulation approach.

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