

Study on the influence of fire alarm time on evacuation time in typical shopping malls based on pathfinder

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Abstract. The fire floor personnel are affected by the evacuation of non-fire floor personnel during the evacuation process. Congestion in the evacuation stairwell leads to failure to evacuate in time, which affects the evacuation efficiency. In this paper, a typical shopping mall is taken as the research object, and the Pathfinder simulation software is used to simulate the safe evacuation of personnel. In the simulation, the influence of alarm time on evacuation time is studied by setting the fire layer and delaying the alarm time of non-fire layer, and finally the optimal evacuation scheme is obtained. It can be used as a reference for typical shopping malls to formulate safety evacuation plans or for the revision of relevant specifications.

Keywords: Pathfinder; Evacuation Time; Alarm Time; Typical Mall.

1. Introduction

When a fire occurs, a reasonable reduction in evacuation time can effectively ensure the safety of personnel. DING Yuanchun et al. used Pathfinder software to simulate the evacuation of high-rise buildings, and found that priority evacuation from low-rise to high-rise can effectively improve the evacuation speed [1]. Zhang et al. used Pathfinder software to simulate the influence of slope on evacuation in subway tunnel fire [2]. Zhang Xuezhi used FDS and STEPS software to simulate the safe evacuation of the theater part in a large commercial complex [3]. Lu Feng et al. used Pathfinder software to explore the influence of safe exit on evacuation time [4]; xing Luning et al. compared and analyzed the correlation between different stair forms and the number of stair conversion platforms and evacuation efficiency [5]; Fan et al. studied the influence of the residence time of the refuge layer on the evacuation of high-rise buildings [6]. Zhang Huan et al. used pathfinder software to conduct evacuation simulation research on an office commercial complex, and finally concluded the problems existing in the evacuation of the office commercial complex and gave corresponding solutions [7]. Tang Yu et al. used pathfinder software to simulate the evacuation of a shopping mall, determined the evacuation time and congestion location, and finally optimized the evacuation by reducing the evacuation distance and increasing the evacuation width [8]. The existing related research mainly focuses on the research and analysis of the influencing factors affecting the safe evacuation of personnel. The author takes a typical shopping mall as the research object to study the influence of alarm time on evacuation time, and discusses how to shorten the evacuation time and speed up the evacuation. In order to provide theoretical guidance and scientific basis for the safe evacuation of typical shopping malls.

2. Evacuation Model

The model selected in the experiment is a fire compartment of a typical shopping mall, and the plan is shown in Fig.1. The single-storey building area is 2965 square meters, with a total of six floors and a floor height of 5 meters. A total of six evacuation passages are set up. The design meets the requirements of GB 50016-2014 'Code for fire protection design of building' and GB 50352-2019 'Unified standard for civil building design'.

2.1 Number of evacuees

According to the seventh paragraph of Article 5.5.21 in the current Code for Fire Protection Design of Buildings (GB50016-2014), the minimum value in the table is taken to calculate the number of personnel on each floor. The calculation results are shown in Table 1 :

Table 1. Number of Store Stratification Personnel

Tier number	1	2	3	4	5	6
Number of personnel (person)	1274	1274	1156	890	890	890

The total number of simulated evacuations in this typical mall is 6374.

2.2 Proportion of evacuees

The proportion of personnel in typical shopping malls is complex. There are different groups of people in typical shopping malls, such as adult males, adult females, children and the elderly. By consulting the relevant literature, the proportion of simulation experimenters was set to 40 % of adult males, 40 % of adult females, 10 % of the elderly, and 10 % of children. The number of people in different groups is shown in table 2.

Table 2. The number of different groups of people in each layer

Tier number	Total number of people	Adult male	Adult female	Elderly	Child
1	1274	510	510	127	127
2	1274	510	510	127	127
3	1156	462	462	116	116
4	890	356	356	89	89
5	890	356	356	89	89
6	890	356	356	89	89

2.3 Evacuation speed

The experiment does not consider the use of different parts of the building and the evacuation speed that may be affected by different evacuation parts. According to the evacuation speed in SFPE ' fire safety manual ', the default values of evacuation speed for different groups of people are taken respectively. The evacuation speed of adult male, adult female, elderly and children is 1.1m / s, 1.0m / s, 0.8m / s and 0.9m / s respectively.

2.4 Body size of evacuees

According to the statistics of Chinese body size in recent years, the average height of adult males is 175 cm and the shoulder width is 47.66 cm. The average height of adult women is 165 cm, shoulder width is 42.35 cm ; the average height of children is 120 cm, shoulder width is 32 cm ; the average height of the elderly is 170 cm, shoulder width is 45 cm.

The evacuation model of the mall is shown in Fig.2.

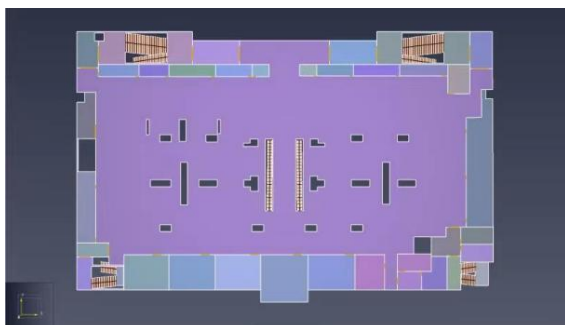


Fig.1 Mall plan

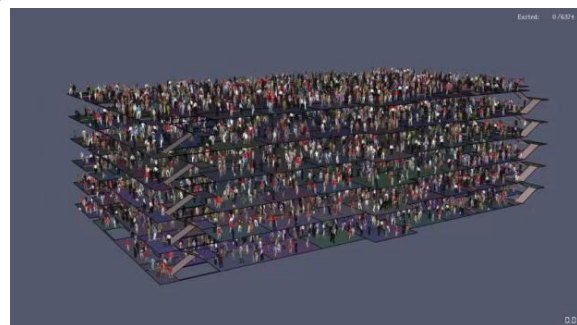


Fig.2 Mall evacuation model

3. Simulation experiment and result analysis

In this simulation experiment, the four floors of the building are set as the fire layer. When all people evacuate at the same time, the evacuation time of the fire layer is 638.3 s, and the evacuation time obtained by retaining only the fire layer is 95.2 s. It can be seen from the two data that there is a big gap in the evacuation time of the fire floor in the two cases, which is caused by the evacuation of stairwell congestion.

Next, a phased simulation is used to evacuate the part above the fire layer as a whole, and the part below the fire layer as a whole. When only considering the influence of evacuation above the fire layer, the evacuation time of the fire layer is 189.0 s. When only considering the influence of evacuation below the fire layer, the evacuation time of the fire layer is 214.7 s. From the above data, it is known that the evacuation time of the fire layer during the overall evacuation of the four to six layers increased by 93.8 s, an increase of 98.53 %. The evacuation time of the fire layer during the overall evacuation of the first to fourth floors increased by 119.5 s, an increase of 125.53 %. The influence of the overall evacuation of the four to six floors on the fire layer is less than that of the overall evacuation of the one to four floors, but the influence is greater than that of the separate evacuation of the fire layer, so the alarm time above and below the fire layer is delayed respectively during evacuation.

3.1 Delay five to six floor alarm time evacuation results and analysis

The experiment takes five to six layers as a whole. By delaying different alarm times, the evacuation time of the fire layer is shown in Table 3 :

Table 3. Different delay time evacuation schedules above the ignition layer

Delay time(s)	Evacuation time(s)	Fire layer evacuation time(s)
0	1235.8	611.2
10	1256.8	608.0
20	1247.7	596.1
30	1232.7	594.1
40	1241.8	594.3
50	1194.7	589.2
60	1188.1	572.1
70	1186.2	574.3
80	1199.5	587.8
90	1140.7	515.9
100	1154.3	533.7
110	1151.7	519.0
120	1126.7	546.6

As can be seen from Table 3, when the people above the fire layer and the fire layer are evacuated as a whole, the delay time of the personnel is simulated every 10 seconds from 0s to 120s. Considering that when a fire occurs on the fourth floor, the fire risk of the personnel is the greatest, so it is preferred to let the personnel on the fourth floor completely evacuate to the closed evacuation stairwell. At this time, the evacuation time of the fire floor is 611.2 s when evacuating alone. When the delay time is 90 s, the evacuation time of the ignition layer is 515.9 s, and the evacuation time of the ignition layer increases with the delay time. It can be concluded that when the people above the fire layer are evacuated as a whole, the best delay time is 90 s.

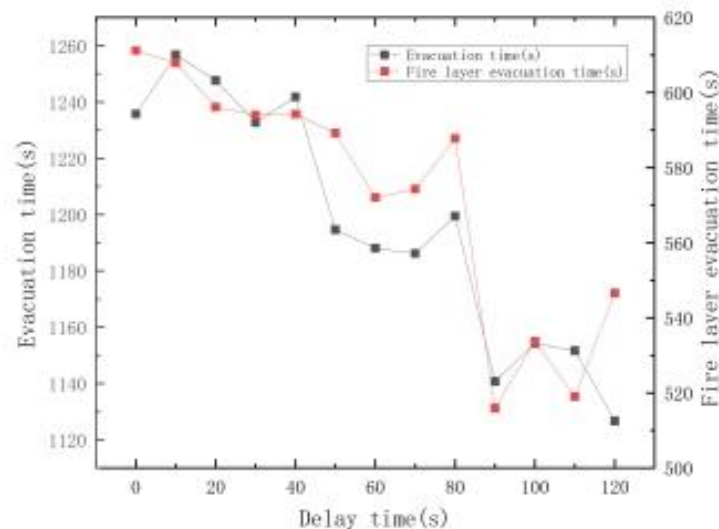


Fig. 3 Evacuation time diagram of different delay time above the ignition layer

3.2 Delay one to three alarm time evacuation results and analysis

The experiment takes one to three layers as a whole, and the fire layer is evacuated at the same time. People on the first floor of the shopping mall do not need to evacuate through the stairwell, only delay the evacuation time of two to three floors. The data of ignition layer evacuation time and delay time are shown in table 4.

Table 4. Evacuation schedule under different delay times below the ignition layer

delay time(s)	Evacuation time(s)	Fire layer evacuation time(s)
0	1235.8	611.2
10	1236.7	615.5
20	1251.4	637.7
30	1269.7	634.9
40	1220.9	655.9
50	1270.1	648.2
60	1299.5	675.5
70	1307.6	695.8
80	1297.5	692.0
90	1330.2	675.9
100	1330.5	730.2
110	1324.1	718.8
120	1303.6	711.5

The data obtained by the simulation experiment are shown in Table 4. The delay time of the simulation experiment is from 0s to 120s, and the evacuation simulation is performed every 10s. The evacuation time of the people below the fire layer and the evacuation time of the fire layer are obtained. When there is no delay, the evacuation time of the ignition layer is 611.2 s, and the total evacuation time is 1235.8 s. When the delay is 40 s, the evacuation time of the fire layer is 655.9 s, and the total evacuation time is 1220.9 s. The total evacuation time was shortened by 14.9 s. From the data in Table 4, with the increase of delay time, the evacuation time of the fire layer increases with the increase of the total evacuation time. Therefore, the part below the fire layer is evacuated as a whole and when the first layer is not delayed, the second to third layers are delayed by 40 s, the evacuation time of the fire layer is 655.9 s, and the total evacuation time is 1220.9 s. It can be concluded that when one to four floors are evacuated as a whole, the optimal delay time is 40 s, and the evacuation time is 1220.9 s.

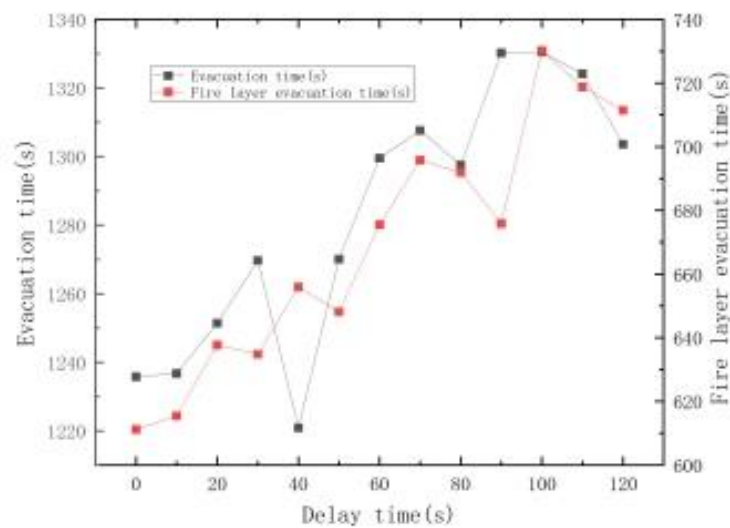


Fig. 4 Evacuation time diagram of different delay time below the ignition layer

3.3 Evacuation results and analysis of delayed alarm time above and below the fire layer respectively

The personnel above and below the fire layer are taken as a whole to ensure the priority evacuation of the fire layer personnel, and put into the whole building model for the overall evacuation simulation experiment. The results are shown in Table 5.

Table 5. Delayed evacuation schedules at different times above and below the fire layer

Personnel above the fire layer(s)	People below the fire layer(s)	Total evacuation time(s)	Fire layer evacuation time(s)
90	0	1170.6	482.1
90	10	1142.4	463.8
90	20	1232.2	564.6
90	30	1237.0	561.7
90	40	1213.9	571.8
90	50	1218.4	607.7
90	60	1310.7	653.4
90	70	1243.2	618.2
90	80	1281.7	639.8
90	90	1234.4	657.3
90	100	1260.0	622.2

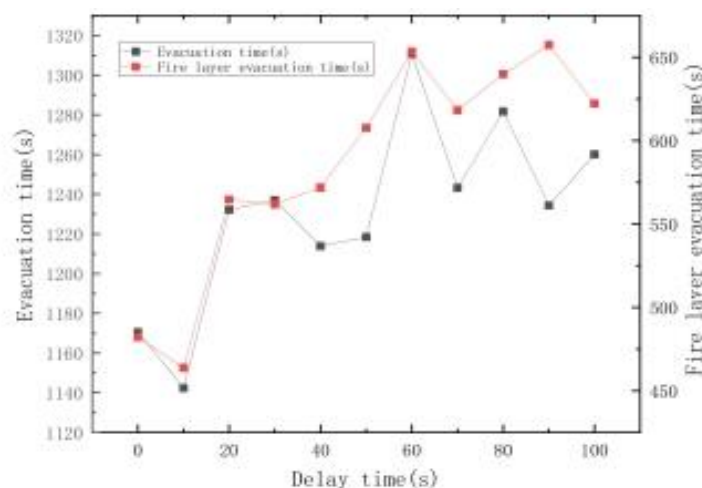


Fig. 5 Evacuation time diagram of different delay time above and below the ignition layer

It can be seen from Table 5 that when the personnel above the fire layer are delayed by 90 s and the personnel below the fire layer are delayed by 10 s, the total evacuation time is reduced by 93.4 s, and the evacuation time of the fire layer is shortened by 147.4 s. With the increase of personnel delay time below the fire layer, the total evacuation time also increases, and the evacuation time of the fire layer changes slightly but the change range is small.

4. Conclusion

(1) After a fire in a typical shopping mall, the main reason why people cannot evacuate in time is that the closed stairwell is blocked. When the fire floor personnel evacuate through the closed stairwell, the congestion of evacuation from other floors cannot be evacuated in time.

(2) The influence of people below the fire layer on the evacuation of the fire layer is greater than that of people above the fire layer.

(3) Delaying the alarm time above and below the ignition layer respectively can greatly shorten the evacuation time of the ignition layer and slightly increase the total evacuation time.

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