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Smoke Insulation Performance with Multi-level Hang Wall in Corridor

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Abstract: The influence of the height of three-level hang wall on smoke insulation effect was study through simulation. One corridor connected to a room was constructed by computational fluid dynamics (CFD) software, then the smoke and the temperature distribution under different height of three-level hang wall were investigated. The result shows that the three-level hang wall played a good role on smoke insulation and the smoke and heat insulation performs the best when the height of three-level hang wall is 0.9m, 0.7m and 0.5m respectively. However, with the continuous development of the fire, the hang wall will eventually fail under all setting conditions.

1. Introduction

With the rapid development of urbanization, high-rise buildings emerged in large numbers in cities due to huge people rushing into city. According to the Council on Tall Buildings and Urban Habitat (CTBUH)[1], 1502 buildings over 200 meters have been constructed in the world by 2019 and the number has almost tripled over the past 10 years. However, it would increase the difficulty level in fire control. In general, various kinds of shaft structures, such as stairwells, elevator shafts, ventilating ducts and atriums are set in the modern high-rise buildings for vertical transportation of personnel and materials. When a fire breaks out, the toxic smoke will overflow the fire room and enter the building shaft structure along the corridor. Once the smoke spread into the vertical shafts, it can spread very fast to other floors if the stack effect forms[2]. At this time, if the evacuation efficiency is insufficient, it is very easy to cause serious casualties. Statistics show that more than 80 percent of fatalities in fires are caused by toxic gases instead of the burning fire[3]. Therefore, it is of great significance for reducing casualties to avoid smoke spread into shaft structure from corridor and prolong evacuation time.

Hang wall is a common method to prevent smoke diffusion during fire accidents, which played a good role on controlling smoke diffusion. Many studies have been conducted to investigate smoke insulation with hang wall in corridor. Wang et.al[4] investigated the fire smoke movement behavior under different hang wall heights in long-narrow channel. The results showed that the hang wall increases the length of the rolling zone in the density jump and reduces the range of air entrainment, resulting in a corresponding decrease in the mass flow rate of smoke. Shao et.al[5] conducted a set of simulations to study the influence regulations of the space between two hang wall on the smoke retardation effect in a corridor. Yang et.al[6] analyzed the smoke insulation effect of vertical air jet combined with the hang wall.

However, the smoke insulation utilized multilevel hang wall were usually ignored or partly considered in previous studies. In this paper, an inner corridor building with three-level hang wall is constructed by computational fluid dynamics (CFD) software. And a series of CFD simulations would be conducted to analyze the effect of smoke insulation in a corridor under different height of hang wall.

2. CFD simulations

In this study, the smoke and temperature distribution was analyzed based on a series of CFD simulations with the FDS software, which was released by the National Institute of Standards and Technology (NIST). In these simulations, different height of hang wall is considered. The Navier–Stokes equations for fire-driven fluid flow are solved by large Eddy Simulation (LES), which is second-order accurate with respect to space and time differences. The governing equations for smoke flowing in a fire are the conservation laws of mass, momentum and energy. More details on the LES can be found in the references [7].

3. Model configuration

The dimension of corridor section is 20.5m×1.6m×3.0m (L×W×H). The left end of the corridor is directly connected to the shaft and the right end of the corridor is

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connected to the room through a door. The dimension of room connected to the corridor is 6.0m×4.6m (L×W) and the dimension of the door is 0.9m×2.0m (L×H). The three-level hang wall is set up on the top of the corridor and its dimension is 0.2m×1.6m (L×H). According to the distance from the room, the hang wall is marked as No.1 , No.2 and No.3, respectively and the interval between each hang wall is 6.0m. The model configuration is shown in Fig 1.

The rectangular fire source is located on the sofa which is made of polyurethane and the size of fire source is 0.3×0.2m (L×W). According to the Shanghai engineering construction standard Technical specification for smoke control code, the heat release rate (HRR) in actual building fire is 0.5MW-3.0MW. Considering the most dangerous condition, the HRR of fire is set 3MW in all CFD simulations. In order to analyze the smoke barrier effect of hang wall, a temperature detection plane and thermocouple are set at the corridor. The temperature detection plane is 0.5m away from the left end and the thermocouple is 0.2m away from the ceiling.

Pr , Sc and C_S are the most important parameters for CFD simulation, especially in the prediction of smoke temperature. According to the study by Zhang et.al [8] in FDS simulation, the values of Pr, Sc and C_S are set to be 0.5, 0.5 and 0.18 respectively. The fire simulation time is 300s.

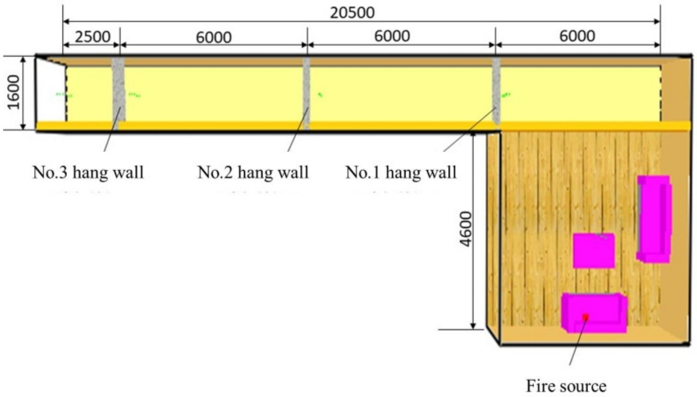


Fig 1. Model configuration

Different heights were set up in all simulation under the premise of the same total height in order to study the influence of the hang wall's height on the smoke insulation effect. According to the standard of hang wall (GA533-2012), the height of hang wall must be greater than 0.5m. Therefore, six different cases are set according to the height of each hang wall. The details of different cases are shown in Table 1.

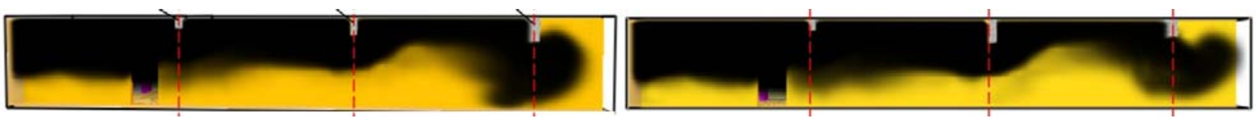
Table 1. Hang wall setting

Case	The height of NO.1 hang wall /（m）	The height of NO.2 hang wall /（m）	The height of NO.3 hang wall /（m）
1	0.5	0.7	0.9
2	0.5	0.9	0.7
3	0.7	0.5	0.9
4	0.7	0.9	0.5
5	0.9	0.5	0.7
6	0.9	0.7	0.5

4. Results and Discussions

4.1 Smoke distribution in corridors

Under different cases, the smoke insulation effect is different. When the fire simulation is 47.5 s, the smoke distributions under different case are shown in Fig 2. From the Fig 2, it is can be seen that a certain amount of smoke has begun to diffuse through the NO.3 hang wall in 1-4 cases, which indicate that smoke insulation in these cases has failed and the smoke bypassed the hung wall and flowed into the shaft structure. While in case 5 and case 6, the smoke is still be insulated by the NO.3 hang wall. It indicates that the case 5 and the case 6 have better smoke insulation effect than other cases.



(a) (b)

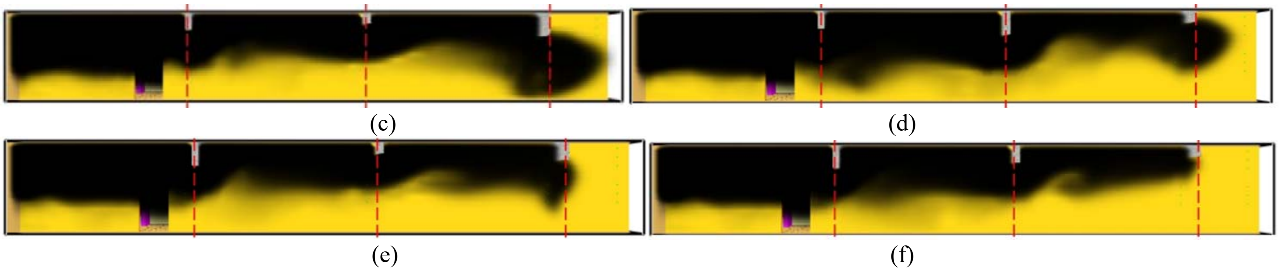


Fig 2. Smoke distribution in corridor: (a) case 1; (b) case 2;(c) case 3; (d) case 4; (e) case 5; (f) case 6.

4.2 Temperature distribution in corridors

Fig 3 presents the temperature contour text by the temperature detection plane under different cases when the simulation time is 47.5s. It is can be seen in 1-4 cases, the temperature near the shaft structure increased clearly and the high temperature is mainly concentrated in the upper regions of corridor which was agreed with the characteristics of buoyancy. While compared with the case 5 and the case 6, as shown in Fig 3(e) and Fig 3(f), the same regions remained at normal temperature. This consistent with the above analysis results, which indicate that the case 5 and the case 6 has better smoke insulation effect than other cases.

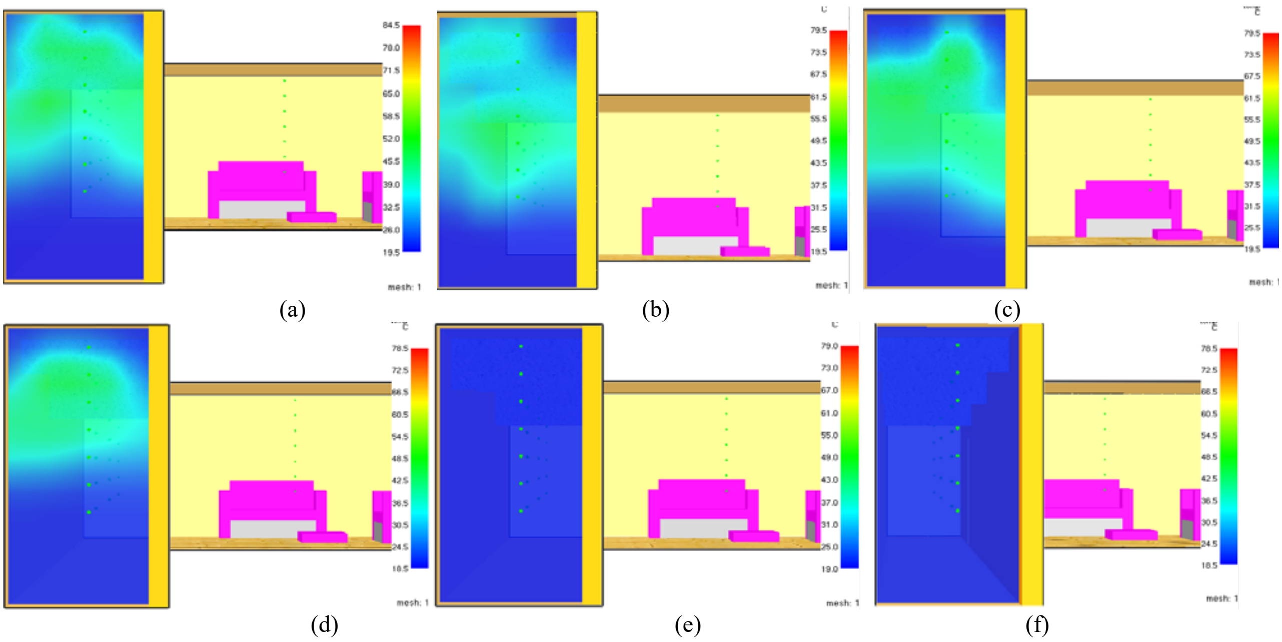


Fig 3. Temperature distribution in corridor: (a) case 1; (b) case 2;(c) case 3; (d) case 4; (e) case 5; (f) case 6.

According to the above analysis, the best smoke insulation effect appears in case 5 and case 6. However, which case is better is still unclear. In order to further compare the smoke insulation effect of case 5 and case 6, the temperature distribution was observed when the simulation time is 50.0s. The temperature distribution at this time in case 5 and case 6 is shown in Fig 4. Compare case 5 with case 6, it is can be seen that the high temperature is appeared in the case 5 and the case 6 since the smoke layer has passed the NO.3 hang wall and the smoke flowed into the stairwell. While the temperature on the upper regions in case 5 is about 73°C, which is higher than the temperature (about 65°C) in case 6. The results suggest that compared with case 5, the smoke insulation in case 6 are more effective.

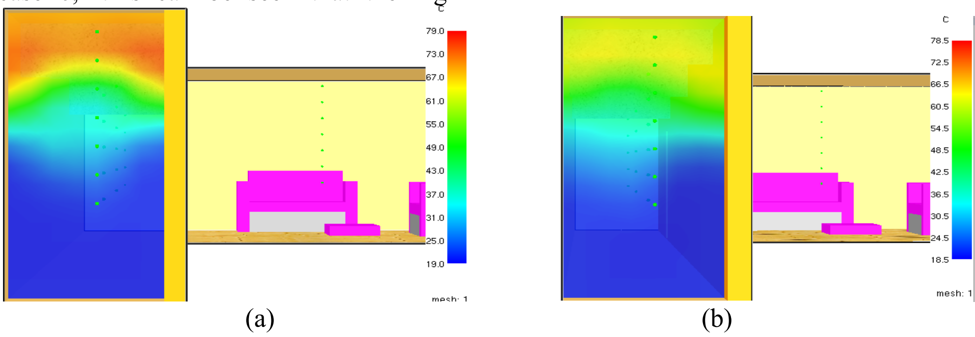


Fig 4. Temperature distribution in corridor at 50s: (a) case 5; (b) case 6.

Fig. 5 shows the temperature curves test by thermocouple varying with time in different cases. It can be seen from Fig 5, within 120s after the fire, the temperature distribution in case 5 and case 6 is lower than that of other cases. Meanwhile, it can also be found that the temperature reduction in case 6 is more obvious than that in case 5, which is consistent with the above analysis. The result shows that the smoke insulation effect is the best when the height of the three-level smoke screen is set at 0.9m, 0.7m and 0.5m respectively. And it could conclude that when setting the height of multi-level hang wall, the height should increases with the decrease of distance from the fire room.

It can also be seen from Fig. 5 that after the fire ignited 120s , the temperature in each cases was tend to be same, which is mainly because the thickness of smoke layer passed the height of hung wall after 120s and the smoke bypassed all hang wall and flowed into the shaft structure. Thus, the hang wall can only insulate smoke in the early stage of fire. If the fire continues to develop, the hang wall in all cases will eventually fail.

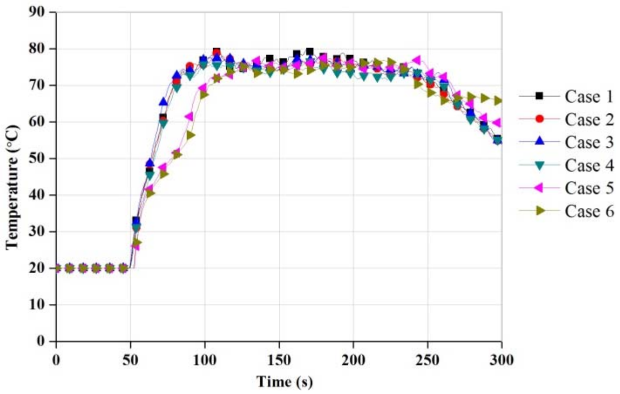


Fig 5. Temperature curves test by thermocouple varying with time

5. Conclusion

In this study, a set of CFD simulations using FDS were carried out to study the influence of the height of three-level hang wall on smoke insulation effect. According to simulation results, in the early stage of fire, the three-level hang wall can significantly insulate fire smoke in the corridor, which can extended the evacuation time. In all cases, when the height of the three-level hang wall is set at 0.9m, 0.7m and 0.5m respectively, the smoke insulation effect is the best. It was revealed that the height of multi-level hang wall should increases with the decrease of distance from the fire room. However, if the fire continues to develop, at full development stage, the hang wall in all cases will eventually fail.

References

1. The Skyscraper Centre, The Global Tall Building Database of the CTBUH. [Online], Available: http://skyscrapercenter.com, Last accessed on August 5th,(2019).
2. Li, L. J. and J. Ji, et al.. Experimental investigation on the characteristics of buoyant plume movement in a stairwell with multiple openings. Energy and Buildings **68**(2014).108-120.
3. Luo, N., et al., An experiment and simulation of smoke confinement and exhaust efficiency utilizing a modified Opposite Double-Jet Air Curtain. Safety Science, **55 (**2013). 17-25.
4. Wang H, Qi Q, Jiang H , et al. Study on smoke movement characteristics in long- narrow channel with smoke barrier. Journal of Safety Science and Technology, **13.**6 **(**2017). 150-156.
5. Shao L, Yang J, Li Z, et al. Numerical simulation of fire smoke spread retarded by smoke barriers of different spaces in long-narrow space. Safety & Security, **41**,6, (2020),59-62.
6. Yang Y, He J, Zhou R,et al.Research on combination of vertical jet flow and smokescreen in control ling the spread of smoke.Fire Science and Technology, **30**,7 (2011),574-576.
7. MCGRATTAN K, FORNEY G. Fire dynamics simulator user's guide . Gaithersburg: NIST, (2013).
8. Zhang, W., Hamer, A., Klassen, M. et al.. Turbulence statistics in a fire room model by large eddy simulation. Fire Safety Journal.**37** (2002).10-18.