Conference Agenda

15th ROOMVENT Conference

Session

FS: Underground ventilation & Fire and smoke control

Session Chair: **Jae-Weon Jeong**

Presentations

A semi-empirical approach for modelling the thermal pressure ventilation in under ground spaces

Ying Zhang[1,2], Thomas Olofsson[2], Chenbo Zhao[1,2], Bin Yang[1,2], Angui Li[1,2]

[1]Xi'an University of Architecture and Technology; [2]Umeå University, Sweden;

Natural ventilation is an important way to provide fresh air and maintain a satisfying indoor air temperature in underground spaces with a large amount of heat flux. In this work, a semi-empirical model is developed to determine the relationship between the thermal pressure ventilation rate and the heat source intensity of the two underground zones. In the case study, it is found that the dynamic pressure loss of the joint sections within the air loops and the inlets areas have an important effect on increasing the total airflow rate, as well as the flow rate distributing to each storey.

Research status of thermal environment in underground space: air temperature and temperature variation of surrounding rock based on practical experience in China

Angui Li[1,2], Arsen Krikor Melikov[3], Risto Kosonen[4], Thomas Olofsson[2], Bin Yang[1,2], Ying Zhang[1,2]

[1]Xi'an University of Architecture and Technology, China, People's Republic of; [2]Umeå University, Sweden; [3]Technical University of Denmark; [4]Aalto University;

At present, with the development of the urbanization process, the research of underground space has become a new trend in China. The temperature variation of air and surrounding rock of underground space are the key research directions of tunnel ventilation control technology. The research and practical experience in China can provide knowledge for the establishment of prediction models for air and surrounding rock temperature in underground spaces, as well as ventilation design and environmental management. This paper reviews the research status of the thermal environment in underground space in China.

Natural ventilation of tunnels: Mechanisms of cold air penetration that generate formation ice

Mats Sandberg, Leif Claesson

University of Gavle, Sweden;

Mats Sandberg,Leif Claesson Faculty of Engineering and Sustainable Development, University of Gävle, SE-80176, Gävle, Sweden

Keywords: Cross ventilation by wind, ventilation by buoyancy, opposing flows

Wind generates a cross flow through the tunnel and a temperature difference between the tunnel and the ambient generates a flow. The resulting flow is dependent on the ratio of the height difference between the tunnel ends and the height of the tunnel crossection. A multitude of different flow patterns may occur. Layers of air at different temperatures (densities) can either assist each other or counteract each other. One example of counteracting flows are penetration of cold air into the tunnel. This may cause degradation of the rock lining the tunnel and give rise to freezing generating ice and icicles. This may cause a risk of safety to both the vehicles and the passengers. An additional example of a counteracting flow is wind counteracting a buoyancy driven flow, see Fig. 1.

The sytem did not allow me to paste the pictures

Fig 1. Counteracting flows. Left: penetration of cold air. Right: wind counteracting buoyancy driven flow

The paper shows result from model test where measurements of flow rates, temperatures and velocity profiles with laser Doppler anemometer have been carried out. The flow pattern was analyzed by visualization. The results show which parameters controls the different types of flows that may occur and when the transitions between the different types of flow patterns occur. The overarching goal is to provide a survey of natural ventilation in tunnels and when possible a comparison with natural ventilation in buildings.

Theoretical prediction on radiant field of tunnel floor in near field of fire source based on a new flame shape model

Lin Xu[1], Yi Lu[1], Honghui Guo[2], Chao Ding[3]

[1]Shandong Jianzhu University, China, People's Republic of; [2]Tongyuan Design Group Co., Ltd.; [3]Energy Technologies Area, Lawrence Berkeley National Laboratory, Berkeley, USA;

Fires in tunnels have attracted special attention due to catastrophic fires. Radiation plays an important role in fire growth and spread mechanisms. Therefore, for accurate fire modelling and prediction, it is critical to understand the correct radiation fraction of fire source. Two sets of fire experiments were conducted in a 1/20 reduced scale wind tunnel to study the jet fire behavior in a tunnel with longitudinal ventilation. Two different gas burners were used as fire sources. Unique visible flame shapes were observed in both experiments. The flame can be described by a "back-to-back frustums of a cone", which is very different from the existing 'cylinder' shape used in the solid flame model from the literature. An analytical model is proposed to describe this new geometry using 9 key geometric parameters. Based on the fire images, the geometric parameters and their variations with the momentum flux ratio are calculated. The predictive radiation fractions of two tests were calculated and compared with other tests from literature. The

predictive values show significant departure from the traditional used values in tunnels and increase with the augment of J. And an experimental correlation suitable for engineering application is given out.

Study of Fire Smoke Spread of Solar Roof Fires based on CFD Simulations

Xin Zhang, Dahai Qi
Université de Sherbrooke, Canada;

As one of the fastest-growing renewable energy technologies, power generation using solar panels is booming worldwide due to the rapid fall in price of both solar power technologies and photovoltaics. However, historical experience in the usage of solar energy indicates that as more and more buildings are installed with solar panels on the roof (hereafter solar roof), the risks of incidences of solar roof fires increase significantly, which will be a major roadblock for wide adoptions of solar panels. Fumes from solar roof fires could spread into the buildings through roof openings, such as chimneys and ventilation openings, which creates toxic conditions for people in and around the buildings, leading to smoke inhalation injuries. Moreover, solar panels on the roof also present firefighters with new challenges. They often complain about how to deal with solar panel fires and concern about their own safety because of insufficient study on the spread of solar roof fires. Therefore, it is essential to understand how the smoke spreads from the solar roof fires to the inside of the building through the roof openings. This study conducted full-size CFD simulations using Fire Dynamics Simulator to investigate the smoke spread from the solar roof fires under different conditions. The impacting factors, including roof angles, vents and solar panels layouts, are considered, which were found to influence the fire smoke spread significantly. The results of the study could provide key information to the solar roof design and fire fighting activities, which is important for reducing the fire safety concerns in the application of solar panels on the building roof, thus promoting the use of solar panels.

Air temperature prediction of the combined radial and axial directions in tunnels

Weishi Liu[1], Shugang Wang[1], Jihong Wang[1], Shuang Jiang[2], Tao Jiang[1], Zhanfu Luo[3]
[1]Dalian University of Technology,People's Republic of China; [2]Dalian Minzu University, People's Republic of China; [3]China Railway Tunnel Consultants Co.Ltd., People's Republic of China;

The depth of excavated tunnels has increased dramatically in recent years. High geothermal temperature, a chief obstacle in the construction of deep tunnels, will deteriorate the construction environment, and reduce the labor productivity and increase the accident rate. Rational temperature field prediction and ventilation system should be developed in the deep tunnels to improve the construction environment. According to the heat conduction equation in the lining and surrounding rocks as well as the prediction model of air temperature distribution in tunnels, the two--dimensional axisymmetric heat conduction model of the combined radial and axial directions in tunnels as finite hollow composite cylinders has developed by introducing the Newton's cooling law and considering the underground water and heat from equipments as source terms. An analytical solution of the temperature distribution in tunnels is derived in the finite hollow composite cylinders based on the Levy method. The obtained temperature field keeps an agreement with data reported by the literature. Taking Gaoligongshan tunnel of Dali-Ruili railway in China as an example, its temperature field of the lining, surrounding rocks and the air flow is predicted and analyzed. Furthermore, the air and wall temperature distribution of 100 m away from the heading face are calculated, and the heat taken away by ventilation at maximum air supply in air ducts, and the cooling load are estimated when the acquired temperature is kept in the tunnels. In addition, the predicted temperature distribution lays a solid foundation for the further study about the thermal stress field in high geothermal tunnels.

Ventilation and Pressurization of Fire Protected Staircases in Multistorey Buildings

francesco saverio ciani, giovanni casano, stefano piva
DE department of engineering, universita' di ferrara, Italia;

In case of fire in a multistorey building, it is necessary to ensure that the vertical escape routes are always available and practicable to the occupants. If the smoke makes a staircase unavailable, other vertical egress routes able to ensure a safe evacuation should be available. If there is a single staircase and it is not possible to build a second one due to, for instance, historical preservation purposes, it is possible to provide active protection systems that enable the staircase to be always available during the fire. In particular, it is possible to protect the staircase by using a smoke control metodology, denominated “pressurization”, consisting in the introduction of a large air flow in the staircase, in case of fire. This smoke control system uses fans that supply air to the staircase, pushing the smoke outside. First, the fans should assure the proper flow rate through those doors opened for the evacuation of the occupants. Secondly, when the doors are closed, the fans should be able to assure a proper flow rate through the leakages (for example those around the doors), useful to maintain the proper pressure in the staircase.

The design of a pressurization system implies the application of a performance based design method, the so called “Fire Safety Engineering” (FSE), in order to achieve the fire protection and the life safety goals. FSE can be performed by using CFD techniques, thus demostrating that the occupants can safely evacuate without being exposed to smoke and temperature. For this assessment the most used parameter is the available safe egress time (ASET).

The design of the pressurization system also implies the selection of the credible and most demanding scenarios. The factors mainly affecting the system performance are number and position of the doors to be considered open during the system operation. These factors depend on the doors opening dynamics, that can be phased or simultaneous.

Another factor affecting the performance of the system is the position of the fans that supply air to the staircase, because the pressurization system should be designed in order to ensure a homogenous distribution of the values of air pressure along the staircase. The design should also avoid short circuits of air supply due to the open doors.

The purpose of this paper is to illustrate some results for a staircase pressurization system designed by using CFD techniques. The performance of the system are assessed by calculating the ASET for the particular escape route.

The credible and most demanding scenarios, representative of the worst cases, have been selected. In particular, the scenarios have different number of simultaneoustly open doors and different position and number of simultanously activated fans.

Finally, the selection of the above mentioned scenarios allows the reconstruction of the characteristic curve of the most demanding pressurization system, in order to choose the correct fan and to design the details of the pressurization system.

Improved winter performance of attachment ventilation by relayed fans and low level exhausts - a pilot study

Bin Zhou[1], Bin Yang[1,2], Zhe Li[1], Angui Li[1,2], Olofsson Thomas[2]

[1]Xi'an University of Architecture and Technology, China, People's Republic of; [2]Umeå University, Sweden;

Stratified ventilation and air distribution methods were widely used by intensified conditioning human occupied spaces without wasting energy for conditioning spaces above human height. As one of the methods, displacement ventilation (DV) was successfully applied in engineering projects. However, it can not be used for summer cases with high cooling loads and most of winter cases. Attachment ventilation combined the characteristics of mixing ventilation (MV) and DV, which could generate DV mode air lake and can be used for both summer and winter cases. Because of high air supply speed, warm air lake can be well generated and attached on the floor in winter. However, buoyant force may also cause airflow deflected upwards to some extent after attaching the floor for a certain distance, especially for spaces with large depth. As solutions, workstation/chair mounted relayed fans and low level exhausts could effectively improve attachment effects of warm air lake. A pilot study, by validated CFD simulation models, was performed. Energy efficiency and temperature efficiency were used to evaluate the performance improvement. Since certain percentage of air is exhausted to outdoor environments by introducing same amount of fresh air, temperature of exhaust air from different heights may affect energy efficiency.

Simulation research of piston wind and air infiltration from entrances in metro stations

Zhenghao Xu, Lin Lin, Tao Zhang, Xiaohua Liu

Department of Building Science, Tsinghua University, China, People's Republic of;

Metro station is one of the most important infrastructures for cities. Nowadays more and more metro stations have been put into use in China and how to achieve an efficient environment control system in the stations is becoming an urgent issue. Piston wind is a special characteristic existing in metro stations and its influence on the thermal environment as well as ventilation performance is important and still to be determined. In this paper, computational fluid dynamics (CFD) method is used to study the variation law and influencing factors of piston permeation wind in metro stations.

The STESS software is firstly used to build a ventilation model of a metro station, and the piston wind speed at entrance and exit of tunnel is simulated when a train enters or exits the metro station, which is used as the boundary condition for subsequent simulation. It's found that the maximum wind speed for the tunnel when the train entering station is close to 7m/s, and close to 4m/s during the train exiting station. There will be air infiltration from entrances of the station due to the influence of piston wind. This kind of air infiltration should be quantificationally determined in the design and operation of the environmental control system in a metro station.

Then a three-dimensional physical mathematical model of a metro station using CFD software is built according to the common station parameters. Piston wind speed calculated by the STESS model is also adopted as the input parameters. The CFD model is validated with the simulation results in literature. The model is adjusted to simulate the variation law of the piston infiltration wind under different train operating conditions, different buried depths, different environmental control schemes and different seasonal factors.

The result shows the minimum fresh air volume in each operating condition is 5532m³/h, 7376m³/h, 9220m³/h with 6 pairs, 8 pairs, 10 pairs train departure by each hour respectively, while the corresponding fresh air design requirements for occupants is 2854m³/h, 3995m³/h, 5708m³/h. It's indicated that the passageway pistons caused by the train piston wind can provide enough fresh air to meet the fresh air demand of the occupants in the station, even under extreme conditions. Therefore, the influence of piston wind in the metro station is significant and the operation of the mechanical ventilation system should take the influence of piston wind into consideration. The present research is a preliminary study on the piston effect in metro stations and it's believed the influence of infiltration from entrances in metro stations will be investigated in our further research.

Air distribution of oxygen supply through guardrail slot diffusers in high-altitude hypoxic areas

Ran Gao[1], Haimeng Li[1], Ting Lai[1], Angui Li[1], Bin Yang[1], Melikov Arsen K[2]

[1]Xi'an University of Architecture and Technology, China, People's Republic of; [2]Technical University of Denmark, Denmark;

Oxygen supply is necessary for high-altitude hypoxic areas, especially public spaces with high occupant density. Traditional oxygen supply systems, including individual oxygen supply (IOS), distributed centralized oxygen supply (DCOS) and diffusion-type oxygen supply (DTOS) are limited in completing oxygen delivery tasks by the balance between low cost and high efficiency. This study elaborated a method for air distribution by adopting guardrail slot diffusers (GSDs) for oxygen-rich air delivery directly to the human breathing zone without changing the basic layouts of high and large spaces. The dynamic breathing zone was obtained by monitoring the swing of people waiting besides a guardrail. Two indicators, the oxygen concentration target value and the dimensionless diffusion-type oxygen supply efficiency, are introduced to facilitate the evaluation of oxygen supply through GSDs. The angle, width and velocity of the jets from the GSDs installed on the guardrail were optimized; the values obtained were θ=146°, W=30.0 mm, and V=3.0 m/s. A physical measurement confirmed that the indoor oxygen concentration increased by 2%, corresponding to a reduction in altitude of 600 m. Compared with oxygen supply through other existing air distribution systems in high and large spaces, the GSDs have 9% to 27% higher effectiveness, expressed in terms of the oxygen concentration target value, and the dimensionless diffusion-type oxygen supply efficiency is 100% to 940% higher. The implementation of the system was studied at altitudes of 2000 m, 3000m, 4000 and 5000 m, which proved that this oxygen supply system has better implementation effects. By increasing the height of the guardrail by 100 mm, the GSDs can meet the oxygen demand for air inhaled by European and North American adults. These results indicate that this method realized efficient oxygen supply in high-altitude hypoxic areas while reducing oxygen consumption and operating costs.