

Study on Emergency Evacuation of Kindergarten based on Pathfinder

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Abstract

In order to explore the influence of children's behavior characteristics on evacuation efficiency, this paper established a three-story kindergarten model based on Pathfinder to conduct evacuation simulation research, and analyzed the relationship between children's different walking speed and exit flow rate and evacuation time. In the evacuation simulation results, it is found that the value of children's walking speed has a direct impact on the safety evacuation effect of the simulated kindergarten building. Reasonably increasing the walking speed can improve the evacuation flow rate of the safety exit and reduce the total evacuation time. The research results and data can provide a basis for kindergarten architectural design and safe evacuation strategy formulation.

Keywords

Kindergarten, Pathfinder, Emergency Evacuation, Children.

1. Introduction

With the popularization of preschool children's early education in China, the safety of kindergartens has been paid attention to, among which how to ensure the safe evacuation of teachers and children in emergency situations is the focus of attention. The interior design of the kindergarten is special, and there are many young children. Improper evacuation in emergencies is easy to cause significant personnel and property losses.

Compared with adults, children's psychological and physiological characteristics determine their walking speed and other behavioral characteristics, which are more uncertain in emergencies. However, there are still few experimental research results on kindergarten evacuation in emergency situations, and the influence of children's behavioral characteristics on evacuation efficiency is not clear. In order to make up for the shortage of the experiment, the evacuation study of kindergarten can adopt the method of simulation. The commonly used fire evacuation software for personnel evacuation simulation includes Pathfinder, FDS+Evac, Building, EXODUS, Simules, STEPS, etc.

Based on the research methods of evacuation simulation of children in international literature in recent years [1,2] and the behavioral characteristics of children in kindergarten evacuation in China, this paper uses Pathfinder evacuation simulation software to conduct evacuation simulation for children and analyzes the influence of different walking speeds on safe evacuation of kindergartens. The research results and data can provide theoretical basis for kindergarten architectural design and safe evacuation strategy formulation.

2. Model Construction

2.1 Introduction to Pathfinder

Pathfinder is an evacuation and mobility simulator developed by Thunderhead Engineering to simulate evacuation in both normal and emergency situations. This software provides users with a graphical user interface for simulation design and operation, as well as 2D and 3D visualization tools for result analysis [3]. Pathfinder models rooms, staircases, exits and evacuees, who respond to changes in their environment.

In terms of specific parameter setting, Pathfinder contains two modes of personnel movement :SFPE mode and Steering mode. In SFPE mode, pedestrians take path length as the main criterion for path selection, and their movement rate is determined by the crowd density in the room. While the Steering mode is controlled by the comprehensive effects of path planning, guiding mechanism and collision handling. When evacuating personnel, the route should be confirmed according to the path and the distance of personnel [4,5]. The Steering mode is more close to the actual evacuation situation of the kindergarten, so this paper adopts the latter as the movement mode of personnel.

2.2 Introduction to Kindergarten Model

The kindergarten model used in this study has three classes, namely, big class, middle class and small class. The kindergarten has nine classrooms on three floors, each of which is 9m long and 7m wide. In addition, each floor is equipped with a bathroom with a length of 5m and a width of 7m respectively. A safety exit with a width of 2m is set on both sides of the kindergarten, and the width of stairs between each floor is 2m. Each classroom is equipped with two exit doors, each door width is 1m, considering the toilet and classroom layout is different, each bathroom exit door is set to 2m. Each floor has a 32m long and 2m wide corridor. There is no door between the corridor and the landing. In terms of the number of personnel, considering that the evacuation scene is during normal classes, 30 children and one teacher are set in each classroom, and five people are set in each bathroom at the ratio of 95% students and 5% teachers. In emergency evacuation, assuming that both exits can be used normally, personnel can choose the nearest exit for evacuation.

2.3 Parameter Setting

2.3.1 Spatial Modeling

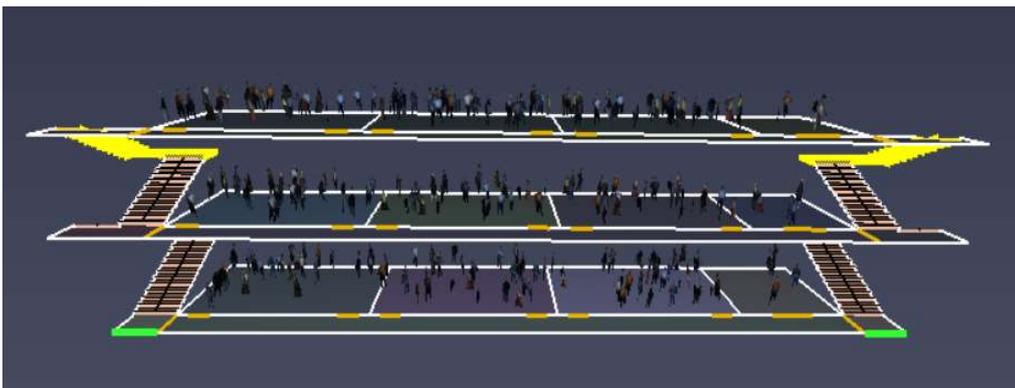


Figure 1. Schematic diagram of kindergarten model

The kindergarten model used in this paper is 3 floors, and each floor is 4m high. In the establishment of the physical model, the grid spacing is 1m. After setting the floor plane room, the construction of the second floor and the third floor plane is completed by copying operation combined with the actual building structure. Between each floor, a 4m long and 2m wide rest platform is set up to connect the stairs between floors. The kindergarten has three classrooms and a bathroom on each of the three floors. At both ends of the corridor on each floor, a door with a width of 2m is set as the entrance and exit according to the actual situation. When the grid spacing is set as 0.5m, two doors with a width of 1m are set for each classroom. Each bathroom is equipped with a 2m wide door. Exit 1 is set on the

right side of the first floor of the kindergarten and exit 2 is set on the left side of the first floor of the kindergarten. The specific 3D model is shown in Figure 1.

2.3.2 Personnel Parameter Setting

Personnel parameters, such as walking speed and shoulder width, will directly affect the results of evacuation simulation, and the default values of personnel parameters set in the software all take adults as the template. In order to analyze the impact of children's walking speed on the evacuation effect of kindergarten, corresponding changes need to be made. In this paper, the walking speed values of children in previous literature are 0.4m/s, 0.76m/s and 1.05m/s respectively, which are relatively reasonable values[6,7]. Most of the kindergartens are 3-6 years old children. Through checking relevant data [8,9], it is set that the average height of children is 1.07m and the average shoulder width is 0.26m. Since most of the faculty members were women, the height of the staff was set at 1.65m and the average shoulder width was set at 0.4m. Considering the physical and psychological characteristics of children, in case of emergency escape, teachers should guide and assist evacuation, so the walking speed of teachers in the model is set to be the same as that of children. The values of relevant parameters in the three working conditions are shown in Table 1.

Table 1. Personnel parameter setting

Working condition of evacuation	Children's height(m)	Children's shoulder breadth(m)	Teacher's height(m)	Teachers shoulder breadth(m)	Children's walking speed(m/s)	Teacher's walking speed(m/s)
I	1.07	0.26	1.65	0.4	0.4	0.4
II	1.07	0.26	1.65	0.4	0.76	0.76
III	1.07	0.26	1.65	0.4	1.05	1.05

2.3.3 Number of Personnel

Considering that most kindergartens are taught in small classes with staff ranging from 20 to 40, the conventional value of 30 is taken in this study, that is, there are 30 students in each class. In terms of teacher staffing, there is one teacher in each classroom. In addition, restrooms on each floor are staffed at a ratio of 95% students to 5% teachers. In the simulation, restrooms are actually staffed with 4 students and 1 teacher.

3. Analysis of Simulation Results

3.1 Evacuation Time of Each Exit

In combination with Pathfinder evacuation software, this paper defines the evacuation time as the time from the first child out of the room to all the personnel evacuated to the outdoor safety area. Evacuation simulation was conducted according to the three working conditions of children's walking speed, and the evacuation time of two safety exits was obtained under various working conditions. The summary results are shown in Table 2.

As can be seen from Table 2, when children's walking speed is 0.4m/s, the evacuation time of exit 1 and exit 2 is 242.2s and 352.9s respectively. When children's walking speed is 1.05m/s, the evacuation time of exit 1 and exit 2 is 95.4s and 102.8s respectively. When children's walking speed is 0.76m/s, the evacuation time is between working condition 1 and working condition 3. Through the comparative analysis of children's walking speed and the required evacuation time, it is found that the faster children's walking speed, the less evacuation time, which is approximately inverse proportion.

Among the three working conditions, the total evacuation time of working condition 3 is at least 102.8s, and that of working condition 1 is at most 352.9s. It can be concluded that increasing

children's walking speed within the research scope can reduce the total evacuation time. Therefore, in case of emergency, kindergarten teachers can reduce the total evacuation time by guiding children to improve their walking speed within an appropriate range, thus reducing the occurrence of safety accidents.

Table 2. Evacuation time of each exit

Emergency exit	Working condition of evacuation	Children's walking speed(m/s)	Exit width(m)	Number of people evacuated	Evacuation time(s)
1	I	0.4	2	111	242.2
1	II	0.76	2	123	121.4
1	III	1.05	2	139	95.4
2	I	0.4	2	183	352.9
2	II	0.76	2	171	147.7
2	III	1.05	2	155	102.8

3.2 Evacuation Flow Rate of Each Exit

The results of evacuation operation under three conditions of children's walking speed were statistically analyzed, and the evacuation flow rate of each safety exit was obtained by combining the width of each safety exit. Table 3 shows the average exit flow rate, found in various operating conditions on the same exit, children walk fast evacuation conditions, the range of the outlet flow rate is opposite bigger, the average flow rate is relatively large, such as export in condition 1 when the average flow rate is 0.49 (people/s), in the condition of 3 when the average flow rate is 1.57 (people/s), the six to one.

It can also be seen from the table that children's walking speed is positively correlated with each safety exit, that is, the faster children's walking speed is, the greater the evacuation flow rate of the safety exit is.

Table 3. Evacuation flow rate of each exit

Emergency exit	Working condition of evacuation	Children's walking speed(m/s)	Exit width(m)	Number of people evacuated	Average evacuation flow rate (people/s)
1	I	0.4	2	111	0.49
1	II	0.76	2	123	1.10
1	III	1.05	2	139	1.57
2	I	0.4	2	183	0.53
2	II	0.76	2	171	1.21
2	III	1.05	2	155	1.58

4. Conclusion

In this paper, Pathfinder evacuation software is used to establish a three-story kindergarten model for evacuation simulation. In the simulation, evacuation simulation was carried out for three different

conditions of children's walking speed, and the relationship between the evacuation time, safety exit flow rate and children's walking speed was obtained.

The results show that children's walking speed has a significant impact on the evacuation time and exit flow rate of kindergarten. When children's walking speed is larger, the evacuation speed of exit is faster, the average flow rate is also relatively larger, and the required evacuation time is shorter. It can be seen that children's walking speed has a great influence on the evacuation simulation results of Pathfinder evacuation software. Therefore, in actual emergencies, reasonable regulation of children's evacuation walking speed can improve the efficiency of evacuation and reduce personnel and property losses.

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