Performance-Based Analysis for Air Flow through Crossover Sections of Metro Tunnels

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INTRODUCTION

Critical velocity is crucial in the design of tunnel ventilation system as the system is designed to prevent back layering in emergency situation to help passengers' safe evacuation along the tunnel. Due to a revision in the critical velocity equation [1], the revised calculations yield higher critical velocities, especially for relatively low design fire loads – such as for metro and light rail transit systems – with respect to higher design fire sizes of road tunnel.

This study focuses on the crossover sections of the tunnels. An existing generic station along one of İstanbul metro lines is selected as the case study. The station has its dedicated tunnel ventilation fans operating and is one of the largest stations with over approximately 2,000,000 passenger circulation, monthly. Track line entering the station consists of three crossover sections where the lines converge and these crossover sections form the basis of the study. For the system reliability, pedestrian flow simulation is performed to demonstrate ASET/RSET analysis.

PROBLEM DEFINITION

The geometry of the cross-overs along with the boundary conditions obtained during site test results is shown in Figure-1. There are three crossovers connecting track lines, and they all are connected to each other and to the cut&cover type station. For this study, the crossover structures and the tunnels connecting them are in consideration. Tunnel ventilation fans are connected to the tunnels between crossovers and the station through ventilation shafts.

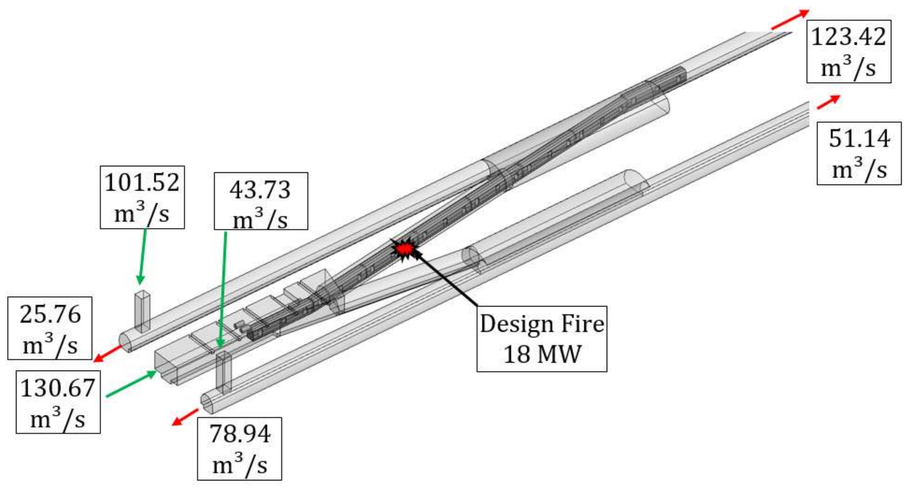


Figure 1: Schematic of the Crossover with Boundary Conditions

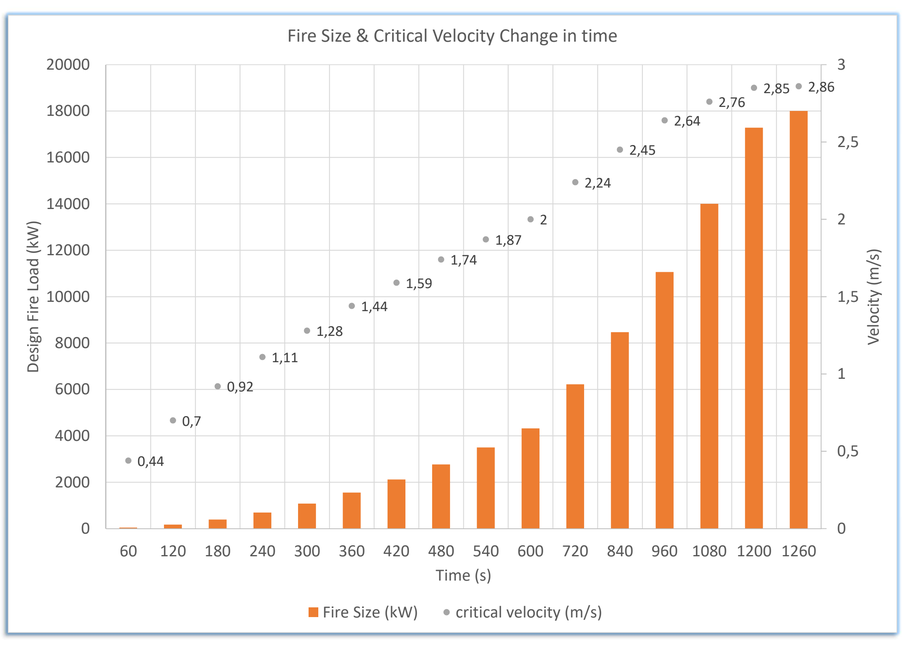
In order to analyze the situation, a train fire is assumed along the tunnel between crossovers. The analysis involves the following steps:

- 1-D SES (Subway Environment Simulation) analysis for the design fire size – the results of this analysis are compared with the test results and they provide the boundary conditions for the CFD simulation.
- 3-D CFD analysis for the design fire size – to evaluate tenability conditions and limits for ASET analysis.

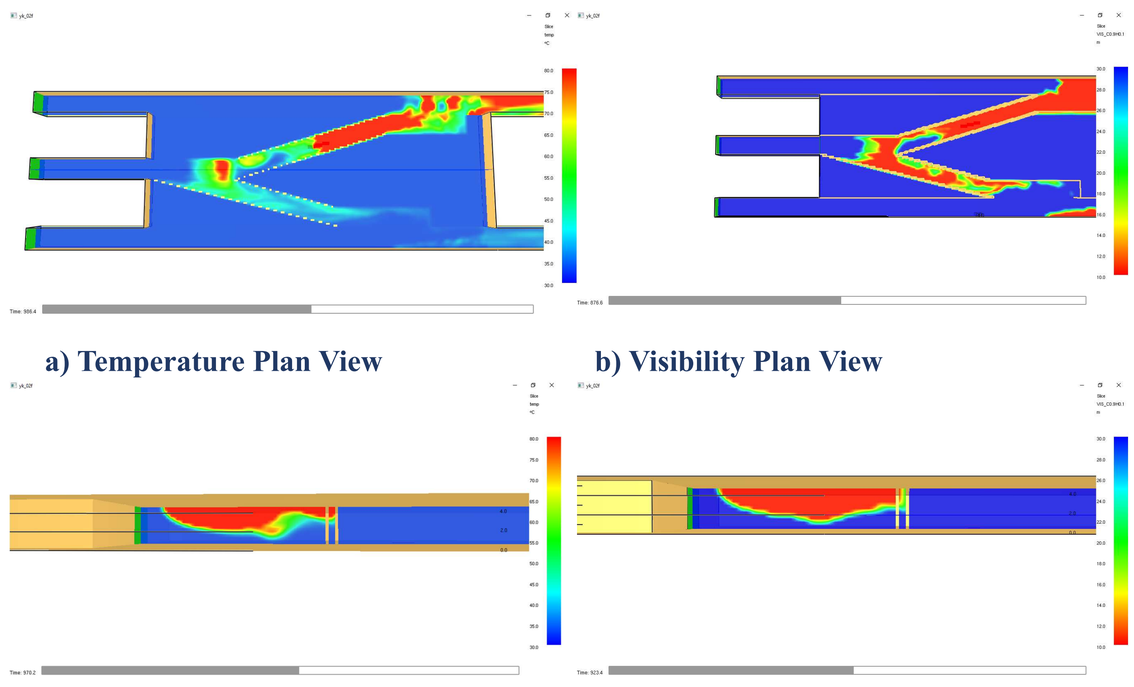
Simulation of pedestrian flow – to evaluate RSET analysis.

RESULTS & DISCUSSION

- Airflow velocities obtained performing SES analysis are in accordance with the site test results. Velocities through the station to the tunnel connections are further modified testing the related fire scenario, operating station ventilation fans to support tunnel ventilation fans placed on both ends of the station.
- Critical velocity is analyzed with respect to design fire load in every 60 s.



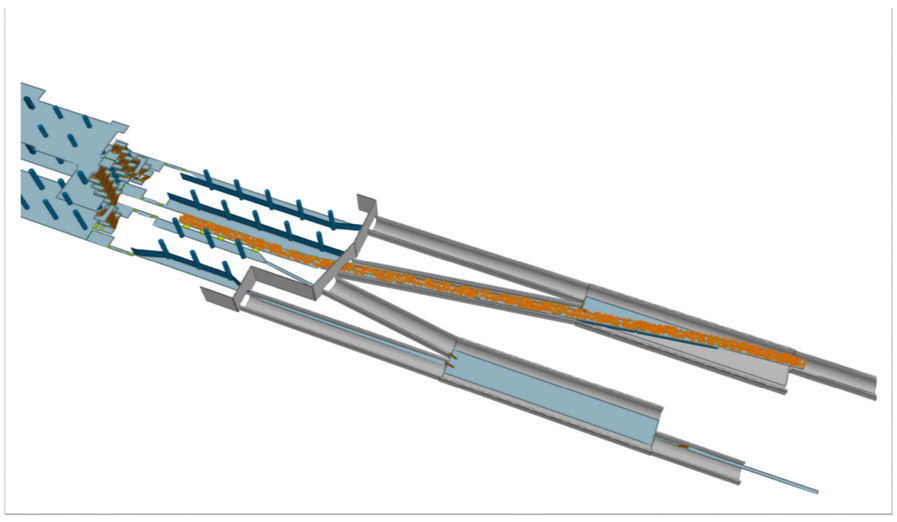
- Critical velocity (~2.5 m/s) is satisfied until approximately 900 s.
- CFD study yields tenable environment for approximately 923 s.
  - ASET ≈ 00:15:23



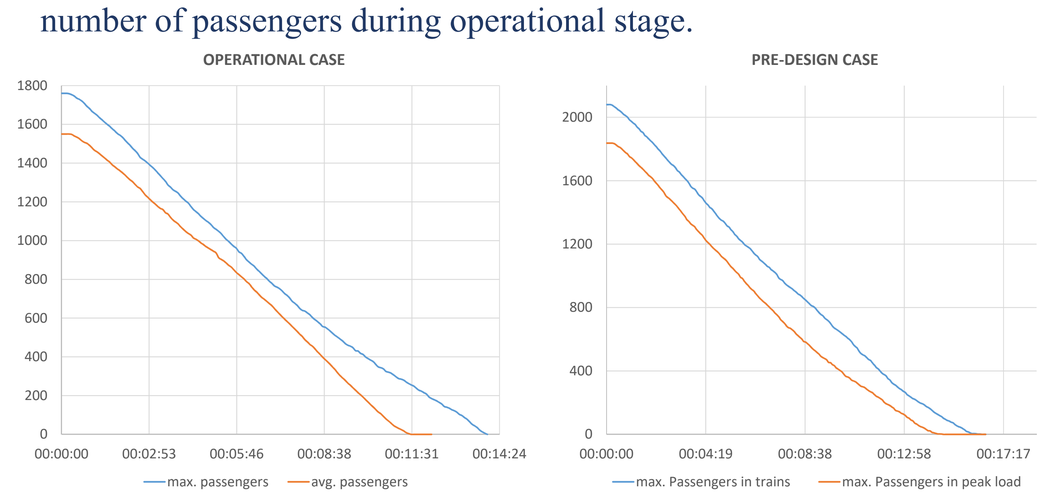
a) Temperature Plan View **b) Visibility Plan View**

c) Temperature Section View **d) Visibility Section View**

- Pedestrian Flow Simulation is performed for:



- Pedestrian evacuation results depend on passenger numbers. Results shown are for a) estimated for peak hours during pre-design stage; b) maximum and average number of passengers during operational stage.



- RSET ≈ 00:11:25 - 00:13:45 (for operational case)
- RSET ≈ 00:14:35 - 00:15:55 (for pre-design case)

CONCLUSION & FUTURE STUDY

- ❖ Estimated passenger numbers and operational ones vary. Assuming train with full load capacity yields overdesign.
  - ❖ Implemantation of risk analysis shall be developed.
- ❖ Walkways configuration around crossovers may provide additional alternative routes for evacuation.
- ❖ Critical velocity is important, however further studies shall focus on how critical is the critical velocity?
  - ❖ Future study shall investigate confinement velocity for risk-informed solutions as well.

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