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Research on Fire Safety Management and Control of a College Dormitory under Different Evacuation Speeds

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Abstract

In order to analyze the safety evacuation characteristics of personnel in the event of fire in a university dormitory, this paper uses the Pathfinder software to introduce an example of a university dormitory building, establishes different evacuation scenarios, and analyzes the effect of different evacuation speeds on the evacuation time of personnel. The results show that when the dormitory building is a male dormitory, the evacuation speed of 1.36~1.8m/s is conducive to the safe evacuation of all personnel; when the dormitory building is a female dormitory, the evacuation speed of 1.31~ 1.70m /s is conducive to the safe evacuation of all personnel Evacuate safely. The research can provide theoretical support for safe evacuation in emergency situations.

Keywords

Evacuation Speed; Dormitory Fire; Safety Control.

1. Introduction

Student dormitories in colleges and universities are densely populated, and as a comprehensive place for students' daily life, rest and study, students spend most of their time in the dormitory. Due to the common problems of long-term establishment and aging of construction equipment in colleges and universities in China, coupled with the large number of combustible materials in dormitories, the fire load is large [1], once a fire occurs, the loss will be huge. On the one hand, the fire will cause great economic losses. On the other hand, during the evacuation of students, it is very easy to cause secondary disasters such as congestion and stampede due to panic. For example, the fire in the foreign student dormitory of Yantai University in 2016 and the fire in the dormitory of Zhejiang University of Technology in 2019 [2].

For the research on the evacuation of people in building fires, the existing research generally focuses on two aspects: one is to optimize the personnel evacuation model, and the other is to optimize the personnel evacuation path. For researches on optimizing personnel evacuation models; Choi and Chi[3] developed a model to determine the optimal evacuation route with the help of hazard prediction data, so as to obtain the safest and shortest path to the nearest exit; Wang et al[4] developed a multi-mode evacuation simulation model using the Netlogo platform.; Hyeong and Banerjee[5] combined with geographic information system (GIS) to propose a multi-agent emergency evacuation discrete simulation model for geographic personnel; Tan et al[6] constructed an agent-based building evacuation model, including spatial knowledge and event knowledge. For researches on optimizing personnel evacuation paths, Boguslawski et al[7] proposed an automatic construction method for variable density networks for determining exit routes in hazardous environments, which can improve the prediction accuracy of exit route planning; Abdelghany et al[8] proposed to integrate the genetic algorithm into the microscopic personnel evacuation model to formulate personnel evacuation plans for multi-exit buildings; Liu et al[9] Constructed an improved quantum ant colony algorithm for evacuation path search from multiple initial positions to multiple destinations; Wagner et al[10] used autonomous interactive agents for fire personnel emergency evacuation and decision-making simulation model, which is highly configurable characteristic.

At present, there is a lack of progress in the research on evacuation speed. Too slow evacuation will increase casualties, and too fast evacuation will easily lead to crowding and stampede accidents, which also does not meet the requirements of safe evacuation. This paper takes a university student dormitory as the research object, uses Pathfinder software to establish a three-dimensional model of a university dormitory, sets up multiple evacuation scenarios, and simulates the effect of different evacuation speeds on the evacuation results in a fire scenario. The results can provide a theoretical basis for the evacuation of personnel in the university dormitory under special disaster conditions.

2. Theory and Methodology

University student dormitories belong to densely populated public buildings, and the allowable time for safe evacuation is 5 minutes[11]. When a fire occurs in a building, whether people can evacuate safely depends on the available safe evacuation time (ASET) being greater than the required safe evacuation time (RSET), which can be expressed as Eq. (1)[11].

$$T_{AEST}>T_{RSET} \tag{1}$$

If Eq. (1) is established, it shows that all personnel can be evacuated to a safe area when a dangerous state comes; otherwise, accidents are prone to. When it does not meet the requirements, it is necessary to optimize the evacuation path, speed up the evacuation, or strengthen the fire protection measures to delay the advent of the dangerous state. The determination of the safe evacuation time of personnel is shown in Figure 1.

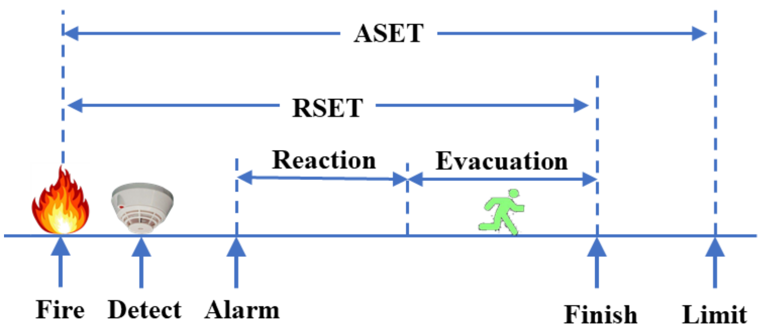

Figure 1. Criterion on judge whether a person can evacuate safely

3. Case Study

The project example used in this paper is a dormitory building of a university. The building is a reinforced concrete frame structure with an inner corridor-like symmetrical layout. The dormitories are all 6-person rooms, and there are 20 dormitories on each floor, which can accommodate 720 people. There are stairs at both ends of the dormitory, and only the two ends of the first floor have escape doors. The detailed dimensions of the rooms, corridors, dormitory balconies and stairwells are shown in Table 1.

Table 1. Dimensions of each part of the dormitory building

Structure name	Structure size			Door	
	Length(m)	Width(m)	height(m)	Width(m)	height(m)
Room	3.6	8.0	3.0	1.0	2.0
Corridor	54.0	2.0	3.0	1.5	2.0
Dormitory balcony	3.6	1.5	3.0	1.2	2.0
Stairs on both sides	1.8	6.5	1.5	3.6	2.0

3.1. Modeling

The architectural model is completed by Pathfinder software, which is characterized by high computational efficiency and 3D visualization. On the basis of the data in Table 1, the 3-D model of a university dormitory established is shown in Figure 2.

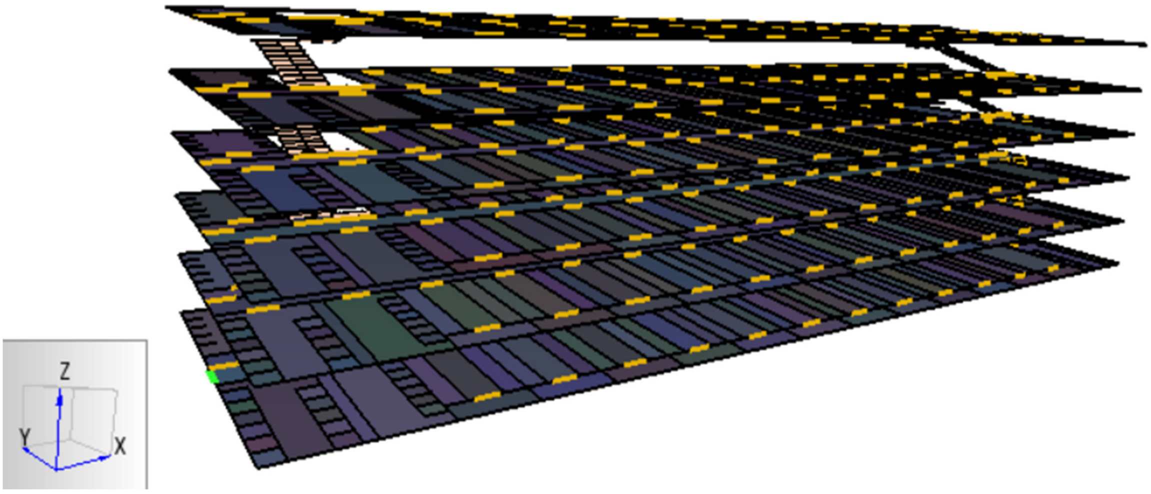

Figure 2. 3-D model of the dormitory

In the Pathfinder software, the movement of personnel includes Steering and SFPE modes. According to the data survey [12], the Steering mode is closer to the actual evacuation situation, so this paper chooses the Steering mode for personnel evacuation.

3.2. Establish Evacuation Scenarios

The fire evacuation scenarios of male dormitory and female dormitory were established respectively. Referring to corresponding researches [13,14], the evacuation speed range of male is 1.1~1.81m/s, and the shoulder width was 0.42m; the evacuation speed range of female is 1.0~ 1.74m/s, and the shoulder width is 0.38m. Since the fire signal is mainly transmitted in the dormitory building by means of broadcasting or people shouting when a fire occurs, the personnel response time is set to 60s [15], that is, the personnel begin to evacuate after 60s. The established evacuation scenarios are shown in Table 2.

Table 2. Evacuation scenarios

Dormitory	Evacuation speed (m/s)
Male	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8
Female	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7

Assuming that the fire occurred at night, which is the most unfavorable time period, at this time, there are 6 people in each dormitory, each floor includes 20 dormitories, 6 floors, and the total number of people is 720. Figure 3 shows the 3-D evacuation model of the dormitory where people are placed.

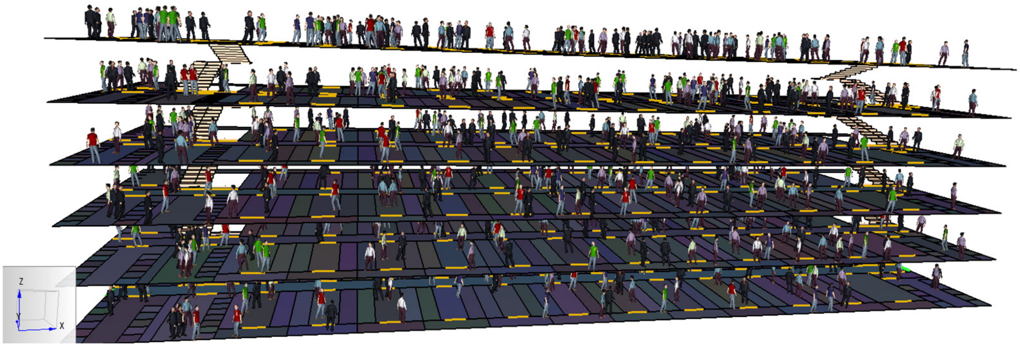

Figure 3. 3-D evacuation scene with personnel placed

3.3. Results and Disscusion

According to the simulation results, the evacuation time under different evacuation speeds is shown in Table 3.

Table 3. Evacuation time at different evacuation speeds

Male dormitory	Speed (m/s)	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
	Time (s)	339.8	357.5	320.8	287.5	262.3	254.0	238.8	232.8
Female dormitory	Speed (m/s)	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
	Time (s)	384.3	365.3	330.5	302.0	282.5	264.8	255.0	241.5

For the male dormitory, the time spent at different evacuation speeds is shown in Figure 4. During the evacuation process, the evacuation time decreases with the increase of the evacuation speed, which roughly conforms to the evacuation law, and only occurs when the evacuation speed is 1.2m/s. Evacuation time anomalies. Considering the safe evacuation time, according to the approximate calculation of the insertion method, when the evacuation speed is greater than 1.36m/s, it can be guaranteed that all personnel can be evacuated to a safe area after a fire occurs.

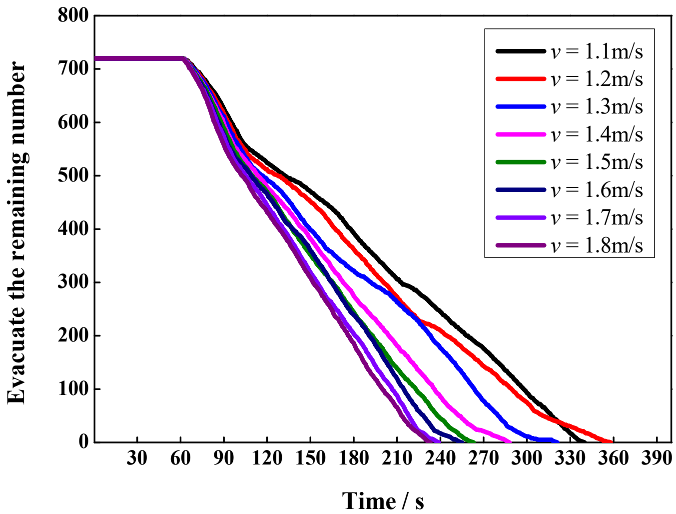

Figure 4. Evacuation time chart of male dormitory

For the female dormitory, the time spent at different evacuation speeds is shown in Figure 5. During the evacuation process, the evacuation time decreases with the increase of the evacuation speed, which roughly conforms to the evacuation law. According to the approximate calculation of the insertion method, when the evacuation speed is greater than 1.31m/s, it can be ensured that all personnel can be evacuated to a safe area after a fire occurs. This is because females have smaller shoulder widths than males and are less hindered during evacuation.

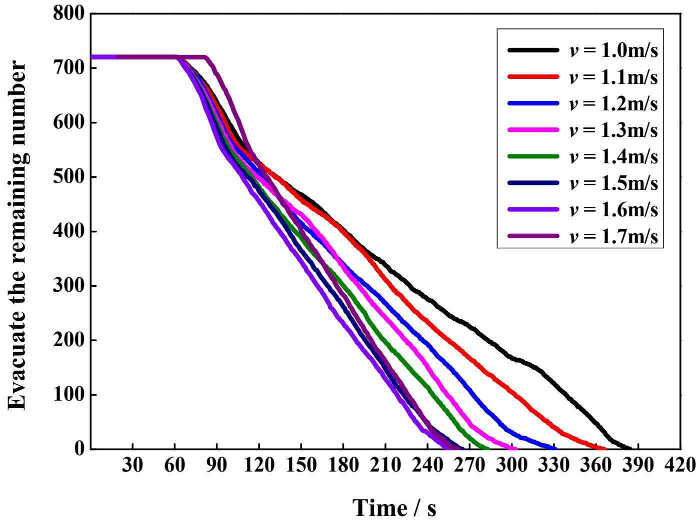

Figure 5. Evacuation time chart of female dormitory

3.4. Measures

Since the evacuation of personnel generally follows the evacuation law, taking the evacuation speed of the male dormitory as an example of 1.4m/s, the distribution of personnel density when the accident occurs 80s is shown in Figure 6. According to the simulation results, the safe evacuation paths of personnel are all "room-Corridor-stairs-gate". Therefore, the evacuation bottlenecks are the corners of the stairs and the gate on the first floor.

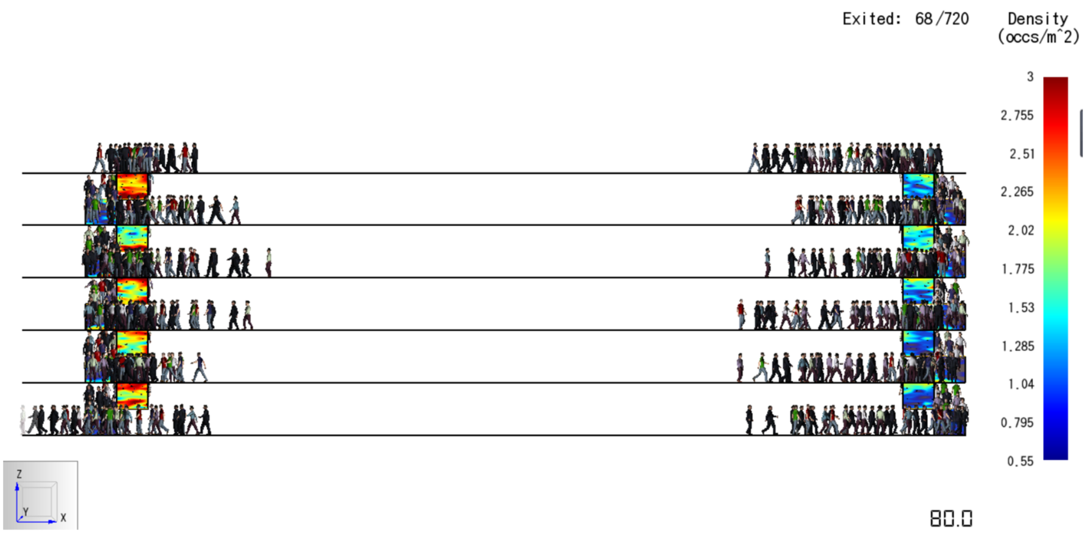

Figure 6. Evacuation density distribution of people

For the safe evacuation of university dormitories, the following two points should be done: (1) Carry out more fire drills, improve the evacuation speed, and reduce collisions and stampede incidents during the evacuation process; (2) The door on the first floor should be kept open at

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all times to avoid it in the process of evacuation. Evacuation efficiency is affected in emergency evacuation.

4. Conclusion

(1) This paper uses the Pathfinder numerical simulation software, introduces an example of a university dormitory building, establishes different evacuation scenarios, and analyzes the effect of different evacuation speeds on the evacuation time of personnel. The research results can provide theoretical support for safe evacuation in emergency situations.

(2) When the dormitory building is a male dormitory, the evacuation speed of 1.36~1.8m/s is conducive to the safe evacuation of all personnel; when the dormitory building is a female dormitory, the evacuation speed of 1.31~1.70m/s is conducive to the safe evacuation of all personnel. And based on the simulation results, corresponding measures are proposed.

Acknowledgments

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