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Research on Fire Safety Evacuation Management and Control of a Teaching Building under Different Gender Ratios

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Abstract

In order to analyze the safety evacuation characteristics of personnel in the event of a fire in a university teaching building, this paper uses the Pathfinder numerical simulation software to establish different evacuation scenarios by introducing an example, and analyzes the impact of different gender ratios on personnel evacuation. The results show that when the proportion of males is less than or equal to 80%, the gender ratio has little effect on the evacuation time of personnel, and when the proportion of males is greater than 80%, the evacuation time increases significantly. And when the proportion of males is 60%, the evacuation time is the shortest 970.525s; when the proportion of males is 100%, the evacuation time is the longest 1272.03s. The results of this research can provide theoretical support for the safe evacuation of university teaching buildings in emergency situations.

Keywords

Gender Ratio; Teaching Building Fire; Safety Control.

1. Introduction

As the main teaching place of colleges and universities, the teaching buildings of colleges and universities have a high degree of personnel density, and there are certain difficulties in the management of emergencies [1]. Although the on-campus facilities of colleges and universities have been gradually improved, with the continuous expansion of university enrollment in China, there are serious safety hazards such as congestion of evacuation passages and personnel trampling in the evacuation of high-rise teaching buildings [2]. Therefore, it is necessary to study high-rise teaching buildings. Safe evacuation of personnel in case of fire.

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

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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 the impact of different genders on personnel evacuation. This paper takes a teaching building in a university as the research object, uses Pathfinder software to build a three-dimensional model of the teaching building, sets up multiple evacuation scenarios, and simulates different fire scenarios. Effect of gender ratio on evacuation time. The research results can provide a theoretical basis for the evacuation of personnel under the disaster accident of the teaching building in colleges and universities.

2. Theory and Methodology

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.

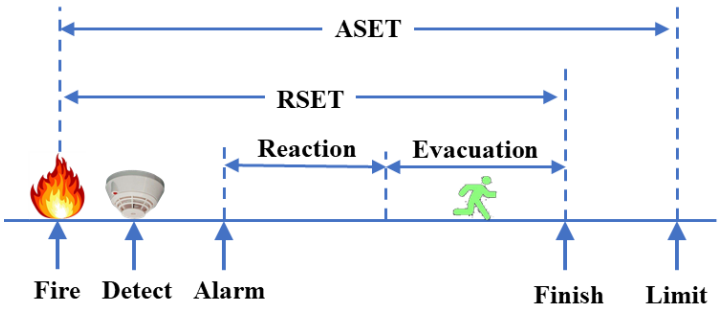

Figure 1. Criterion on judge whether a person can evacuate safely

3. Case Study

3.1. Modeling

Taking a teaching building in a university as an example, the first floor plan of the building is shown in Figure 2.

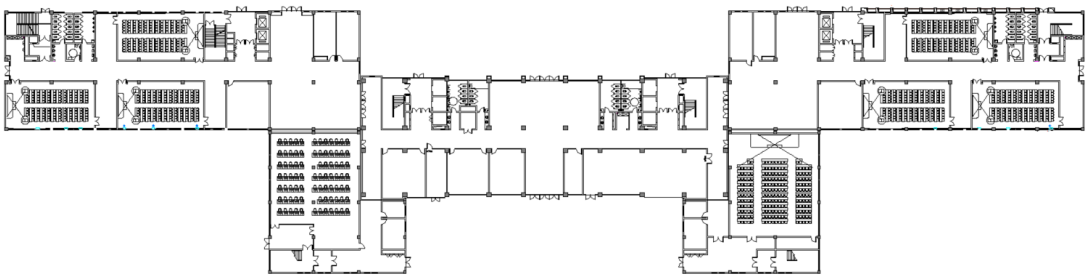

Figure 2. Floor plan of the first floor of the teaching building

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Using Pathfinder numerical simulation software, based on the construction drawings of the teaching building, the 3-D evacuation model established is shown in Figure 3 In the Pathfinder simulation software, the movement of personnel includes Steering and SFPE modes. According to the research [12], the Steering mode is closer to the actual evacuation situation, so this paper selects the Steering mode for personnel evacuation.

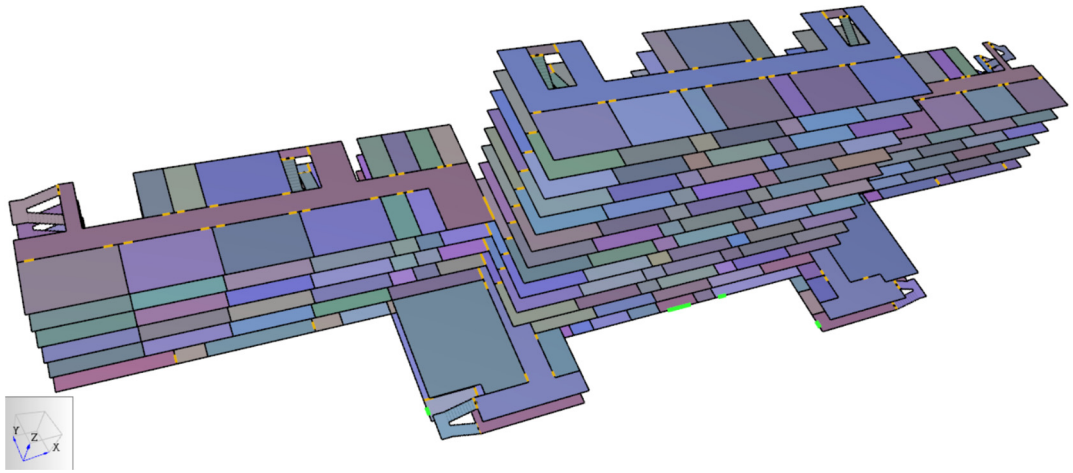

Figure 3. 3-D model of the teaching building

3.2. Establish Evacuation Scenarios

Since the teaching buildings of colleges and universities are mainly young people, according to relevant research [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. Take the time of personnel reflection as 60s [15], that is, the personnel can be safely evacuated after 60s. The evacuation scenarios under different gender ratios established from this are shown in Table 1.

Table 1. Evacuation scenarios

Male proportion	0%	10%	20%	30%	40%	50%
Female proportion	100%	90%	80%	70%	60%	50%
Male proportion	60%	70%	80%	90%	100%	
Female proportion	40%	30%	20%	10%	0%	

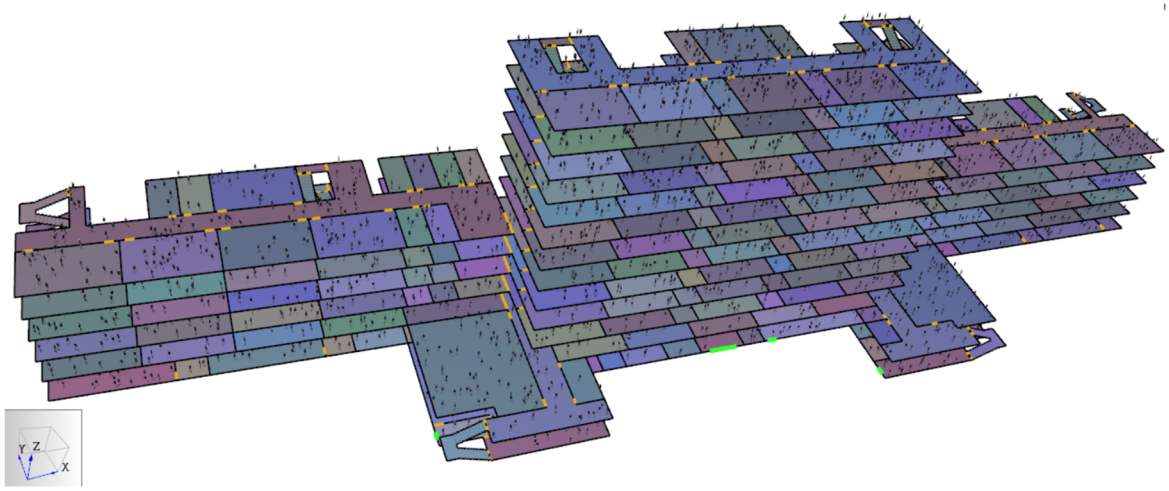

Figure 4. 3-D evacuation scene with personnel placed

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Assuming a fire occurs when the flow of people is the largest, according to the maximum capacity of the teaching building, the 1st floor can accommodate 1100 people, the 2nd floor can accommodate 800 people, the 3rd to 6th floors can accommodate 750 people, and the 7th floor can accommodate 750 people. Each of the 13 floors can accommodate 300 people. A total of 7,000 people need to be evacuated. During the accident, the vertical lift is not used for personnel evacuation, and personnel can only be evacuated by walking stairs [11]. Figure 4 is a 3-D evacuation scene with personnel placed.

3.3. Establish Evacuation Scenarios

According to the simulation results, the evacuation time under different gender ratios is shown in Table 2.

Table 2. Evacuation time under different gender ratios

Male proportion	0%	10%	20%	30%	40%	50%
Time/s	1030.03	1041.28	1049.78	1040.53	1059.53	998.025
Male proportion	60%	70%	80%	90%	100%	
Time/s	970.525	973.525	1037.28	1158.03	1272.03	

When the proportion of males is less than or equal to 80%, the gender ratio has little effect on the evacuation time. When the proportion of male is greater than 80%, the evacuation time increases significantly. This is because the shoulder width of men is wider than that of females. While evacuation is faster, there is a greater chance of being hindered during the evacuation. When the proportion of males is 60%, it takes the shortest time for all personnel to evacuate to the safe area, which is 970.525s; when the proportion of males is 100%, it takes the longest time for all personnel to evacuate to the safe area, which is 1272.03s. Figure 5 shows the relationship between evacuation time under different gender ratios.

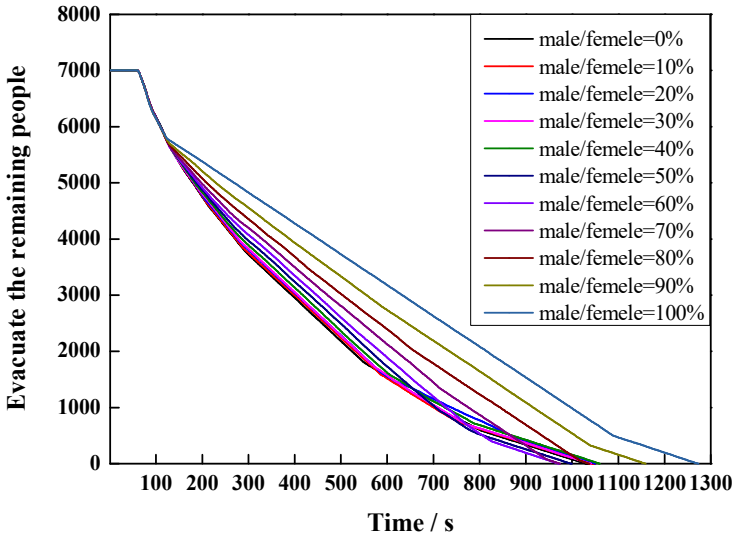

Figure 5. The relationship between evacuation time under different gender ratios

Taking the longest evacuation time, that is, the proportion of males is 100%, as an example, Figure 6 shows the evacuation of people at different times. According to the numerical simulation results, the safe evacuation paths of personnel are all "classroom-corridor-staircase-first floor gate". Therefore, evacuation bottlenecks are stairs and stair corners.

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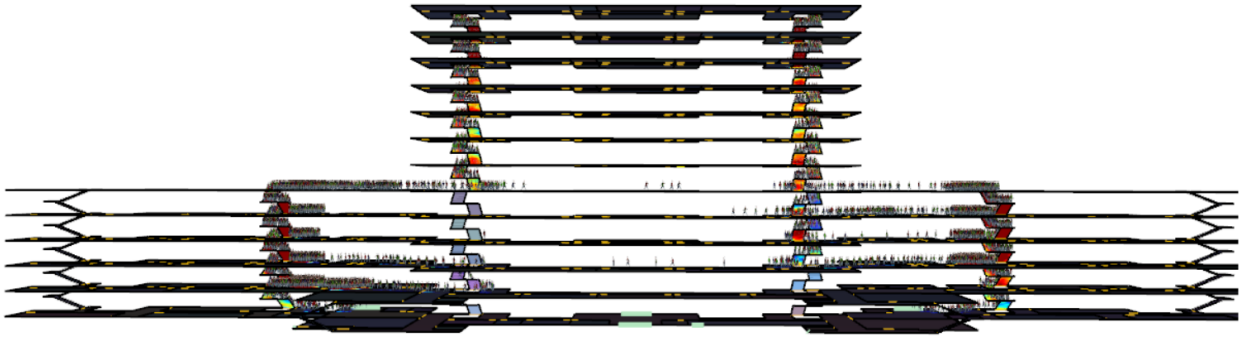
(a) t=90s



(b)t=240s

(c)t=360s

Figure 6. Distribution of personnel at different times (males account for 100%)

3.4. Measures

The evacuation of personnel generally follows the evacuation rules. Since the teaching building belongs to an area with a large flow of people, in the event of a disaster such as a fire, the disaster signal is mainly transmitted through broadcasting or personnel shouting, coupled with personnel panic and herd mentality, which are all important to safety. Evacuation has adverse effects. For the safe evacuation of teaching buildings in colleges and universities, the following two points should be done: (1) Carry out as many fire drills as possible, 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 all times, to avoid affecting the evacuation efficiency during the evacuation process.

4. Conclusion

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

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(2) When the proportion of males is less than or equal to 80%, the gender ratio has little effect on the evacuation time. When the proportion of males is greater than 80%, the evacuation time increases significantly. When the proportion of males is 60%, it takes the shortest time for all personnel to evacuate to the safe area, which is 970.525s; when the proportion of males is 100%, it takes the longest time for all personnel to evacuate to the safe area, which is 1272.03s.

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