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Fire Risk Assessment and Safety Evacuation Analysis of Experimental Buildings in University

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Abstract

In recent years, experimental building fire accidents occurred frequently in colleges and universities, which caused great economic losses and casualties. In this paper, based on the analysis of the causes of fire accidents, in order to understand the fire development process and the law of smoke spread in the experimental building, Pyrosim is applied to simulate the fire caused by inadvertent use of electrical appliances, and the smoke spread, visibility, temperature, and temperature during the fire development process are studied.
The results show that in the process of fire development, both temperature and carbon monoxide concentration exceed the range of human body, and the safety of personnel evacuation does not meet the current national standards. Finally, according to the simulation results, the corresponding conclusions and suggestions for improvement are given in order to provide reference for the fire of experimental buildings in colleges and universities and improve the safety performance.

Key Words: *Experimental building; fire assessment; safe evacuation .*

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1. INTRODUCTION

In recent years, college laboratory building fire accidents are common, there are hundreds of experimental fire accidents every year, electrical equipment is one of the most important factors causing fire, some college laboratories were built decades ago, the line has long been aging, completely can not meet the current safety assessment standards, coupled with the laboratory building there are equipment such as tow board, hot water kettles, etc. On November 14, 2008, a laboratory in a university in Shanghai caught fire due to illegal use of electric heating, resulting in four deaths [1]. In addition, smoking is also one of the important factors causing laboratory building fires. The general building structure of university laboratories is relatively simple, the number of single-storey rooms is large, the personnel density is large, and the fire channel is not enough to meet the evacuation of a large number of students in a short time. At the same time, the laboratory, such as

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paper, equipment, tables and chairs and other items have a low ignition point, and once a fire occurs, it will produce immeasurable losses. Scholars at home and abroad have done a lot of work on the fire research of experimental buildings in colleges and universities. At first, experts simulated the fire process by creating physical models, but this method was too expensive, the experiment was not reproducible, and the results were not accurate. The emergence of computer numerical simulation technology has greatly improved these problems. With the help of powerful computing and processing power of computer and imaging technology, the use of finite element method or finite volume analysis method can effectively simulate fire under different working conditions. Long Xinfeng et al. [2] used Pyrosim to study the smoke spread in a six-story experimental building when the doors and Windows were fully opened and the Windows of the burning room were closed and the door was opened. Zou Xinjie et al. [3] used Pyrosim to study the effect of whether the automatic sprinkler system failed on the fire smoke flow. The results showed that under two working conditions when the Windows were opened at the same time, the smoke concentration, temperature and visibility were significantly improved when the sprinkler system was opened. Wang Li et al. [4] evaluated the evacuation capability of a 5-story experimental building in a university based on FDS+EVAC, and the results showed that the available safe evacuation time was less than the necessary safe evacuation time, and put forward improvement suggestions to increase the net exit width and reduce the personnel density. Based on FDS, Teeranon Saelao et al. [5] set the fire source in the room near the open-air staircase, and studied the impact of the size of the escape exit and whether to install smoke baffle on the evacuation of the building. The results showed that increasing the size of the door and increasing the smoke baffle could significantly reduce the evacuation time. In summary, at present, there are many studies on building fire evacuation using BIM technology and Pyrosim and Pathfinder software, but most studies only judge building fire evacuation safety performance based on simulation results, and few studies on fire protection design optimization combined with data. According to the investigation, many experimental buildings in colleges and universities in China are old and have high fire risk. Therefore, it is necessary to analyze the fire evacuation safety performance of experimental buildings in colleges and universities, and carry out fire safety hidden danger prevention measures and fire protection design optimization research.

Pyrosim is a fire dynamic simulation software developed by the American Institute of Standards and Technology (NIST), which is widely used in the study of fire development and smoke movement [6]. Pyrosim has a wide range of applications in fire simulation, and supports the import of model files in FDS and DFX formats. Users can create their own models in its design interface, set boundary conditions, fire source, ignition point and combustion materials, for studying the fire smoke flow law under different working conditions, and can post-process the simulation results. After the operation, the development stages of the entire fire and the smoke flow process can be observed in the visualization program Smokeview, and the monitoring equipment set up by the experiment can also generate the change curve of the smoke temperature, visibility, concentration and other fire indicators.

2. Simulation software and research model

2.1 Overview

The research object of this paper is an experimental building of a university, with a total construction area of 13345 m², a floor height of 24.0m, 5 floors above ground, 3 evacuation stairs,13 evacuation exits, including 3 main exits and 3 stairways. The hall of the first floor of the experimental building is ventilated, so the fire source is set in the natural seismic laboratory on the second floor, and thermocouples and gas phase devices are set at the exit, corridor and stairway, and slices are set at 1.81m on the first floor and 1.73m on the second to fifth floors, as shown in Figure 3. Considering the most unfavorable situation, in the process of fire development, the doors and Windows of the non-fire room are all closed, and the influence of obstacles such as experimental equipment on personnel evacuation is considered, and the obstacles are retained in the personnel evacuation simulation model.

Figure 1: An experimental building of a university

The experimental building was built in 2002, the circuit, water pipes and other facilities in the building have been put into use for a long time, some equipment does not meet the safety assessment standards, and there is no smoke exhaust system, fire alarm device and automatic spray fire extinguishing system installed in the building.

2.2 Research model

In this paper, the change of smoke spread, visibility, temperature and carbon monoxide concentration in the course of fire development is studied by simulating the fire in an experimental building of a university. The research model is shown in Figure 2.

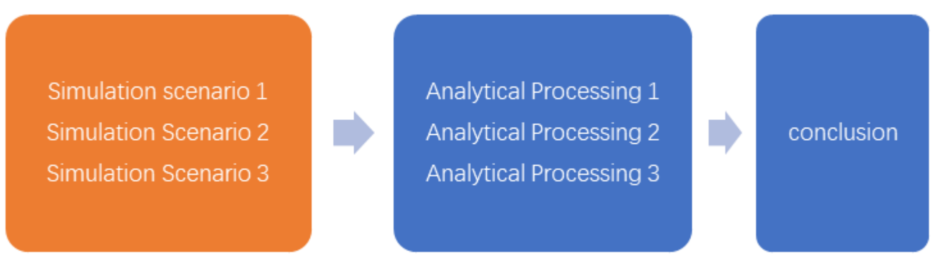


Figure 2: Research model

2.3 Fire Scenario Settings

The fire scene is a qualitative description of the overall development process of a fire, and focuses on the characteristics of the fire, so as to distinguish it from other possible key events of fire [7]. In the experimental building, there are many combustibles such as plates, tables and chairs. This paper studies the fire caused by improper use of electrical appliances to ignite paper, tables and chairs. Assume that each laboratory and fuel layout is almost the same, the roof material is PVC plate, the table material is wood, the floor, walls, stairs are ceramic tile, reinforced concrete and other inert surfaces do not participate in the combustion reaction. The type of fire was set as fast, the heat release rate as 1500kW/m², and the simulation grid of the experimental building was set. Due to the large model, the grid was divided into three parts, the size of the grid cell on the left and right sides was 1.0m*1.0m*1.0m, and the size of the middle grid cell was 0.5m*0.5m *0.5m. The total number of grids is 123165. In this simulation, the fire source was set near the table in the middle room of 2F of the experimental building to simulate the electrical appliance fire experiment. In this fire scenario, a monitoring section (2D section) is set at 1.9m above the ground of each floor to monitor the visibility of smoke and the diffusion of gases such as temperature, carbon monoxide, carbon dioxide, and oxygen, assuming that all doors and Windows are open.

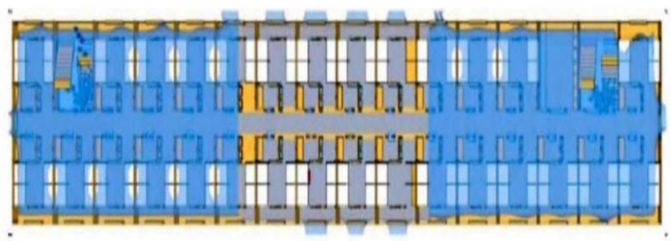
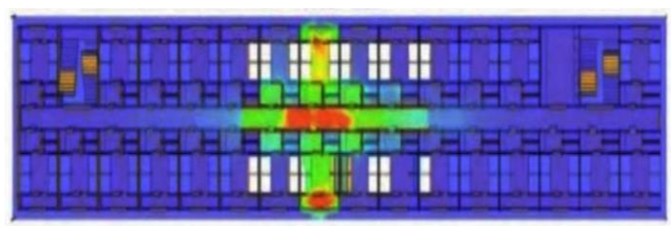
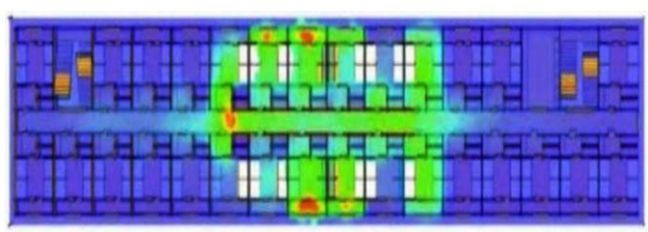


Figure 2. Distribution map of the visibility range of 5m in the fire scene at 169.6s



(a) Temperature distribution map at 100s on the 2nd floor



(b) Temperature distribution on the 2nd floor at 300s

Figure 3. Temperature distribution of the 2nd floor at different times

3 Analysis of simulation results

3.1 Analysis of smoke spread

Fires are often accompanied by a large number of toxic black smoke, and some smoke that cannot be discharged in time may settle, resulting in rapid reduction of visibility inside the building and obstruction of sight. In this paper, the fire is set in 2F electrical laboratory. After the fire, the smoke spreads rapidly in the room and the visibility decreases sharply in a short time. At 100s, the black smoke has spread to the adjacent room, and the four rooms on the left and right sides have been invaded by the smoke, and the visibility in other areas is good except near the fire source. When the fire lasted until 200s, the smoke had spread to all rooms of 2F, and a significant reduction could be seen, and some of the smoke was discharged to the outside through the open Windows. When the fire lasted to 300s, the 2F fire smoke spread rate decreased, the smoke layer began to drop, and more and more smoke was discharged from the window.

3.2 Visibility Analysis

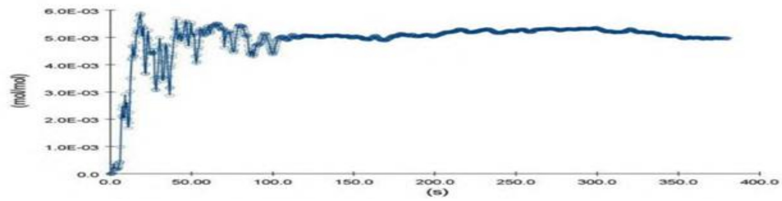
Visibility is one of the important indicators to measure the scale of fire development, smoke contains a large number of solid or liquid suspended particles, these suspended particles have absorption, reflection and refraction of visible light, indoor visibility has a huge impact. According to the relevant provisions of the Australian Fire Engineers' Guide, the visibility at 2m floor is less than 5m as the critical value, and the visibility below this critical value will affect the evacuation of personnel [8]. After the fire, the smoke flowed along the middle aisle to both sides, most of the rooms were not invaded by smoke, and the visual condition was good; At 64.7s, the smoke spread caused the visibility of the whole aisle to be lower than 5m, and began to invade the evacuation stairwell. At this time, the visibility critical value affecting the evacuation of personnel has been reached, and all personnel on the second floor need to arrive at the evacuation stairwell before this time. When the fire developed to 169.6s, the visibility of the whole area of the second floor was lower than 5m, as shown in Figure 1, and crowded disturbances or even stampedes were prone to occur during personnel evacuation.

3.3 Temperature Analysis

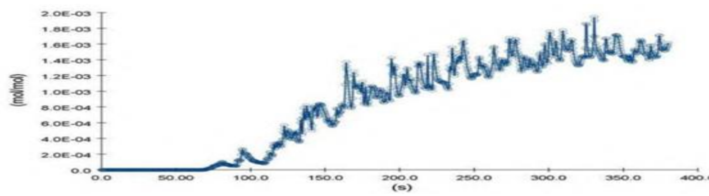
Temperature is another important indicator of the scale of fire development, and it is crucial for people to be able to evacuate safely. Under normal circumstances, the human body can not tolerate 1h in an environment exceeding 80 ° C, and the threshold of human endurance is set to exceed 80 ° C in this paper. The temperature change process is shown in Figure 2. At 100s, the fire has not fully spread, except for the area around the fire source, the ambient temperature still maintains the normal 20℃, and the temperature around the fire source rises to more than 200℃. A large amount of hot smoke gathers in the aisle opposite the fire source laboratory, and the temperature is as high as 620℃. When the fire developed to 200s, more and more rooms poured into the high temperature smoke. With the diffusion and flow of the hot smoke, the temperature in the middle aisle area decreased. At 300s, the temperature in the middle area of the 2nd floor was stable at about 300℃, the area of the high temperature area was further expanded, the temperature in the local area of the corridor reached 80℃, and the temperature in most of the other areas did not change significantly. During the simulation, the temperature of the stairwell on the left and right sides of the evacuation hardly changed, which had little effect on the evacuation of personnel.

3.4 CO concentration analysis

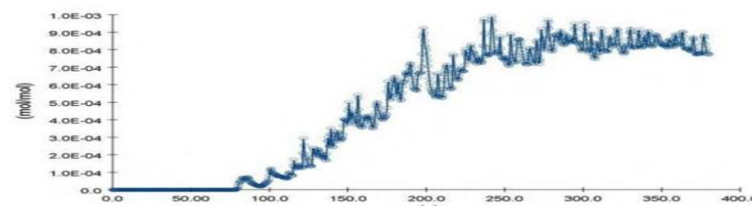
In the smoke produced by fire, carbon monoxide is the most dangerous intense toxic gas [9]. When the human body inhales carbon monoxide, the hemoglobin in the blood combines with it to form carboxyhemoglobin, thereby losing the ability to transport oxygen, resulting in hypoxic poisoning of human organs. The tolerable limits of human body under different concentrations are shown in Table 1. If the concentration set in this paper exceeds 1*10-3mol/mol, it will cause danger to human body. As shown in Figure 3, the concentration of carbon monoxide in the fire room rises rapidly, and the carbon monoxide concentration reaches the human body within 10 seconds. At this time, if there are still people in the room who are not evacuated in time, as the concentration of carbon monoxide continues to rise, there will be life danger. The highest concentration is nearly 6*10-3mol/ mol. It stabilizes at about 5*10-3mol/mol after 120s. Smoke arrives at 65s



(a) Curve of CO concentration change in the fire room on the 2nd floor



(b) Curve of CO concentration in the left stairwell on the 2nd floor



(c) Curve of CO concentration in the stairwell on the right side of the 2nd floor

Figure 4.Changes in CO concentration at different locations

On both sides of the stairwell, then the CO concentration in the stairwell slowly rose, and the concentration in the left stairwell reached 1*10-3mol/mol at 165.3s, breaking the range of the human body, and posing a great threat to those who were not evacuated. In the right stairwell, the CO concentration is always lower than 1*10-3mol/mol during the simulation process, which is within the range that the human body can tolerate.

4 Conclusions and Suggestions

In order to study the development law and risk of fire smoke in experimental buildings of colleges and universities, Pyrosim was used to study the fire caused by careless use of electrical appliances in the middle laboratory of the second floor of an experimental building of colleges and universities, and to verify the fire smoke spread under the condition of open doors and Windows, no smoke control and no automatic spray system. Through the measurement of temperature, visibility, CO concentration and other points and slices, the results show that the temperature changes mainly occur in the fire room and the adjacent room area, and have little impact on the safety evacuation stairwell. The visibility of the whole area on the second floor dropped to 5m at 169.6s, which was a great threat to the safety of personnel evacuation. The concentration of CO in the fire room rose extremely rapidly, and the concentration reached a dangerous value in the left stairwell at 165.3s, so the risk factor was high and it did not meet the evacuation requirements.

It is suggested that as an important area for daily experimental teaching of college students, more attention should be paid to fire safety. According to the numerical simulation results in this paper, the college experimental building does not meet the requirements for personnel evacuation, and the school should strengthen fire control facilities, improve fire awareness, strengthen student management and other means to make corresponding improvements. First, the smoke curtain should be added to the ceiling of the laboratory. The smoke curtain can effectively prevent the flow of smoke in the ceiling, and also strengthen the smoke exhaust effect of each partition to prevent the further expansion of the fire. Second, fire curtains should be added to the evacuation stairs, and all layers of fire curtains should be closed after the evacuation of all layers of personnel, so as to prevent the smoke from continuing to spread to the safe evacuation channel. Third, the addition of smoke exhaust pipes and the use of mechanical smoke exhaust equipment can quickly and effectively discharge toxic smoke to the outside, reduce the indoor smoke concentration, maintain a negative pressure environment indoors, and create favorable conditions for the safe escape of personnel. Finally, in order to improve the students' fire safety awareness and self-rescue ability, the school should often organize students to conduct fire drills, cultivate fire skills, and strengthen fire management, prohibit the use of high-power electrical appliances in the dormitory, and improve the equipment of fire fighting equipment on each floor. Do a good job in all aspects of fire management, in order to avoid fire accidents as much as possible, to create a good and safe living environment for students.

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