Highlight in 'smoke simulation in an underground train station using computational fluid dynamic (CFD)', ReCAR 2013

The design of the ventilation and fire safety systems for the Johor Bahru Sentral, a semi-underground train station, part of the Integrated Custom, Immigration and Quarantine Complex (ICIQ) is based on normal Malaysian Standards (MS), British Standards and the local fire department's requirements. However, the large and complex space in the underground station coupled with scheduled diesel-powered locomotives which frequent the station by stopping or passing require detailed simulations. Both ventilation and the fire safety systems employ computational fluid dynamic (CFD) methods to provide realistic balance against the typical calculations based on spread sheets and certain design software. This study compares smoke simulations results performed by the mechanical and fire consultants with the simulations carried out through this project. An assumption of a locomotive catches fire near the main platform is made as the source of the smoke. The smokes flow around the building with buoyancy forces and extracted via exhaust fans using Star-CCM+. The process of the simulation includes modeling and meshing processes on the structure of the railway station imported from Inventor CAD Autodesk software drawing. Through this simulation, we found that when a locomotive catches fire, the passengers could evacuate the building safely before the fire department machinery arrives. Furthermore, we notice that the ventilation fans activation based on detection of hazardous gases may not be efficient way to remove the latter. Scheduled clean-up synced with train arrivals effectively removes toxic gas.

The geometries of the building structure are obtained from the original JB Sentral plan drawings by focusing to the structure near the main departure platform of the train including the ventilation systems as shown in Fig. 1. The architectural cladding envelopes ventilation ducting on the upper system shown in this figure. The geometries are redrawn using Autodesk Inventor 2010 64bit as shown in Fig. 2. There are six platforms in the station as shown in Fig. 2. The drawing then stored with the IGES or STEP format so that the drawing could be accessed by CFD software.

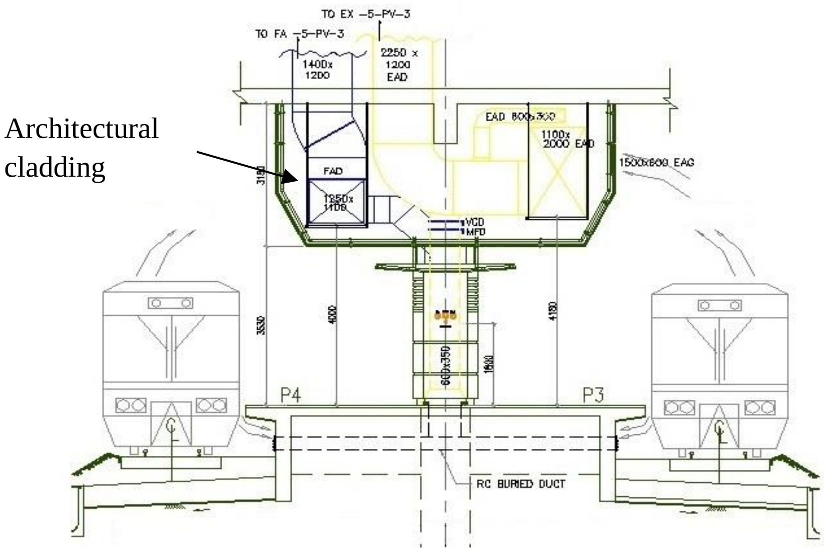

Fig.1. JB Sentral train platform with ventilation system illustration drawing

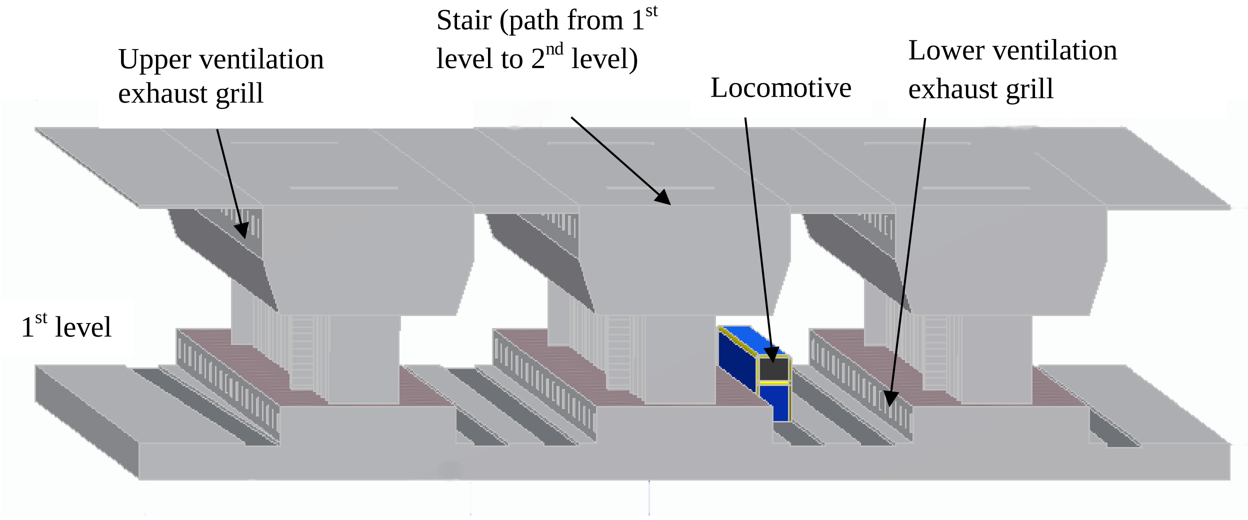

Fig. 2. Illustration of JB Sentral train platform arrangement

In this study, the software used to perform the CFD analysis is Star-CCM+ V7. By using the software, the simulation of the smoke flow in the building can be simulated through basic CFD simulation methods [6]. The smoke and fire wizards were used to run the simulation in Star-CCM+. In the simulation, the maximum heat used as the source of energy released from the burnt locomotive is 50MW by referring to the value from Fire Safety Engineering Performance Based Approach [7]. Fire growth factor used in the simulation is 47 W/s^2 recommended by NFPA 1995 [8]. In addition, the average extraction rate for upper and lower ventilation systems used in the simulation are 1000 l/s and 200 l/s respectively. The 5:1 ratio for the upper to lower exhaust system is due to typical smoke and heat released during normal operation i.e. smoke released by the locomotive which is collected at the ceiling level is much more than the braking heat released from the lower level. The simulation was run by 100 iterations. For the inlet boundary, assumptions of 1 m/s fluid flow used with temperature value 70° are made [9]. Table 1 and Fig. 3 below show the details of the boundary conditions.

Table 1. Boundary condition of the simulation

Surface	Boundary Type
Locomotive	Velocity inlet
Roof of building	Pressure outlet
Building wall	Wall
Train body	Wall
Stairs and pillars	Wall

References

[6] Versteeg, H. K., Malalasekera, W. & Hall, P. 1995. An Introduction to Computational Fluid Dynamics-the Finite Volume Method.

[7] Grubit, S. 2003. Fire Safety Engineering Performance Based. Gerbang Selatan Bersepadu/ Customs, Immigration & Quarantine Complex.

[8] NFPA, NFPA 204m- Guide for Smoke and Heat Venting, National FireProtection Association 1995.

[9] Andersson, M., Hedskog, B. & Nyman, H. 2002. Concept to Improve the Possibilities of Escape from a Single Exit Underground Station. Tunnel Fires 4th International Conference.