Effects of the Horizontal Projection on the Distribution of the Façade Temperature

Jiajia Fu[1, a *], Yinqing Li[1,b] and Jingyan Zhang[1,c]

[1]Institute of Building Fire Research, China Academy of Building Research, Beijing, China

[a]fujj0113@163.com, [b]li-yingqing@263.net, [c]cabrzjy@163.com

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Abstract. To obtain knowledge to prevent upward fire spread caused by ejected hot gas, a numerical modeling and theoretical analysis have been done by FDS software. It is believed that the horizontal projection play an important role of inhibiting vertical flame spread, however, effect of the positon of the horizontal projection on the façade temperature distribution couldn't been concerned in previous research. Changing the length of and the position of the horizontal projection, the hot gas temperature and velocity outside of the fire room were measured and analyzed. The location of horizontal projection closer the top of fire room and the horizontal projection length larger, the effect of inhibiting the vertical spread is more obvious.

Introduction

With the acceleration of urbanization process and the improvement of people's living standards, more and more high-rise buildings appear in our lives. High-rise buildings with diverse functions and more complex structure give people more convenient living, work and leisure activities, but followed by a high-rise building fire problems intensified. Most of the building fires begin with compartment fires inside. For a fully development under-ventilated compartment fire, the flames can be observed to eject from the opening of the compartment with hot gases and smokes, then spread to upper floors and ignite superstructure or burnable wall. Extensive investigations have been addressed on such flame ejecting behavior, on which the characteristic parameters and regulations are focused, including temperature profile [1-3], heat radiation intensity [4-5], heat flux profile [6-7] as well as flame shape and dimensions [6-9]. However, former investigation paid little attention to how to inhibit fire spreading speed and reduce the danger of outflow hot gases by using external conditions.

Due to backward of fire-fighting equipment and water supply for high-rise buildings, it is large difficult to fight the three dimensional flame spread upon the building façade. Thus, inhibition of vertical fire spread and avoiding the formation of three dimensional fire, in addition to improving the external facade fire rating, depend on the fire barrier structure itself that on the building facades is also very necessary. The horizontal project, one of the fire barrier structure, located between the upper and lower windows is the focus of this paper.

The conclusion that the horizontal project can effectively suppress the fire spread vertically has been verified by experimental date and simulation test [10-14].

Darryl Weinert [12] examined a particular geometry of opening in an external wall and found that a horizontal projection between about 0.3m and 0.6m is equivalent to a spandrel.An experimental study was done using a 1/7 scale model of seven-storey high-rise apartment building by Suzuki [13]. They found that temperature in the fire room with horizontal projection was higher than those without horizontal projection.Oleszkiewicz [14] conducted an experiment study that compared a horizontal projection of varying length (0.3, 0.6 and 1.0m), and found that a 0.3, 0.6, and 1m horizontal projection reduced exposure compared with the spandrel by about 50%, 60%, and 85%, respectively.

Though experiment research and CFD simulation have been studied for many years, effect of the positon of the horizontal projection on the façade temperature distribution couldn't been included. The problems that need to attention in the process of design and other aspects briefly, which will provide guidance for future in practical engineering. This paper based on 1:2 reduced-scale test bench we have built using FDS software, which consistent with pre-built test rig size. A series of models for different sizes and location of horizontal projection were simulated. Measuring temperature distribution near and up the opening, trajectories of hot gas and speed variation ejecting from the opening were obtained.

Simulation model

A series of computer models were conducted with 1/2 scale model building using FDS software. Outline of model configuration is shown in Figure 1. The geometry of test bench consisted of 6 rooms. The total size of test bench is 4.78m wide by 3.78m deep by 4.5m high. Ventilation was provided by the window opening only. A 0.78 m wide by 0.91 m high opening was used. The fire room was located on the left side of floor one, and the inside size of the fire compartment is 3.3m wide × 2m deep × 1.3m high.

The location and length of horizontal projection can be adjusted, as shown in Fig. 2. Length of horizontal projection (L_{hp}) varies from 0.1m to 1.0m. The height of windowsill wall (the distance of upper of the lower window and the bottom of the higher window) is L. $L = L_a + L_b$.

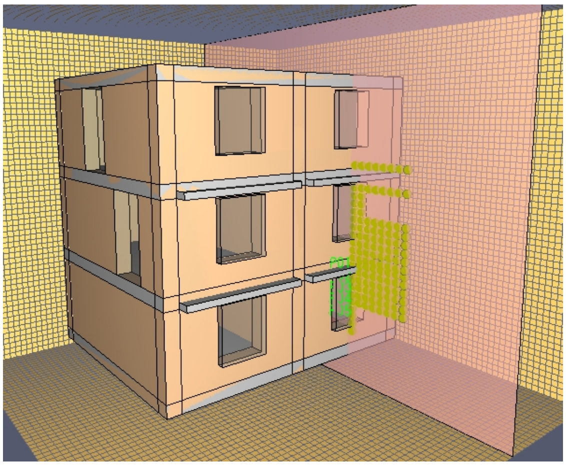


Figure 1. Outline of model configuration

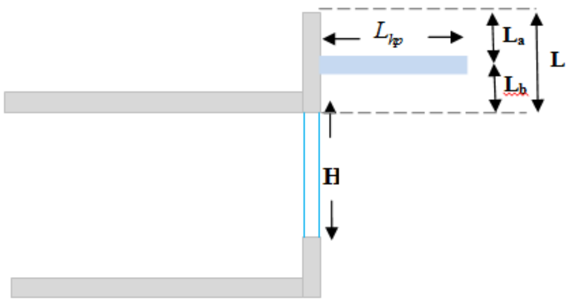
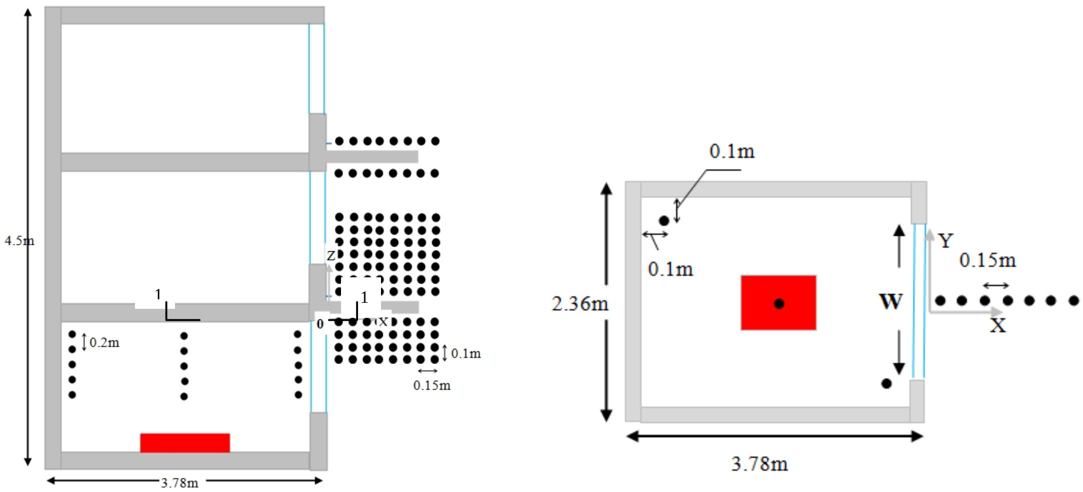


Figure 2. the location of the horizontal projection



(a) side view (b) top view

Figure 3. The distribution of measuring points

Temperatures and velocity outside the fire room were measured and analyzed by monitoring point. The distribution of the monitoring point was show in Fig. 3(a). Also temperature at the corner of the fire room was measured. Location of thermocouple in fire room is shown in Fig 3(b). A three dimensional orthogonal coordinate system was employed for the use of later analyses: The origin is at the top edge of the opening; x -axis perpendicular to the opening plane; y –axis parallel to the opening plane; and z –axis in the vertical direction.

In actual fire, the heat release rate of fire source changes over time. The three phase that smoldering phase of slow growth, fully developed fire and decay phase must be go through. the heat release of the fully development phase is stable and cam be represent by the idealized parabolic equation [15]. And we set the total heat release rate $Q_m = 1MW$.

$Q_m = at^2$. a : growth factor of fire heat release rate (kW/s^2), which can be divided into four types (slow growth, medium growth, rapid growth and ultra-fast growth). This paper we set $a = 0.04689$ as rapid growth. t : burning time after ignition.

Results and discussion

Figure 4 shows the distribution of temperature field under different length and position of horizontal projection. From the temperature field cloud picture, temperature falls slowly along the axial line with the increase of the length of horizontal projection (L_{hp} from 0 to 0.6 m) when fixed position. The horizontal projection installed in the building exterior wall above the window can effectively slow down the heat flux received by the superstructure. Meanwhile temperature raises slowly alone the axial line with the position of horizontal projection fixed up gradually (L_b from 0 to 0.39), whereas the length of horizontal projection does not change. That is to say, the location of horizontal projection closer the top of fire room and the horizontal projection length larger, the effect of inhibiting the vertical spread is more obvious.

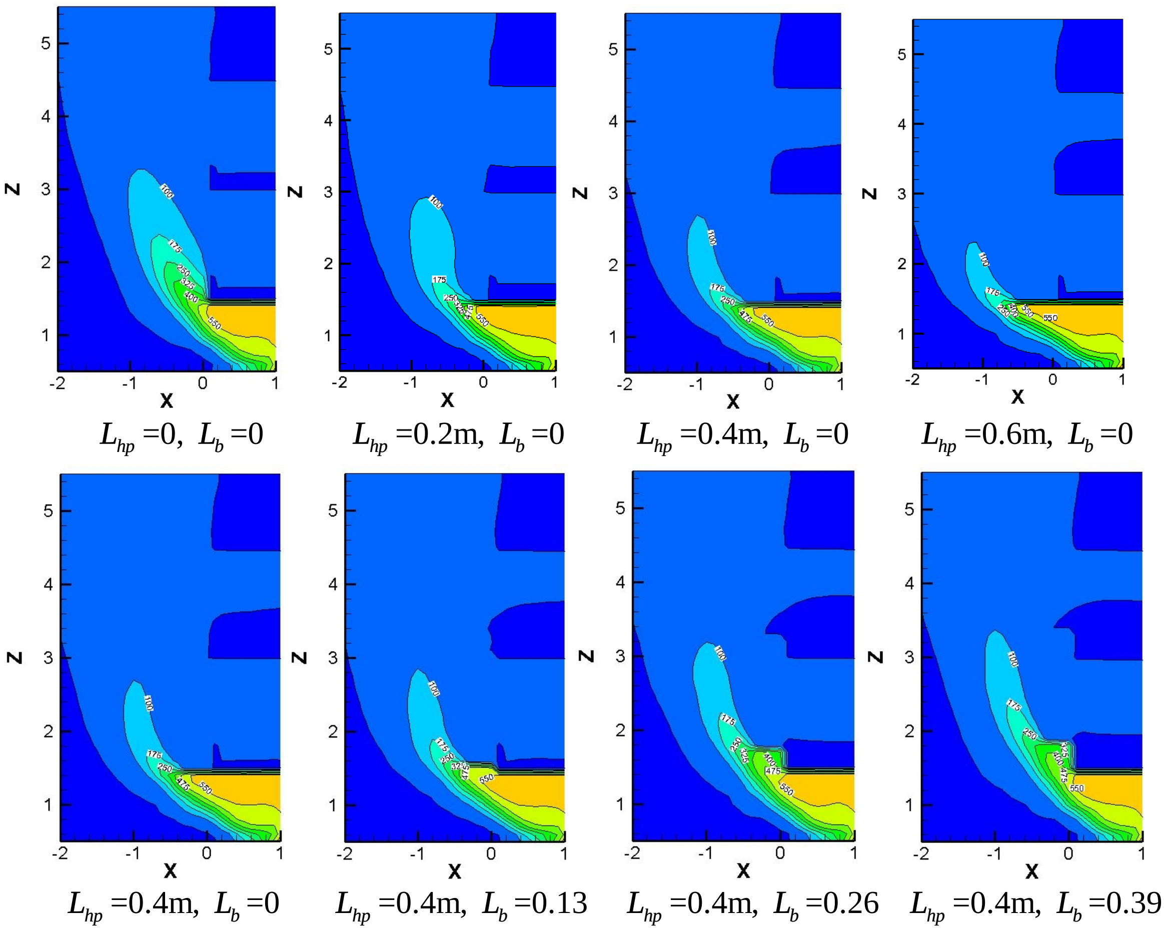
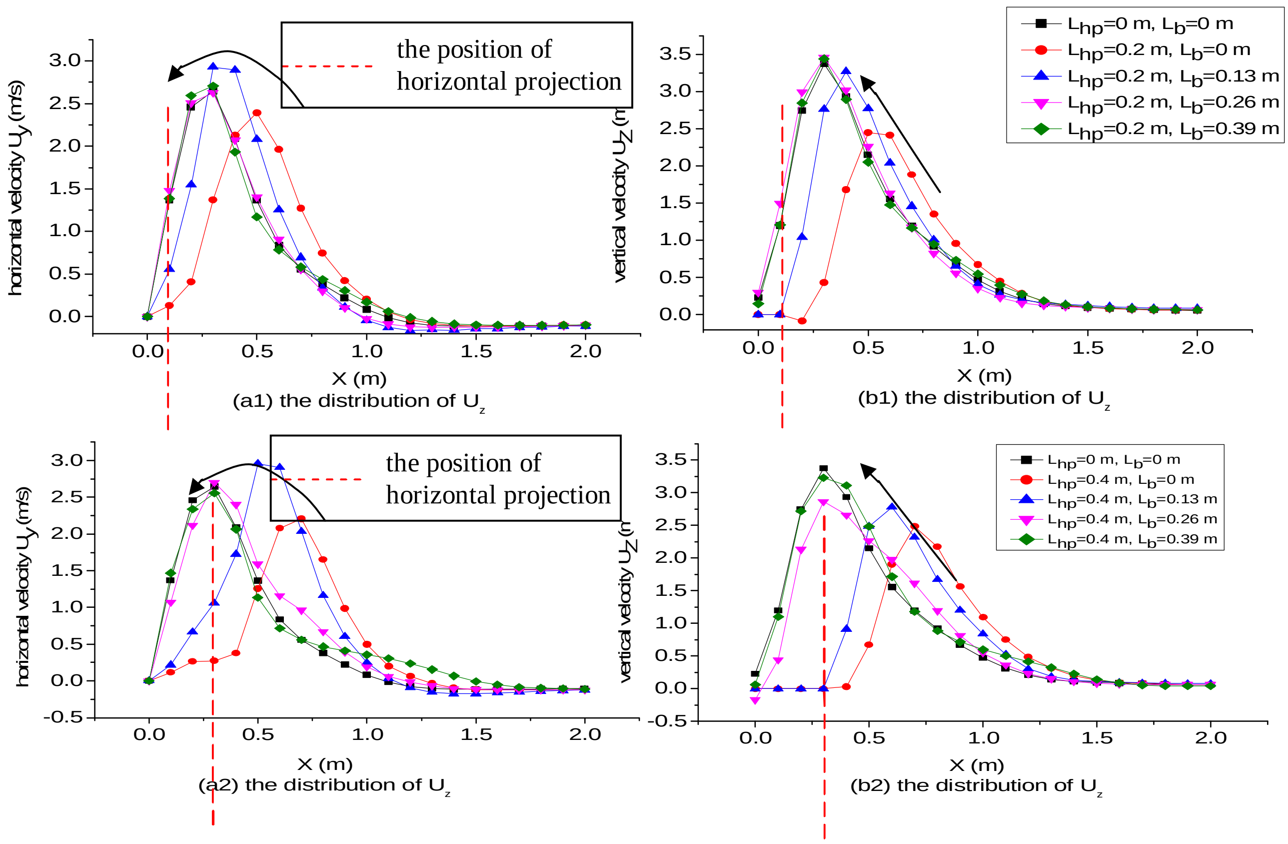


Figure 4. Temperature field cloud under different L_{hp} and L_b

An important characteristic of the flows outside the enclosure is that they are ejected horizontally before turning vertically. The horizontal length after which the flow becomes vertical can be determined from the momentum and buoyancy at the exit of the enclosure. Specifically, the momentum flux M_0 is equal to $M_0 \approx \dot{m}_g V$. V is out flow velocity of the hot gas can be expressed as $V = \sqrt{U_y^2 + U_Z^2}$.

1-1 profile is shown in figure 3 which located on the top of fire compartment window and under the horizontal projection. Fig. 5 shows that the distribution of velocity Uy and Uz along 1-1 profile under different L_b and L_{hp} . The distribution of velocity after the outflow ejected from the window coupling affected the length and location. The horizontal velocity and the vertical velocity are lower than which without horizontal projection located façade building. This behavior is due to decreasing the forward air entrainment and the lateral entrainment with the horizontal projection length increased. When the location of horizontal projection raises and the length remain unchanged, the vertical velocity is significantly lower than that without horizontal projection exiting, and the horizontal velocity first increase and then decrease with the outflow hot gases crossing over the projection.

When L_{hp} = 0.2 m, $L_b \geq 0.26$ m, and L_{hp}= 0.4 m, $L_b \geq 0.39$ m, and L_{hp}= 0.4 m, $L_b \geq 0.52$, the presence of horizontal projection barely impact on the velocity distributions. In other words, the horizontal projection father away from the fire compartment, the barrier action of vertical fire spread is weaker.



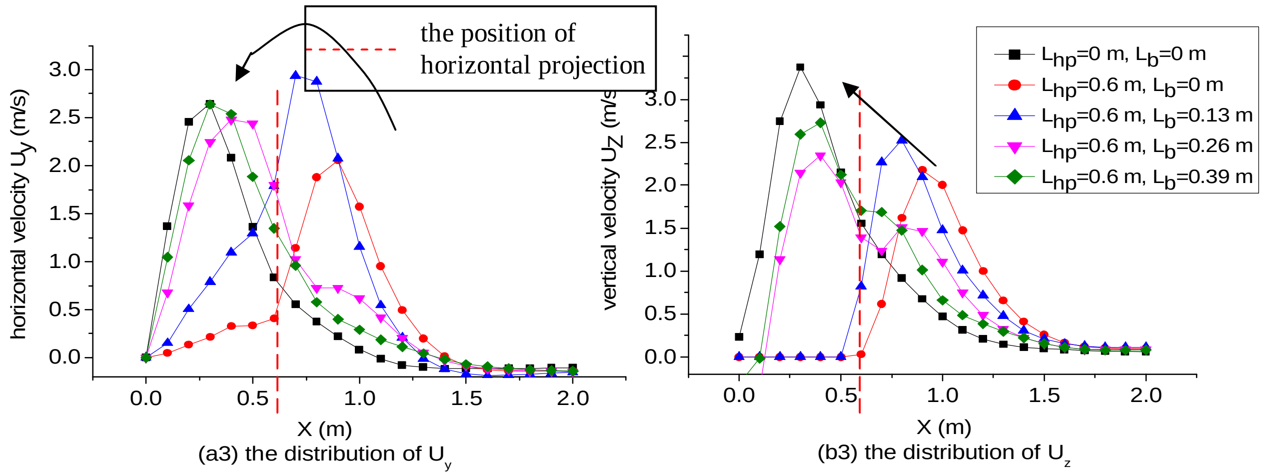


Figure 5. the distribution of velocity U_y and U_z along 1-1 profile under different L_b and L_{hp}

Conclusion

The following conclusions were derived.

1) The location of horizontal projection closer the top of fire room and the horizontal projection length larger, the effect of inhibiting the vertical spread is more obvious.

2) The radial velocity (Uy) first increase and then decrease with the location of horizontal projection raises, but with the length of horizontal projection increase the maximum of radical velocity remains almost unchanged.

3) The maximum of axis velocity (Uz) decreases with horizontal projection length increases and closer to the fire compartment.

Acknowledgements

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