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Analysis on the Impact of Draft Curtains on Hospital Building Fires

Xiaopei Liu and Hasung Kong[1*]

Graduate student, 55338 Dept. of Fire and Safety Engineering, Woosuk Univ, 443 Samnye-ro, Samnye-eup, Wanju-gun, Jeollabuk-do, Korea

***Professor, 55338 Dept. of Fire Protection and Disaster Prevention, Woosuk Univ, 443 Samnye-ro, Samnye-eup, Wanju-gun, Jeollabuk-do, Korea*

Corresponding Author E-mail: zack@stu.woosuk.ac.kr, 119wsu@naver.com

Abstract

Draft curtains are an important tool to reduce the spread of fire smoke in buildings. This paper mainly studies the influence of draft curtains on smoke spread in a hospital outpatient building with a spacious hall. The outpatient building of a county hospital in China is taken as the research object, and a fire simulation model is established based on PyroSim software. Four scenarios are designed: no draft curtains in the hall, draft curtains with a length of 1.5m in the hall, draft curtains with a length of 2.0m in the hall, and draft curtains with a length of 2.5m in the hall. At the same time, considering the worst situation, only the main emergency exit is opened, while the remaining emergency exits and windows are all closed, and the fire-fighting facilities are not activated. The detection point is set at the open emergency exit, 1.8m above the ground. Through the simulation of four scenarios, the effect of draft curtains on smoke spread is discussed from four aspects: smoke layer height, temperature, visibility, and CO concentration. The results show that draft curtains have a significant impact on the spread of smoke in a hospital outpatient building with a spacious hall. The longer the draft curtains are, the better the smoke-blocking effect. It should be noted that in the actual design, the length of the draft curtains should be considered without affecting the evacuation of personnel.

Key Words: *PyroSim, Hospital Outpatient Building, Draft Curtain.*

1. INTRODUCTION

Hospitals are important public buildings with a complex internal population, including a large number of patients and elderly individuals, making evacuation difficult. In the event of a fire, if people cannot be evacu ated in a timely manner, it can result in severe casualties and significant negative social impacts. On April 1 8, 2023, a fire at Beijing Changfeng Hospital resulted in 29 deaths and 42 injuries. Similarly, a fire at a hospi

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Corresponding Author: 119wsu@naver.com
Tel:+82-063-290-1686, Fax: +82-063-290-1478
Professor, 55338 Dept. of Fire Protection and Disaster Prevention, Woosuk Univ, 443 Samnye-ro, Samnye-eup, Wanju-gun, Jeollabuk-do, Korea

tal in northeastern Romania on November 14, 2020, led to 10 deaths and 10 injuries, with 7 of the injured being in serious condition. These tragic incidents serve as stark warnings. Consequently, the issue of hospital fires has garnered significant attention from scholars and related professionals.

With the advancement of technology, computer simulation has made fire modeling more accessible. Many scholars use computer simulations to study the characteristics of building fires. Hu [1] used PyroSim software to simulate the smoke characteristics of high-rise residential buildings, and the results show that the door state of the fire room has a great influence on evacuation. Xu and Peng [2] established a fire model of a teaching building in a university based on PyroSim and studied the impact of fire smoke diffusion on safe evacuation. Ju [3] combined BIM technology with PyroSim software to set up the fire scenario of an urban light rail station hall to obtain the available evacuation time after a fire. Zhang et al. [4] utilized PyroSim and Pathfinder simulation software to simulate smoke diffusion and personnel evacuation in the case of a building fire and proposed that appropriately increasing the width of evacuation doors can ensure the safe evacuation of personnel. Zheng et al. [5] adopted PyroSim software to determine the smoke spread, visibility, CO concentration, temperature, and other conditions at each stairway exit of a university library in case of a fire. Liao et al. [6] employed PyroSim to simulate smoke flow in the underground space in the Starting Area of Guangzhou International Financial City under different fire source positions and studied the impact of fire on evacuation. Ismail and Kharufa [7] applied the PyroSim program to simulate fire spread in a 12-storey building with varying plan corner shapes. The findings reveal that plan corners exhibiting straight configurations devoid of protrusions or recesses exhibit a reduced risk of fire spread compared to irregular shapes. Therefore, PyroSim software is widely used in building fire simulation. Of course, PyroSim software is also widely used in the simulation of hospital building fires. Lu et al. [8] used PyroSim software to study the fire characteristics of hospital wards under different water sprinkler intensities and the results show that the water spray has a certain inhibitory effect on the flame generated by the ward fire, but the suppression effect of water sprinkler on fire smoke is not obvious. Dong et al. [9] established a numerical simulation model of a high-rise hospital building fire to analyze the changes in smoke layer height, temperature, visibility, and CO concentration over time based on Pyrosim.

The smoke from a fire poses a serious threat to the evacuees, and the draft curtains have a good smoke control effect. However, in the previous literature, there is little research on the effect of draft curtains on the fire smoke spread in hospital buildings with a spacious hall.

In this paper, the outpatient building of a hospital in ××× County in China was taken as the research object, and a fire model was established based on PyroSim software to discuss the effect of setting draft curtains on fire smoke flow.

2. RESEARCH MODEL

In this paper, the effect of draft curtains on smoke flow in buildings with a spacious hall is studied through fire simulation of a hospital outpatient building. The research model is shown in Figure 1, and the research questions are as follows.

Firstly, in a building with a spacious hall, once a fire occurs, the smoke spreads rapidly. The draft curtains are set in the hall, and the question is whether they have an effect on smoke control;

Secondly, if the draft curtains are effective in controlling smoke, what is the optimal length of the curtains for achieving a better control effect?

Thirdly, if the draft curtains are effective in controlling smoke, are they effective for all parameters of the smoke?

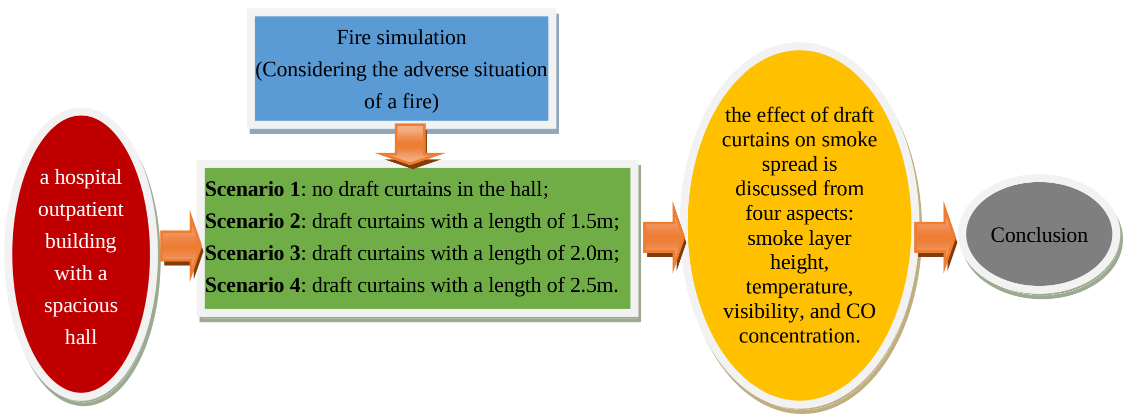


Figure 1: Research model

3. RESEARCH METHOD

3.1 PyroSim Software

PyroSim is a fire dynamic simulation software based on the FDS program, produced by American Thunderhead Engineering Company. PyroSim's biggest feature is visual processing, which allows you to view the built physical model while modeling, without writing complex command lines. At the same time, Smokeview, a built-in visualization tool in PyroSim, can also be used to visually understand the process of fire spread, smoke movement, temperature changes, and more.

3.2 Model Establishment

This paper analyzes the hospital outpatient building in ××× County in China as the research object. Figure 2 shows the floor plan of the outpatient building, which consists of one floor and includes three functional areas: the hall, traditional Chinese medicine diagnosis and treatment, and Western medicine diagnosis and treatment. The building area is 2500m^2 and the floor height is 5m.

A 3D model (.dxf) was established by the drawings of the outpatient building and imported into PyroSim software for fire simulation. Figure 3 shows a three-dimensional model (.dxf) of the outpatient building. Figure 4 shows the PyroSim fire simulation model.

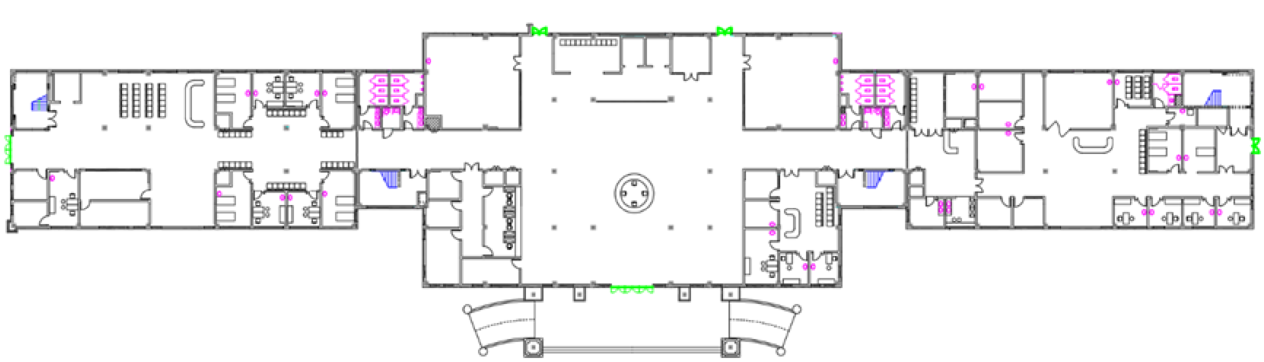


Figure 2: Plan view of the outpatient building

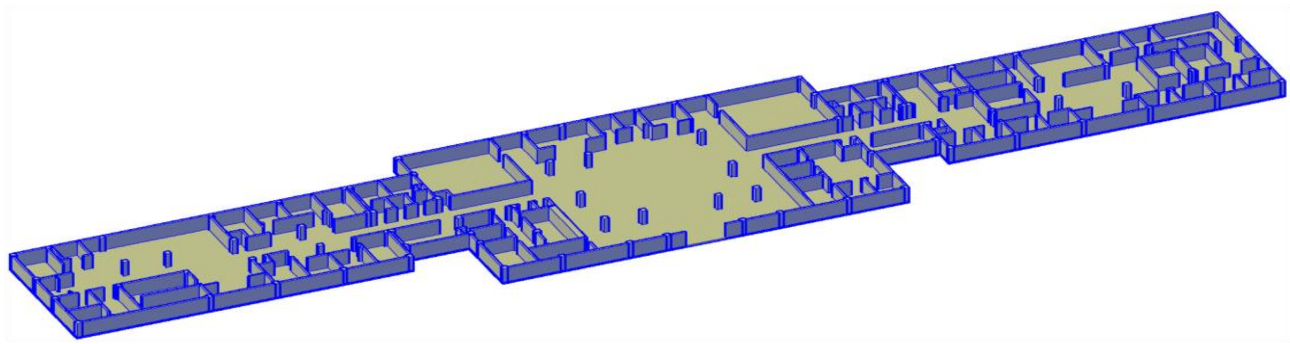


Figure 3: 3D model of the outpatient building

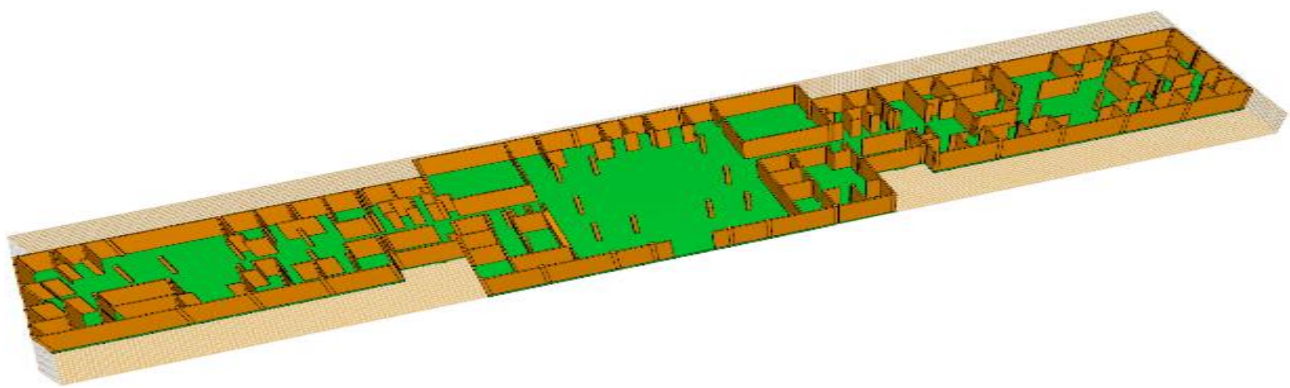


Figure 4: PyroSim model of the outpatient building

3.3 Scenario Design

When a fire occurs, the smoke spread rapidly in the corridor and hall, affecting the safety of personnel evacuation. The application of draft curtains in other buildings has shown a certain smoke control effect [10], but it is not clear whether and how effective it would be for smoke control in the hospital building with a spacious hall. Therefore, four scenarios are designed in this paper: no draft curtains in the hall, draft curtains with a length of 1.5m in the hall, draft curtains with a length of 2.0m in the hall, and draft curtains with a length of 2.5m in the hall. Here, the length of draft curtains means the length from the ceiling. Table 1 shows four fire simulation scenarios.

Table 1: Scenarios

Scenario	Condition
Scenario 1	no draft curtains in the hall
Scenario 2	draft curtains with a length of 1.5m in the hall
Scenario 3	draft curtains with a length of 2.0m in the hall
Scenario 4	draft curtains with a length of 2.5m in the hall

The detection point is set at the emergency exit, shown in Figure 5. The breathing position of ordinary people is 1.5~1.8m, while in this paper, the detection point is set at 1.8m from the ground for safety.

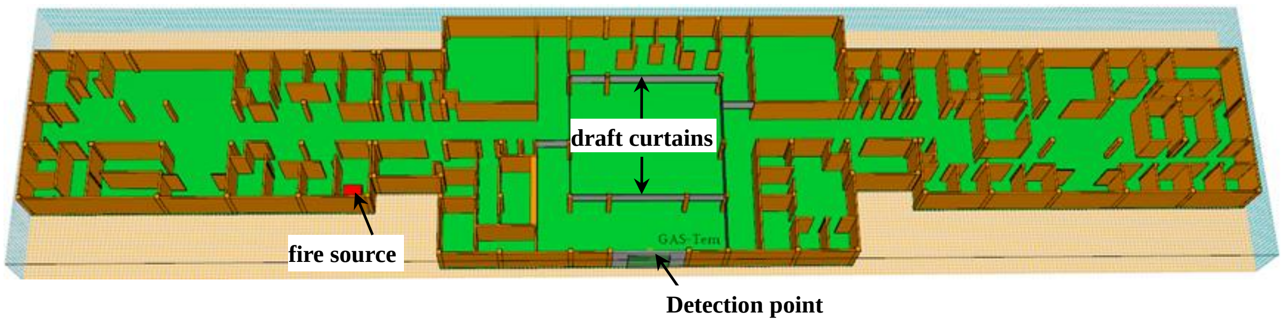


Figure 5: Location of fire source and detection point

3.4 Setting Initial Conditions

In order to conduct fire simulation, various conditions and variables need to be set, such as burning material, fire source size, fire source location, etc. Figure 5 shows the location of the fire source, located in the hospital bed. The specific fire simulation parameters are set in Table 2.

Table 2: Settings of fire simulation parameters

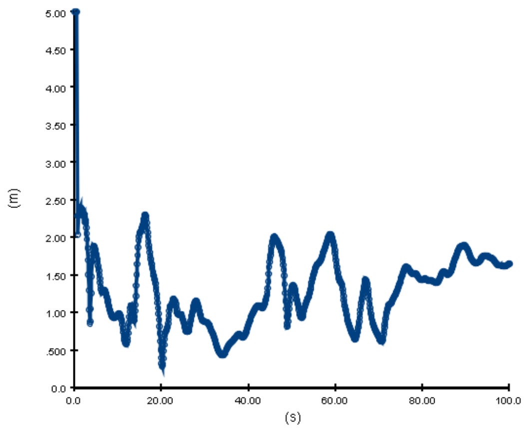
Parameters	Value		
Analytic mesh number	252000（300×70×12）		
Simulation time	100s		
Heat release	Total heat release	fire source size	Heat Release Rate Per Area
	8400kW[11]	2.4m^2（1.2m×2m）	3500kW/m^2
Burning material	Polyurethane		
Environment temperature	20℃		
Windows and other emergency exits	close		
Fire extinguishing installations	failure		

4. RESULTS AND ANALYSIS

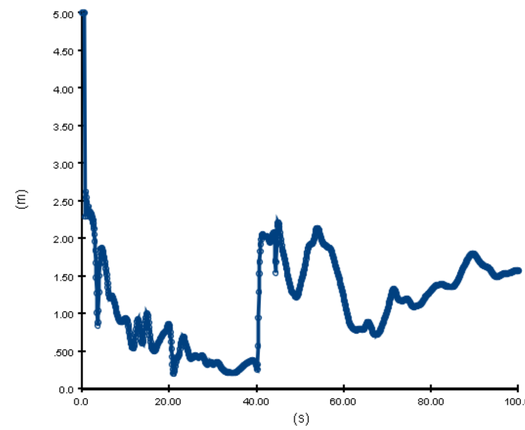
Through the simulation of four scenarios, the influence of draft curtains on smoke dispersion is analyzed fr om four aspects: smoke layer height, visibility, CO concentration, and temperature.

4.1 Analysis of the Smoke Layer Height

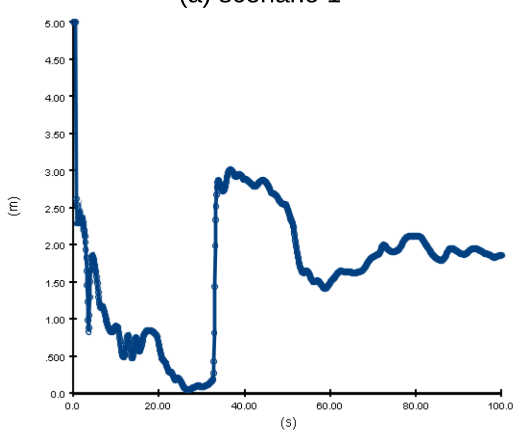
The thick black smoke produced by combustion is mixed with many solid particles. These particles float i n the air and form a smoke layer, which is one of the factors that have the greatest impact on the safe of pers onnel evacuation. Figure 6 shows the changes in the smoke layer at the emergency exit opened in four scenar ios over time. During the simulation time, the smoke layer in all four scenarios decreased to near the ground, but the time required for the smoke layer to reach its lowest point was not consistent. The time required for s cenarios 1-4 was 20s, 22s, 26s, and 47s respectively. Compared to scenario 1, the time required for scenarios 2-4 increased by 10%, 30%, and 135% respectively. Therefore, when the draft curtains are 2.5m high, the co ntrol effect on smoke is the best.



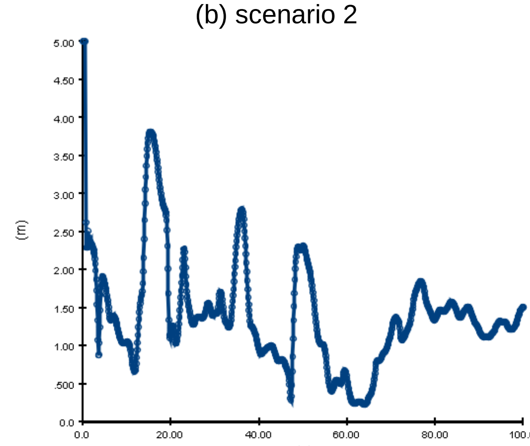
(a) scenario 1



(b) scenario 2



(c) scenario 3



(d) scenario 4

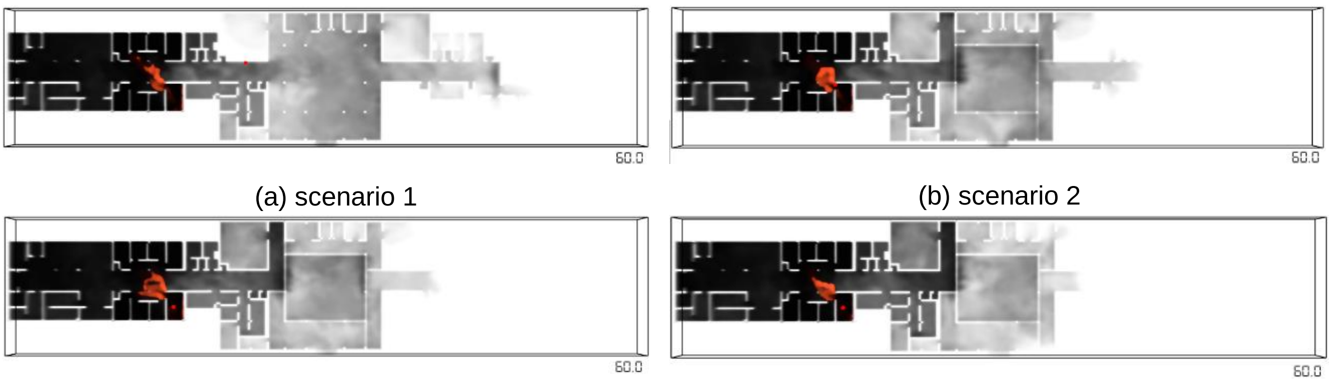
Figure 6: Time-varying curve of smoke layer height in four scenarios

4.2 Analysis of Visibility

According to [11], the minimum allowable visual distance of smoke in the event of a fire in the hospital's outpatient building is 5m. As shown in Table 3, the visibility in all simulation results meets the requirement of more than 5m. Compared to scenario 1, the minimum visibility in scenarios 2-4 increased by 6.25%, 21.8 8%, and 37.50% respectively. Therefore, when the draft curtains are 2.5m, the increase rate of minimum visi bility is the highest. As shown in Figure 7, the draft curtains have a significant effect on blocking smoke.

Table 3: Comparison of minimum visibility in four scenarios

scenario	minimum visibility (m)	increase efficiency
scenario 1	16	/
scenario 2	17	6.25%
scenario 3	19.5	21.88%
scenario 4	22	37.50%



(a) scenario 1 (b) scenario 2

(c) scenario 3 (d) scenario 4

Figure 7: Plan of smoke diffusion at 60s

4.3 Analysis of CO Concentration

In the event of a fire, there are many harmful gases in the smoke, of which carbon monoxide is the most co mmon. Under normal circumstances, 1400ppm is the maximum concentration of CO that an adult can tolerat e [4]. As shown in Table 4, the maximum concentration of CO in all simulation results is less than 1400ppm. When there are no draft curtains in the hall, the CO concentration at the emergency exit detection point is th e highest. When the draft curtains are 2.5m, the CO concentration at the detection point is the lowest, with a concentration reduction of 74.67%.

Table 4: Comparison of maximum CO concentration in four scenarios

scenario	maximum concentration of CO (mol/mol)	maximum concentration of CO (ppm)	increase efficiency
scenario 1	7.5×10-6	7.5	/
scenario 2	7×10-6	7	6.67%
scenario 3	6.5×10-6	6.5	13.33%
scenario 4	1.9×10-6	1.9	74.67%

4.4 Analysis of temperature

As shown in Table 5, the temperature in all simulations did not exceed the human tolerance temperature of 60°C [3]. In scenario 1, the maximum temperature at the detection point was 40°C. Similar to the previous results, the draft curtains also had a certain blocking effect on the diffusion of smoke temperature. Compared with scenario 1, scenario 4 had the best effect, with a maximum temperature reduction of 23.75% at the detection point.

Table 5: Comparison of maximum temperature in four scenarios

scenario	maximum temperature (℃)	increase efficiency
scenario 1	40	/
scenario 2	38.5	3.75%
scenario 3	37.5	6.25%
scenario 4	30.5	23.75%

5. DISCUSSION

This paper analyzes the smoke control effect from four aspects: smoke layer height, visibility, CO concentration, and temperature. We can see:

a) Compared to the scenario without draft curtains, the time required for the smoke layer at the detection point to reach its lowest point is extended by 10%, 30%, and 135% when the draft curtains are 1.5m, 2.0m, and 2.5m high, respectively.

b) Compared to the scenario without draft curtains, the minimum visibility at the detection point increased by 6.25%, 21.88%, and 37.50% when the draft curtains are 1.5m, 2.0m, and 2.5m high, respectively.

c) Compared to the scenario without draft curtains, the maximum CO concentration at the detection point decreased by 6.67%, 13.33%, and 74.67% when the draft curtains are 1.5m, 2.0m, and 2.5m high, respectively.

d) Compared with the scenario without draft curtains, the maximum temperature at the detection point decreased by 3.75%, 6.25%, and 23.75% when the draft curtains are 1.5m, 2.0m, and 2.5m, respectively.

e) Compared with other parameters, the effect of draft curtains on temperature is the smallest.

6. CONCLUSION

Through the simulation and discussion of four fire scenarios, it is concluded that the draft curtains have a certain control effect on the smoke spread in the fire of an outpatient building with a spacious hall. In addition, the smoke control effect of draft curtains is specifically analyzed and discussed from four aspects: smoke layer height, visibility, CO concentration, and temperature.

The draft curtains have a good control effect on the smoke spread in hospital outpatient building with a spacious hall, and the longer the length of the draft curtains, the better the control effect. Compared with the sm oke layer height, visibility, and CO concentration, the draft curtains have the least control effect on temperat ure. It should be noted that when the length of the draft curtains is too long, it can affect normal walking and personnel safe evacuation.

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