A fire simulation method of urban light rail station hall based on building information model and pyrosim software

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Abstract. Fire prevention is one of the key points of emergency management of urban light rail station. Based on the data interaction between building information model (BIM) and pyrosim software, this paper integrates BIM into pyrosim software, sets up the fire scenario of urban light rail station hall, analyzes the criterion index under fire condition, realizes the fire simulation of urban light rail station hall based on BIM, and obtains the fire simulation information and available safety information. Based on building information model, a fire simulation method of urban light rail station hall is established. Simulation verification shows that this method can give full play to the superiority of BIM technology.

1. Introduction
Light rail, an important standard of urban rail transit lines, undertakes the mission of escorting passengers to reach safely. Once a fire accident occurs, it will inevitably have a great negative impact. Therefore, how to effectively carry out emergency evacuation tasks in fire accidents has become one of the problems facing the development of urban rail transit. In recent years, scholars have carried out extensive research in the field of fire emergency evacuation based on BIM technology, and have achieved certain results at the theoretical level [1-4], using simulation software to simulate subway stations and other fire emergency evacuation processes have also obtained many phased results[5-7]. Based on the above research, it is found that based on BIM technology, collaborative design and information transmission can be carried out more conveniently. Therefore, the light rail station information model can be transmitted in Revit software and PyroSim software through this operation method. Using the characteristics of this technology, it can be improved the fire modeling process to enhance the accuracy of the simulation. Therefore, this paper uses the intelligent means of "BIM technology PyroSim software" to show the situation of fire scene in the station hall of urban light rail station, and then studies the influence mechanism of fire smoke propagation and the evacuation algorithm of fire personnel, which provides a novel idea for the traditional emergency evacuation of urban rail transit.

2. Scenario setting

2.1. Decision condition
In the light rail station hall after a fire, a large number of heat, smoke, toxic and harmful gases will be released with the fire, evacuation personnel have limited tolerance to these harmful factors. In case of fire in the station hall of urban light rail station, the time for the relevant personnel to evacuate to the safe area determines the safe escape of these people. Through comparison, it is found that the available
evacuation time is the time period from the fire to the beginning of the fire threatening the safety of people's lives and property, represented by $t_{ASET}$; the required safe evacuation time is represented by $t_{ASET}$, which refers to the time when the relevant personnel in the station evacuate to the safe area. Assuming that the relevant personnel did not evacuate to the safe area before the fire threatened the safety of the personnel, that is $t_{ASET} < t_{REST}$, at this time, it is necessary to optimize and improve the fire control settings in the light rail station hall to ensure that the available evacuation time $t_{ASET}$ is extended, or every effort is made to shorten the required safe evacuation time $t_{REST}$.

2.2. Judgment basis

In this paper, the temperature, visibility and toxic gas (mainly the concentration of carbon monoxide) at the height of 2m above the ground (i.e. the characteristic height of human eyes) are taken as the basis to judge the life-threatening fire. In the simulation process, the key positions in the light rail station hall are simulated, and the information of these indicators is added, and then the critical value of these indicators is taken as the time point when the personnel safety is threatened, and then the available safe evacuation time is summarized by comparison. The critical dangerous state in fire is shown in Table 1.

| Indicator                        | Tolerance limit of human body |
|----------------------------------|-------------------------------|
| Visibility                       | ≥10m                          |
| Temperature in flue gas          | 60°C                          |
| CO concentration                | ≤1400ppm                      |

If the area in the light rail station does not meet the above conditions at a certain time, if the visibility around the area is less than 10m, it is determined that the evacuation personnel in the area will be in danger, and the personnel will be trapped in the fire. Then the evacuation time $t_{ASET}$ can be defined as the duration of the fire from the beginning of the fire to that time.

3. Parameter setting

3.1. Fire type

In this paper, we set the fire scene as the light rail station hall fire. There are many components in the station hall of light rail station, most of which are flammable materials, so the probability of fire is very high. In addition, in the case of fire, the direction of smoke flow on the site is almost the same as the direction of personnel evacuation, and the smoke lingers and the personnel panic, which will make the evacuation environment worse in the process of evacuation.

3.2. Fire type

(1) The scale of station hall fire in light rail station is 4MW, and its development rate is 0.044kw/s2.

(2) The Poisson distribution method based on the fast Fourier transform formula is used to simulate the fire. In order to achieve the best simulation state, the length, width and height of the minimum unit grid size are 1:1:1. If the smallest unit grid does not meet the requirements of length, width and height, and the length is close to each other, or the division of unit grid is unreasonable, pyrosim software will automatically prompt. Open the new grid window through the menu: model > Edit meshes > new, and the new grid dialog box will pop up. When dividing the number of cells on the X, Y and Z axes, set the size of the grid cells by changing the numerical value. The larger the numerical value is, the tighter the division of the grid cells is, and the more refined the fire simulation results are. However, in the process of fire simulation, if the object does not meet the requirements of cell division, the object will be rearranged and positioned by the software. In addition, the object beyond the simulation boundary will be cut off by the boundary, and the part beyond the simulation boundary will not be displayed in smoke view.
(3) The public building area of light rail station is approximately rectangular. Considering the actual situation, the closed area such as station toilet has little influence on the fire simulation results. At the same time, in order to save the simulation time, under the premise of basically describing the public area of the station in the software, the fire simulation research is only carried out for the public area of the station. Therefore, a cubic grid is established, and its length and width are different. The grid size of near fire source is $0.5 \times 0.5 \times 0.5$, while that of far fire source is $1 \times 1 \times 1$, and 1671278 minimum grids are set. The grid parameter settings are shown in table 2.

| Axis | Min   | Max    | Number of grids |
|------|-------|--------|-----------------|
| X    | -1329.0 | -1280.0 | 98              |
| Y    | -137.0  | -106.0  | 62              |
| Z    | 13.0    | 25.0    | 24              |

(4) According to the precondition of fire simulation in light rail station hall, there are some preset conditions in the software, and other conditions need to be obtained by combining with the actual situation. The relevant parameters of this simulation are shown in Table 3.

| Basic parameters          | number     |
|---------------------------|------------|
| Initial temperature       | 20 ℃       |
| Initial humidity          | 50%        |
| Wind speed                | 0 m/s      |
| Fire simulation time      | 1200 s/600s|
| Initial region of fire source | Station hall floor/train compartment fire |
| Fire development coefficient | 0.044kW/s2 |
| Fire development mode     | Fast fire  |
| Maximum rate of heat released by fire | 4MW        |

4. Simulation results

4.1. Smoke spread

After the passenger's luggage ignites, the fire smoke in the hall of the light rail station spreads with time, as shown in Fig.1, Fig.2 and Fig.3. At about 38s, a large amount of smoke soon diffuses around the luggage. When the time comes to 78s, the smoke generated by the fire starts to spread to the upper platform layer of the station through the nearest stairway of the ignition point, and then the smoke continues to rise until it reaches the top of the platform layer, and the black smoke begins to extend its magic claw to the core position of the platform layer; after 191s of luggage burning, most of the public areas of the station hall and platform layer have been filled with black smoke, at this time, the correct evacuation is urgently needed Escape, or the consequences will be unimaginable.

![Figure 1. The spread of fire smoke when t=38s](image-url)
4.2. Temperature change
After the fire, around 78s, the stairs on the left side of the downward area of the station hall of the light rail station are in a dangerous state, while the middle and right stairs can still be evacuated. Therefore, the evacuation personnel in the downward area of the platform floor should try to avoid choosing the stairs on the left side to escape. The fire continues to spread, when 225s, the two elevators on the left side of the up and down area of the station platform floor are in a dangerous state, the evacuation personnel should take evasive behavior, and the staff need to evacuate to the station hall floor as much as possible; 600s after the fire, the high temperature area of the station hall floor begins to transfer to the middle area, and the temperature at the entrance and exit is still within the safe range, because the This does not pose a threat to the evacuation activities in the entrance and exit areas.

4.3. Visibility
The visibility of passengers' luggage in the station hall of the light rail station has declined after 20s of fire. When the fire continues to develop to 110s, the visibility of the stairway of the left station hall drops to less than 10m. According to the evacuation and escape conditions, the surrounding environmental conditions are no longer conducive to personnel evacuation, and the evacuees should change the evacuation route in time. The visibility in most areas of the station hall floor is less than 10m. At this time, if there are people left in the station hall floor, evacuation will not be completed.
Figure 5. visibility distribution of station hall slice when t = 190s

4.4. CO concentration
As shown in Figure 6, the CO concentration distribution in the hall of the LRT station is 600 s after the fire. It can be seen from Figure 6 that the change of carbon monoxide after the fire, by comparing the tolerance limit of human body to the concentration of CO, at this time, the concentration of CO has not caused harm to human body, so it has no great impact on the evacuation efficiency.

Figure 6. CO concentration distribution of station hall slice when t = 600s

5. Conclusion
This paper combines BIM technology with pyrosim software, saves a lot of complex programs, transforms BIM into the required data format in fire simulation software, and makes use of the corresponding advantages of BIM technology to make up for the shortcomings of fire simulation software, so as to effectively avoid unnecessary burden due to repeated work. In this paper, combined with the critical value of each index, the numerical value of the key location related factors (visibility, temperature, etc.) in the light rail station hall fire simulation site is analyzed, and it is concluded that the available evacuation time after the light rail station hall fire is 190s, which also provides reference for the difference between the available evacuation time and the required safe evacuation time in the follow-up study for the basis of research.

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