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BIM-based Model Applied in the Analysis of Fire Simulation and Evacuation of a Building

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Abstract - Fire causes damage to people and things. Nowadays, there are more and more buildings with complex structures.And building height also gradually increased. When the fire occurs, the escape and rescue of people are complicated. Each floor of the building has a different fire situation, which may cause more time to escape and rescue. Moreover, the situation of each fire may be different, such as the location of the fire source, so it will increase the difficulty of fire rescue.
This paper is built by building information model, and works with Fire Dynamics Simulator(FDS) and Fire Dynamics Simulator(FDS) graphical user interface PyroSim. Simulate the fire situation and evaluate and analyze the temperature, visibility and carbon monoxide concentration of the building during the fire. Due to evacuation, people will be affected by some factors to escape, this paper by temperature, visibility, carbon monoxide concentration to understand the extent of the impact on the escape of people, and by the escape simulation software Pathfinder to learn the escape situation and the time required. After integrating the simulated conditions, analyze, evaluate and recommend solutions to the problems caused by these fires.

Keywords**:** Fire, simulation, evacuation, BIM

1. Introduction

The occurrence of fire causes serious damage, and the cause of each fire accident may be different, so its impact level and results are also different. In the event of a fire, the escape time may be reduced due to physical, psychological, or building obstructions. Compared with ordinary residential buildings, when a fire occurs in large buildings such as stadiums or school buildings, the ways and routes of evacuation and evacuation will be more complicated, resulting in a reduced escape time, and due to the larger buildings and complex structures, Therefore, the time and difficulty of rescuers in disaster relief is more severe than that of ordinary residential buildings.

With the development of modern technology, computers can already be used as tools to simulate the situation of fires, and performance analysis can be used to understand the impact of fires on specific buildings. The fire simulation in this article is to use the Building Information Modeling tool software Revit to build the model, and use the fire dynamics simulation software Fire Dynamics Simulator (FDS), the graphical user interface PyroSim of FDS, and the Pathfinder for evacuation simulation to evaluate Analyze the temperature, visibility, and smoke concentration of the building in the event of a fire to simulate the fire situation.

2. Objectives

The fire simulation in this article is to use Building Information Modeling, (BIM) tool software Revit to create a model, with fire dynamics simulation software Fire Dynamics Simulator (FDS), FDS graphical user interface PyroSim, and Pathfinder for evacuation simulation. To evaluate and analyze the temperature, visibility, and smoke concentration of the building in the event of a fire to simulate the fire situation, simulate the second building of the Chunghua University in Hsinchu, and simulate the place where the fire source is close to the stairs, which has a greater impact on the evacuation of escaped personnel. And then through the fire simulation and personnel evacuation simulation to understand the degree of fire hazard and personnel escape and evacuation situation and safety. Discuss that the building information model can be combined with fire simulation software to analyze the hazard factors caused by fire. These are important factors that cause

people to reduce their escape time when escaping from a fire. Finally, methods to solve these problems are proposed to reduce fire hazards.

3. Analysis

In the event of a fire, the escaping personnel will have a certain tolerance limit. The New Zealand Design Guide (Fire Engineering Design Guide) and NFPA130 [Michael Spearpoint, 2008] [National Fire Protection Association, 2000] can be used to evaluate the temperature and carbon monoxide concentration. And the limit value of visibility.

Table 1: Endurance limits for human

	Heat convection	CO	Visibility
Limits	＜60℃	＜1400ppm	＞10m
Time	＜30 min.	＜30 min.	＜30 min.

PyroSim is applied in this phase to simulate the fire and smoke developed in the building. It provides 2D and 3D interfaces for modeling, which can rotate, displace, and measuring length. PyroSim also integrates the functions of FDS and Smokeview, which calculations are executed with FDS module by PyroSim, and the results are displayed in Smokeview module by PyroSim. When simulating a fire condition, one of the input parameters are grid size. Very dense grid results in a longer calculation time, and the larger grid size may cause the simulation to be less accurate. Therefore, the simulated buildings was divided into appropriate grids by many trial runs in advance, it took both the simulation time and proper grid division into consideration, which concludes that the optimized grid size in this research was divided into 0.3m x 0.3m x 0.3m. The original building model is generated by BIM software Revit as shown in Fig.1, and then transformed into PyroSim and is modified and divided as shown in Fig. 2.

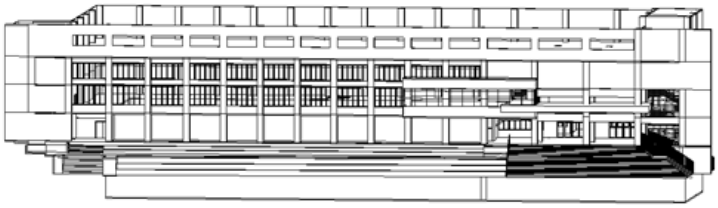

Fig. 1: BIM modeling by Revit.

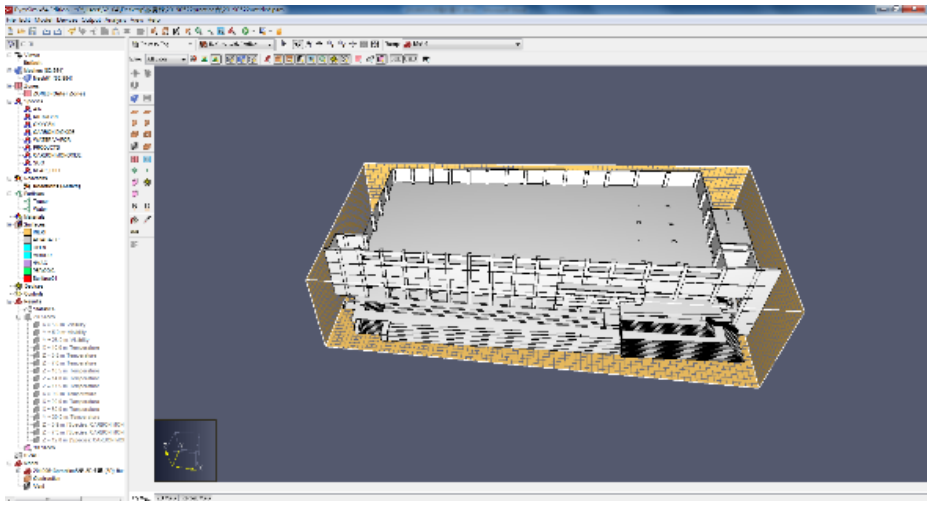

Fig. 2: Fire simulation model for FDS.

The starting temperature is set at 25°C at room temperature. Fire location is set at the first floor as shown in Fig.1, with fire source sized as 90cm length, 120cm width, and 100cm height. Material of fire source is wood, and simulation time is set as 900 seconds. Figure 3 shows the location of the ignition source.

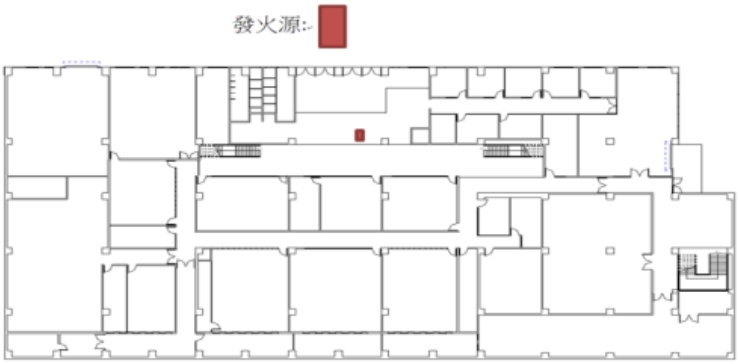

Fig. 3: Fire source location at the first floor.

The examples of analysis results are shown as follows: The carbon monoxide concentration at 900 seconds was 0.65 ppm, which did not meet the risk limit as shown in Figure 4. In terms of visibility, the risk limit is reached at 138 seconds as shown in Figure 5. And in terms of temperature distribution, the risk limit is reached at 111 seconds as shown in Figure 6.

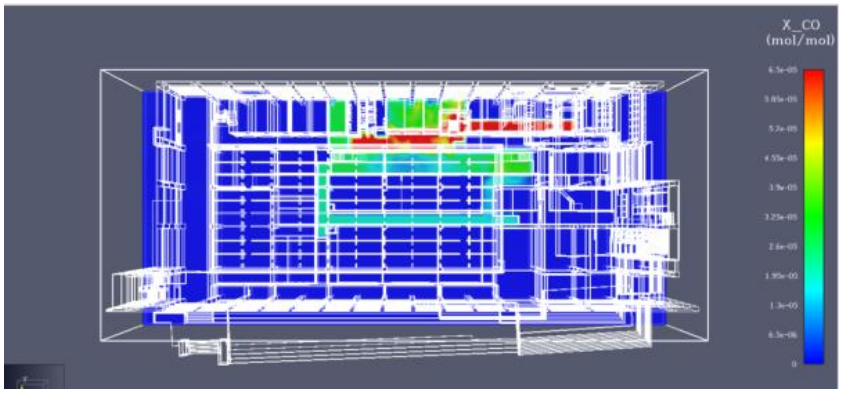

Fig. 4: CO concentration distribution at 900 sec.

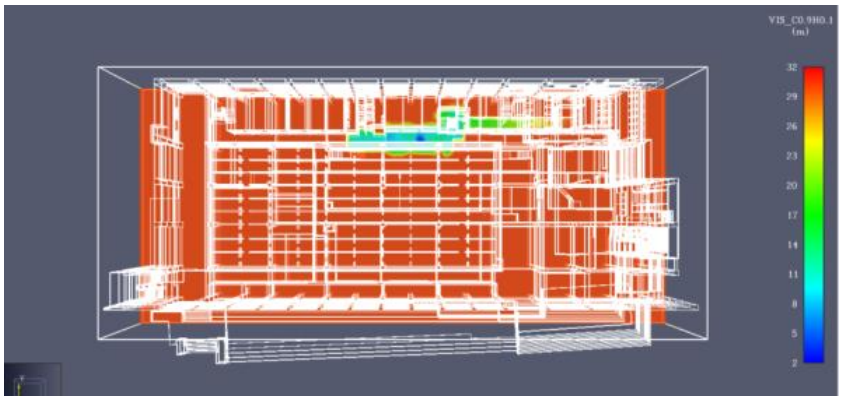
Fig. 5: Visibility at 138 sec.

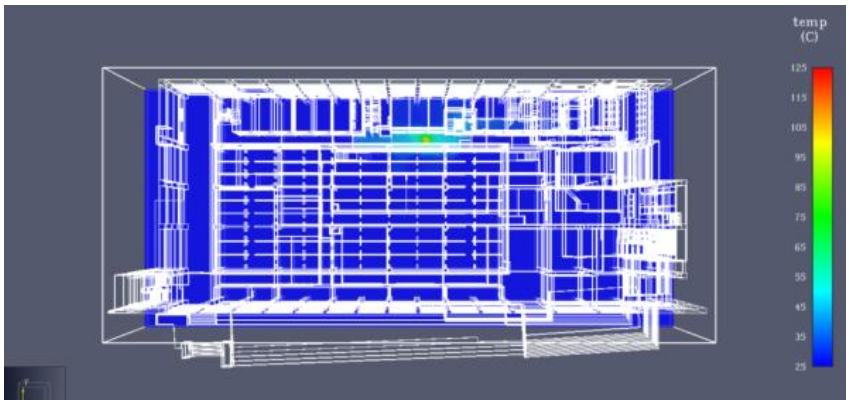

Fig. 6: Temperature distribution at 111 sec.

As for the 2nd floor, regarding the concentration of carbon monoxide, it did not reach the risk limit at 900 seconds as shown in Figure 7. In terms of visibility, at 222 seconds, the visibility has reached the risk limit of less than 10 meters as shown in Figure 8. And in terms of temperature, the temperature has also reached the risk limit of 60 degrees°C at the 226 seconds, as shown in Figure 9. The results of personnel escape simulated by Pathfinder is shown in Fig. 10 for example.

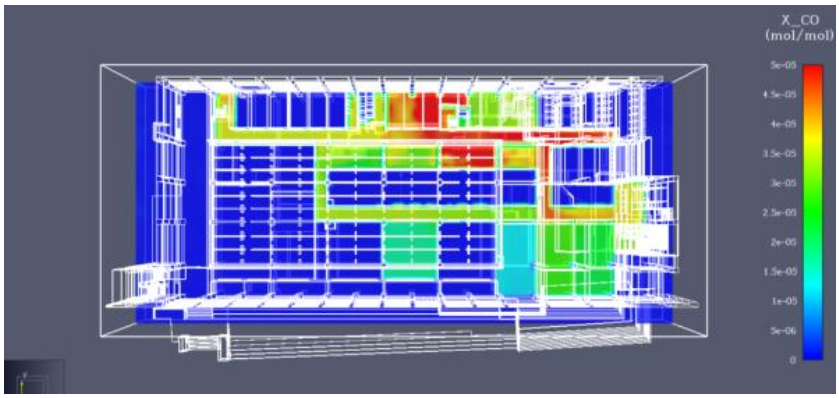

Fig. 7: CO concentration distribution at 900 sec.

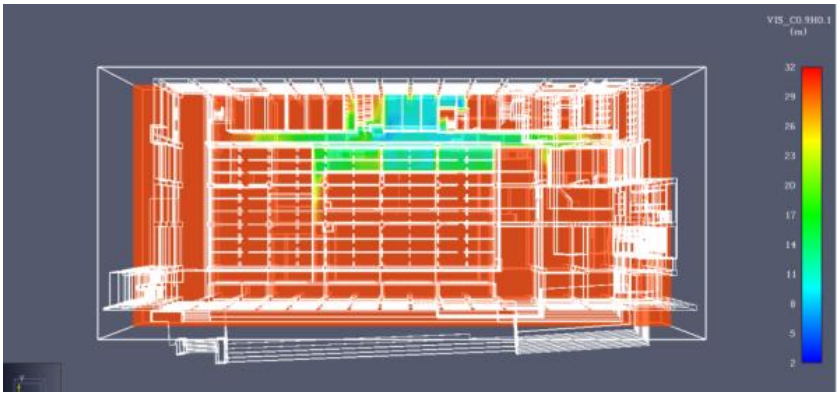

Fig. 8: Visibility at 222 sec.

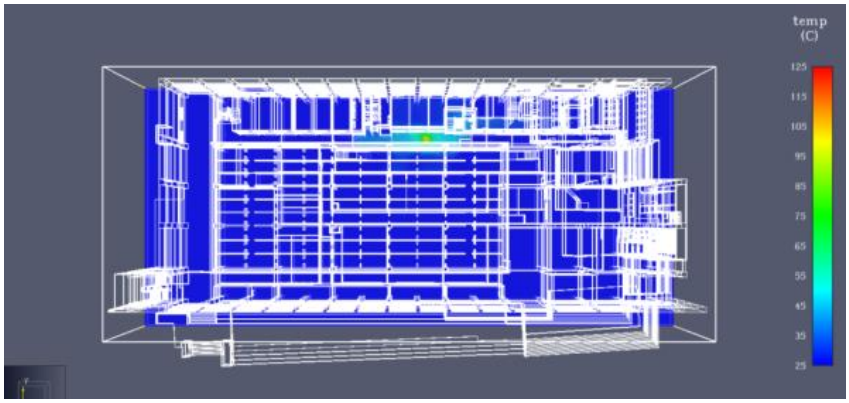

Fig. 9: Temperature distribution at 226 sec.

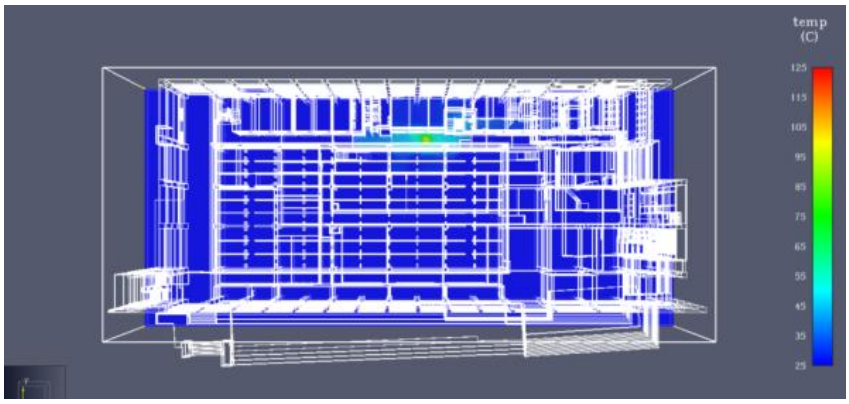

Fig. 10: Temperature distribution at 111 sec.

Pathfinder was applied in the second phase followed to simulate the evacuation of personnel in the building. Required parameters were set, and the evacuation time of personnel escaped were obtained as output for the safety assessment were analyzed. With these simulations and evaluations, we sort out and analyze whether there is a fire endanger, and try to propose corresponding solutions. The exits on each floor were set and taking 3rd floor for example as shown in Fig. 11. One of the personnel evacuation during fire and smoke developing is as shown in Fig. 12.

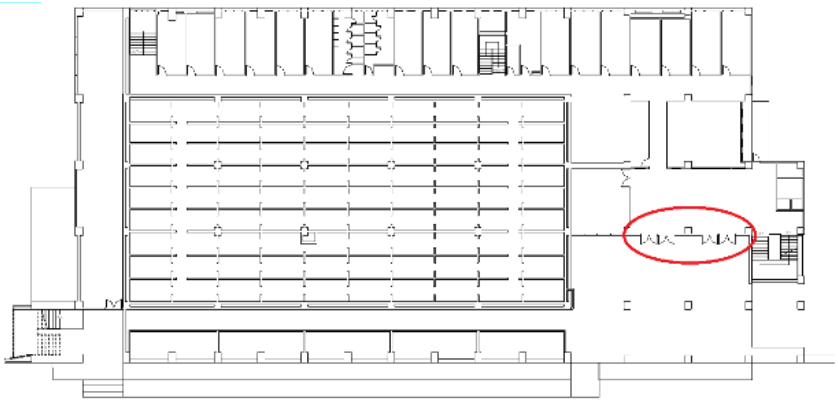
Fig. 11: The exit location set on 3rd floor.

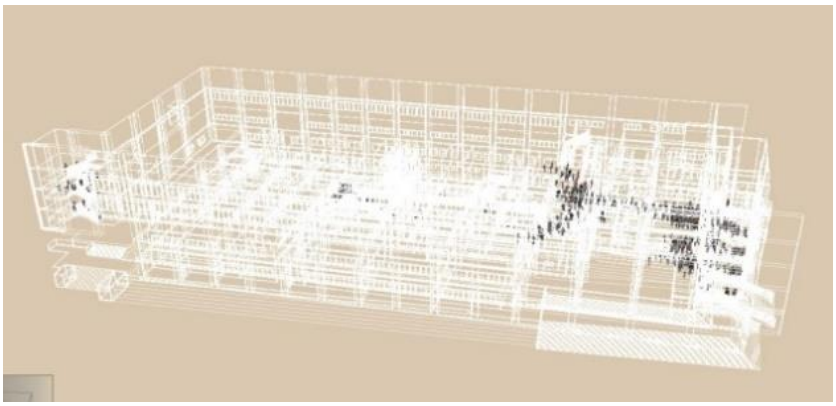
Fig. 12: Fire simulation model for FDS.

4. Conclusion

The evacuation completion time TREST should be less than the available evacuation time TASET, which is set as the criterion for the analysis of safe evacuation. If the evacuation completion time TREST is longer than the evacuation available time TASET, then it must be improved to meet the criterion for safety assessment. The criterion and parameters integrated is defined as follow:

$$T_{ASET} > T_{REST}$$

Where T_{REST}: Evacuation completion time (sec)
T_{ASET}: Available time for safe evacuation (sec)
T_{REST} is integrated by the following formula:

$$T_{REST}=TA+TR+TM$$

Where TA is the alarm time (sec)
TR is the response time (sec)
TM Evacuation walking time(sec)

With each period of time derived and integrated, by matching the evacuation completion time and the evacuation available time, it is calculated and determined whether safety evacuation was achieved or not, for each floors and for the endurance limits been assessed. The brief results is as shown in Table 2.

Table 2: Assessment combined with two simulation phases

Floors	Endurance limits	$T_{ASET(sec)}$ *	$T_{RSET(sec)}$ *	Check
1st	Temperature	900	291	OK
1st	Visibility	900	291	OK
1st	CO	900	291	OK
2nd	Temperature	900	254	OK
2nd	Visibility	900	254	OK
2nd	CO	900	254	OK
3rd	Temperature	130	569	Not OK
3rd	Visibility	134	569	Not OK
3rd	CO	900	569	OK
4th	Temperature	900	513	OK
4th	Visibility	900	513	OK
4th	CO	900	513	OK
5th	Temperature	900	221	OK
5th	Visibility	260	221	OK
5th	CO	900	221	OK

* T_{ASET}:allowable time for evacuation, T_{REST}: time of evacuation

In the fire simulation, the temperature and visibility on the first floor did not meet the specifications, while other analysis results on the first and second floors were in compliance with the specifications. The non-compliant parts may cause unbearable harm to the personnel.

In the simulation, when people are evacuated to the same location such as stairs, it will cause congestion. When multiple people are evacuated at the same time, the evacuation time will increase.

Different positions of the fire source will cause different danger thresholds. The fire condition of each floor of the building would be different, some floors have more serious fire hazards, and other floors are less. The time when the fire

hazard on each floor reaches an unbearable level is also different for each floor. Some floors reach an unbearable level sooner, and some floors arrive more slowly.

By using FDS to simulate the fire situation and combined with the evacuation simulation Pathfinder, it is possible to assess and understand the situation encountered by each floor of the building in the fire scene.

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