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Study on Fire Simulation in College Dormitories Based on Pyrosim

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Abstract

In recent years, the frequency of fires in college dormitories has been increasing, primarily due to outdated electrical wiring and improper use of electrical appliances. Given the high population density in such buildings, fires can cause significant damage to life and property. To better understand the dynamics of dormitory fires, this study uses Pyrosim fire simulation software to model fire scenarios in a six-story male dormitory. The study focuses on analyzing key factors such as heat release rates, smoke spread, temperature changes, and carbon monoxide concentrations during a fire. Simulation results indicate that smoke spreads rapidly after a fire breaks out, significantly reducing visibility and hindering evacuation efforts. Simultaneously, temperatures near the fire source rise quickly, exceeding safe levels, and carbon monoxide concentrations reach dangerous thresholds in a short time, greatly increasing the risk of poisoning. Based on these findings, the study proposes several recommendations to improve fire prevention in dormitories, including installing smoke barriers, improving evacuation routes, adding mechanical smoke extraction systems, and enhancing students' fire safety awareness and skills through regular training. These measures are crucial for reducing fire risks and enhancing fire safety in college dormitories.

Key Words: *College Dormitory , Fire Simulation,Pyrosim, Smoke Spread, Temperature Analysis.*

1. INTRODUCTION

In recent years, fires in student dormitories have become increasingly common, with hundreds of incidents occurring annually. Electrical equipment is one of the main factors causing these fires. Many dormitory buildings were constructed decades ago, and their wiring has aged, falling short of current safety standards. Additionally, dormitories often contain devices like power strips and kettles, which can easily cause fires if not handled carefully. The winter and spring seasons see a high incidence of fires, primarily due to electrical issues. College dormitories are densely populated, and any fire incident can result in significant damage to students' lives and property, as well as negative social impacts. Therefore, it's crucial to consider various

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safety factors in the event of a fire.

Extensive research has been conducted by scholars domestically and internationally on dormitory fires. Researchers have created physical models to simulate the fire process, but this approach is costly, difficult to replicate, and not very precise. The advent of computer numerical simulation technology has greatly improved these issues. Utilizing the powerful computing and imaging capabilities of computers, fire simulations can be effectively conducted under different conditions using finite element or finite volume analysis methods. Long Xinfeng et al. [1] used Pyrosim to study smoke spread in a six-story dormitory with doors and windows fully open and with the window in the fire room closed and the door open. Zou Xinjie et al. [2] studied the impact of the failure of an automatic sprinkler system on smoke flow using Pyrosim, finding that smoke concentration, temperature, and visibility improved significantly with the sprinkler system on. Wang Li et al. [3] assessed the evacuation capability of a six-story dormitory building using FDS+EVAC, suggesting improvements like increasing exit width and reducing population density. Teeranon Saelao et al. [4] studied the impact of escape exit size and the presence of smoke screens on building evacuation using FDS, concluding that increasing door sizes and adding smoke screens significantly reduced evacuation time.

Pyrosim, developed by the National Institute of Standards and Technology (NIST), is a fire dynamics simulation software widely used for studying fire development and smoke movement [5]. It supports importing models in formats like FDS and DFX, allowing users to create their own models, set boundary conditions, fire sources, ignition points, and combustion materials to study smoke flow patterns under different conditions. The simulation results can be processed post-simulation, and the entire fire development and smoke movement process can be observed in the visualization program Smokeview. This study uses Pyrosim to construct a model of a college dormitory, set fire scenarios, simulate, and analyze heat release rates and smoke spread near the fire source, providing a clearer understanding of college dormitory fires and offering more concrete references for safety education and evacuation drills.

2. MAIN TEXT

2.1 Research Model

College Dormitory, 6-Story Building Set the heat release rate to 1000kW/㎡. The grid cell size is set to 1.0m x 1.0m x 1.0m, with a total of 123,165 grid cells. Multiple thermocouple detectors are installed inside the dormitory to monitor smoke visibility, temperature, and the diffusion of gases such as carbon monoxide, carbon dioxide, and oxygen. Simulation Results and Analysis: Analysis of smoke visibility, temperature, and the diffusion of gases such as carbon monoxide, carbon dioxide, and oxygen. Conclusion. The model is shown in Figure 1.

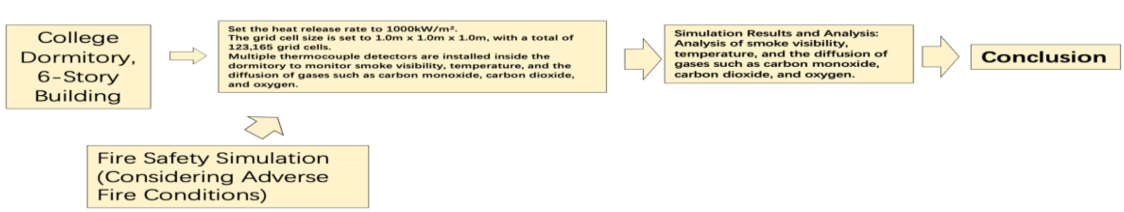

Figure 1: Research Model

2.2 Building Overview

The subject of this study is a six-story male dormitory in a college, with 28 rooms on the first floor and 29 rooms on each of the other floors. Each room measures 8m by 4m, with a floor height of 3m, accommodating 4 people per room. Each floor has three emergency exits, and the staircase width is 1.8m (Figure 2). The dormitory was built in the 1980s-90s, with long-used electrical wiring, plumbing, furniture, and beds. The dormitory lacks smoke exhaust systems, fire alarms, and automatic sprinkler systems.

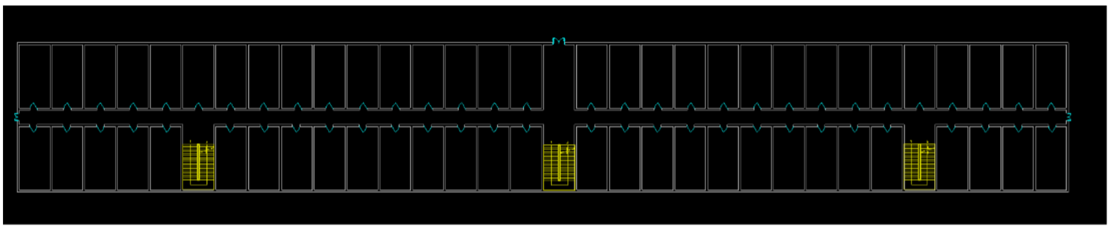

Figure 2: Building Overview

3. FIRE SIMULATION PARAMETER SETTINGS

3.1 Fire Scenario Settings

The fire type is set as a fast-developing fire with a heat release rate of 1000kW/m². The dormitory building's simulation grid consists of 123,165 grid cells, each measuring 1.0m x 1.0m x 1.0m. The fire source is placed in a room on the first floor, simulating an electrical fire. Multiple thermocouple detectors are installed inside the dormitory to monitor smoke visibility, temperature, and the diffusion of gases such as CO, CO2, and O2 (Table 1).

Table 1: Scenarios Settings

Technical Parameters	Value
Grid Count	123,165
Heat Release Rate	1000kW/m²
Combustion Materials	Polyurethane series
Ambient Temperature	25°C
Simulation Time	300 seconds

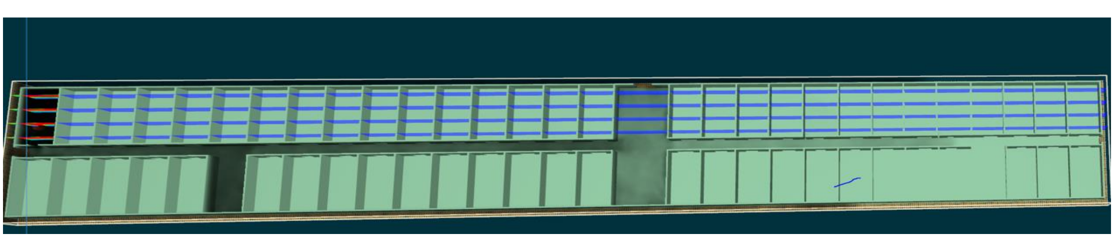

Figure 3: 3D Model

4. ANALYSIS OF SIMULATION RESULTS

4.1 Smoke Spread Analysis

Fires often produce large amounts of toxic black smoke, which can settle if not promptly exhausted, rapidly reducing visibility inside buildings and obstructing evacuation. In this study, a fire is set in a room on the first floor, with smoke spreading rapidly inside the room and visibility dropping sharply in a short time. By 90 seconds, black smoke has spread to adjacent rooms, while visibility in areas other than near the fire source remains good. By 180 seconds, smoke has spread to all rooms on the first floor, with significant visibility reduction, and some smoke is exhausted outside through open windows. By 280 seconds, the smoke spread speed decreases, the smoke layer begins to descend, and more smoke is exhausted through the windows.

4.2 Visibility Analysis

Visibility is a critical indicator of fire development. Smoke contains a large number of solid or liquid susp ended particles that absorb, reflect, and refract visible light, greatly affecting indoor visibility. According to t he Australian "Guide for Fire Engineers," visibility below 5m at a height of 2m in a building affects evacuati on [6]. After ignition, smoke flows along the central corridor to both sides, initially not affecting most rooms. By 74 seconds, smoke has reduced visibility in the entire corridor to below 5m, starting to affect the stairwel l, reaching a critical value for evacuation. By 180 seconds, visibility in the entire first floor falls below 5m (F igure 4), likely causing congestion, panic, or even stampede incidents during evacuation.

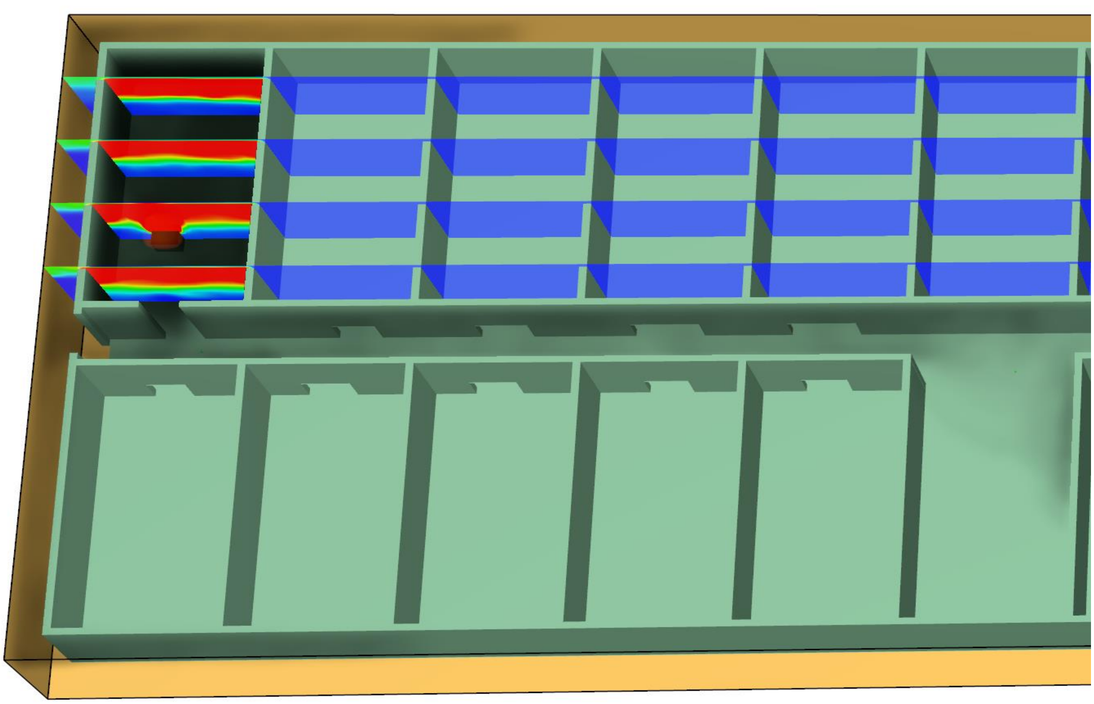

Figure 4

4.3 Temperature Analysis

Humans cannot endure environments exceeding 80°C for more than an hour. This study sets 80°C as the critical tolerance value. The temperature change process is shown in Figure 5. By 100 seconds, the fire has not fully spread, with the environment outside the immediate vicinity of the fire source remaining at 25°C, while temperatures around the fire source rise above 200°C. The corridor opposite the fire source accumulates hot smoke, reaching 620°C. By 200 seconds, more rooms are filled with high-temperature smoke, lowering temperatures in the central corridor. By 300 seconds, the temperature in the left area of the first floor stabilizes around 300°C, with the high-temperature area expanding further. The temperature in the central and right stairwells remains unchanged, having little impact on evacuation.

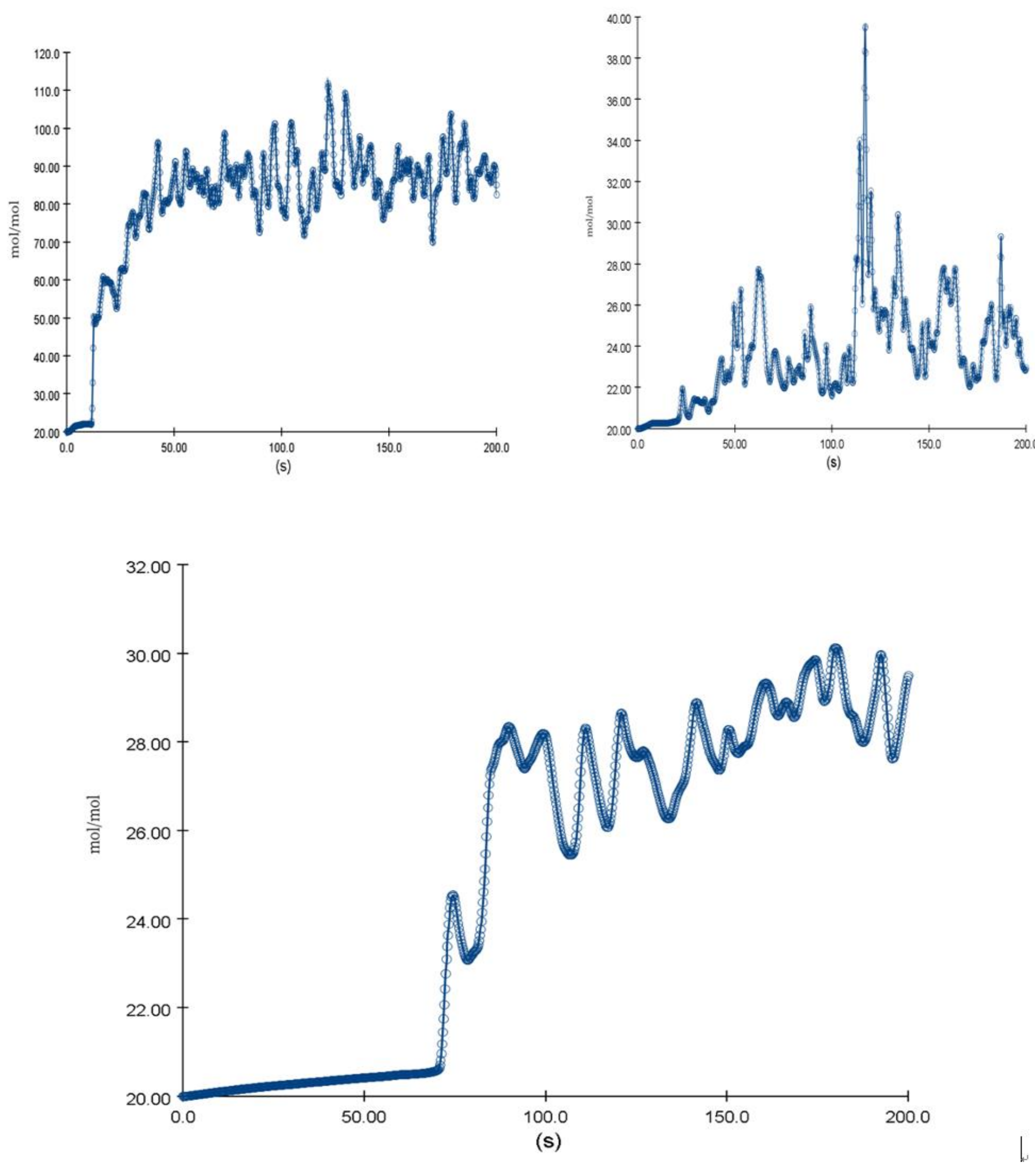

Figure 5

4.4 CO Concentration Analysis

Among the gases produced by fire, carbon monoxide (CO) is the most dangerously toxic [7]. When inhaled, CO binds with hemoglobin in the blood to form carboxyhemoglobin, impairing oxygen transport and causing organ hypoxia and poisoning. This study sets the dangerous concentration at 1*10-3mol/mol. CO concentration changes are shown in Figure 4. The CO concentration in the fire room rapidly rises to a dangerous level within 10 seconds, posing a life-threatening risk to anyone not evacuated in time, with peak concentrations nearing 6*10-3mol/mol and stabilizing around 5*10-3mol/mol after 120 seconds. By 160 seconds, the concentration in the central stairwell reaches 1*10-3mol/mol, posing a significant threat to anyone not yet evacuated. The CO concentration in the right stairwell remains below 1*10-3mol/mol throughout the simulation, within safe limits.

5. DISCUSSION

Dormitories, being crucial for students' daily living and rest, require heightened fire safety measures. Based on the numerical simulation results, the dormitory does not meet evacuation safety standards. Improvements should include enhanced fire facilities, increased fire awareness, and better student management. Specific recommendations include:

1. Adding smoke barriers to the dormitory ceilings to effectively prevent smoke flow along the ceiling and enhance smoke extraction in each zone, limiting fire spread.

2. Installing fire shutters at evacuation stairwells to be closed after evacuation, preventing smoke from spreading to safe evacuation routes.

3. Incorporating smoke exhaust ducts and mechanical smoke extraction equipment to quickly remove toxic smoke, creating a negative pressure environment conducive to safe evacuation.

4. Increasing students' fire safety awareness and self-rescue capabilities through regular fire drills, cultivating firefighting skills, and enhancing fire management by prohibiting the use of high-power electrical appliances in dormitories and improving fire equipment on each floor.

Proper fire management in all aspects is essential to minimizing the risk of fire incidents and providing a safe living environment for students.

6. CONCLUSION

This study utilizes Pyrosim to investigate the development and hazards of smoke in a college dormitory fire, simulating a fire caused by improper use of electrical appliances in a dormitory room on the first floor. It verifies the smoke spread without smoke control or automatic sprinkler systems, measuring temperature, visibility, and CO concentration at various points and cross-sections. The results indicate significant temperature changes near the fire source and adjacent rooms, with little impact on evacuation stairwells. Visibility in the entire first floor falls below 5m by 180 seconds, posing a significant threat to safe evacuation. CO concentration rises rapidly in the fire room, reaching dangerous levels in the central stairwell by 160 seconds, making evacuation challenging.

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