Study on the Relevance of Lightweight Steel Structures and Thermal Hazard During Fires

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Abstract. Lightweight Steel Structures with high application targets, rapid construction and low cost. However, the influence of heat radiation on the internal temperature is very large, and in order to reduce the heat conduction caused by the sun, the user often attaches a flammable heat insulating material inside. In this study, the fire simulation software FDS was used to simulate the lightweight steel structure building fire, and the research on the thermal buoyancy, heat conduction, smoke distribution and building structure collapse limit of this type of building form was calculated. The research found that the steel thermal fluctuation and the fire flashover temperature of 600 °C were achieved after 520 seconds of fire. This study provides lightweight steel structure construction based on numerical calculation results. It is recommended to set the smoke exhaust window appropriately or use fireproof materials for interior decoration to reduce the heat accumulation inside the building to prolong the time of steel thermal fluctuation and make the lightweight steel structure It is not easy to flashover (backdraft) in the building, and the steel structure is not easy to collapse. It can improve the safety factor and make the life of fire rescue personnel more secure.

1. Introduction
In view of the recent serious accidents caused by fires in lightweight steel structures in the international community. This study explores the fire case of "Bakery Store"[1] in Changhua County on April 14, 2014, this disaster caused five people to die in a fire in a lightweight steel structure, Not only aroused the attention of the public to the fire rescue of lightweight steel structures, but also burned the disaster prevention problem of lightweight steel structures.

Lightweight steel structure buildings are seriously inadequate due to structural durability and fire performance. In addition, the accumulation of smoke heat is prone to flashover, backdraft and the risk of building steel structural strength damaged and collapse. Causes people and fire rescue personnel in the building to lose their lives.

The purpose of this study is to understand the occurrence time of flashover and steel thermal desuperheating temperature in the heat distribution of lightweight steel structures, and to analyse the countermeasures to avoid the occurrence of structural durability and fire performance. The collapse of the life of the fire rescue personnel.

2. Methods
This study collects relevant literature to explore fire risk factors for lightweight steel structures. With the "Fire Dynamics Simulator" (FDS) as the case reduction, the difference between the smoke from the roof opening and the smoke flow on the floor exhaust, the improvement plan for the fire collapse damage of the steel-type iron-type building is proposed. The Fire Dynamics Simulator (FDS) [2] is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves
numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.

2.1. Research process
According to the actual building to draw of the fire case (figure 1) and situational simulation (figure 2). The fire building is a double storefront open shop, brick wall, iron sheet to build a 2-storey building.

![Figure 1. Rescue situation at the beginning of the fire.](image1)

![Figure 2. Rebuilding a fire building with FDS.](image2)

2.2. Research tool
This study used the fire simulation software (FDS). A software that uses the CFD (Computational Fluid Dynamic) method to build a fire case model and uses the mixed component combustion mode and equation to calculate the fire high temperature smoke and the heat flow field change in the building space. The direct numerical equation of DNS (Direct Numerical Simulation) can be used to describe the simulated fire dynamic behaviour driven by thermal buoyancy.

In terms of the thermal fire rate of electrical fires. Mei [4], mentioned that: FDS simulates the electric fire case caused by the short-circuit of the extension line in the betel nut booth in Kaohsiung City, in order to allow the simulated fire to generate its own heat, in order to conform to the example situation, the fire source The heat release rate per unit area is set to 1500 kW/m², and the fire is extinguished after 600 seconds. In addition, Feng [5], pointed out that in the study of fire hazard analysis, a high-voltage cable with a diameter of 12 mm of 600V is used, and the conductor is copper. The insulation layer and the outer skin were both PVC. The actual combustion test was carried out. It was observed that the maximum unit heat release rate was 422 kW/m² at 315 seconds, and the total heat release was 106 MJ/m². In addition, Monideep (2002) pointed out in the report of the International Expert Group on Cable-line Fire in Nuclear Power Plants: According to the experimental data, the distribution of the heat release rate of a cable with a length of 15m, a width of 0.6m and a thickness of 0.1m in a well-ventilated environment It is about 0.8 MW to 2 MW, and its growth characteristics follow the t-squared fire model. It takes about 10 minutes to grow to the highest pyrolysis rate. In Shen (2004) research report: set the fire source size of the cable fire to 1 MW and 2 MW, the thermal release rate parameter set HRRPUA = 222 kW / m², the fire growth time is set to 10 minutes, and then maintain the highest heat release rate of 10 minutes.

The combustion parameters of this study are based on the fire damage investigation and appraisal of Changhua County Fire Department. The fire case of this study is the mixer of the middle section of No. 589 on the 1st floor. The cause of the fire does not rule out the possibility of fire caused by electrical factors. No. 589 In the middle section of the first floor, a surface fire source is set up. In the fire cause investigation and appraisal book, the building is placed with a large number of display cabinets and commodity packaging materials. The flammable items such as wooden bed compartments and wardrobes on the 2nd floor have a large amount of fire load, and their growth. The feature also follows the t-squared fire model, which takes about 10 minutes to grow to the highest
pyrolysis rate (Shen, 2004). For the initial temperature parameter setting, refer to the Central Meteorological Administration observation data query system. At 04:45 on April 14, 2014, the temperature of the member city was 22.4°C, the humidity was 84%, the wind speed was 0.6 m/sec, and there was no rain.

3. Results

3.1. Fire simulation lightweight steel structural roof smoke and heat flow condition

Based on the field measurement data of this research case and the research reference of Chen (2014) [3], the fire simulation was carried out by FDS. A 3D graphical analysis was carried out to compare the vertical and horizontal spread of smoke.

Figure 3. Fire simulation [no opening on the roof] Heavy smoke spread.

Figure 5. Fire simulation [floor opening] smoke exhaust situation.

Figure 4. Fire simulation [opening on the roof] Heavy smoke spread.

Figure 6. Flow chart of fire-fighting reaction intervention in the fire.

Lightweight steel structural polyol depending on the use, upholstery, bedding, and other items plurality bedroom fire load of greater, a large amount of smoke after the fire, due to poor adaptation metal buildings, good air circulation, quickly jumped smoke. In this study, the fire of the simulated object was located in the middle of the first floor of No. 589. The fire broke through the ceiling at 259 seconds, and the heat began to accumulate under the iron roof. The fire was filled under the iron roof in 280 seconds; the 282 seconds of fire smoke spread to 591 No. The ceiling began to burn through and the smoke was filled under the roof of the entire iron building in 301 seconds.

The results of this study show that the ceiling of No. 589 is burned to the heat of the 599, which is only 23 seconds. The time below the roof of the iron roof is full of smoke for 42 seconds.

3.2. Changes in sheet metal structure after fire-fighting intervention

From the beginning of the fire until it is extinguished, the entire continuous process is displayed in time-distance mode, as shown in figure 6.
3.3. Analysis of roof temperature of lightweight steel structure

According to Zhuang (2004), the behaviour of steel structures under normal temperature and high temperature is affected by their mechanical properties, such as the yield strength, the modulus of elasticity, which will decrease as the temperature increases. This study explores the temperature of the front, middle and rear sections of the sheet metal roof as a whole, and whether the temperature changes after the intervention of fire-fighting cause the collapse of the steel structure building and threaten the life safety of fire rescue personnel (figure 7).

Temperature after fire-fighting intervention, (1) At the detection point 2 meters next to the road on the sheet metal roof [NO opening on the roof], the temperature reached 595°C at 446 seconds, the temperature reached 603°C at 451 seconds. The detection point 7.5 meters next to the road at 446 seconds, the temperature reached 559°C, the temperature reached 627°C in 569 seconds. The detection point 12 meters next to the road reached 564°C in 538 seconds and 609°C in 625 seconds.

3.4. Comparison of fire-fighting intervention time to flashover time

Based on the study of the dangers of flashover and backdraft to firefighters (Su, 2007) [6], from the moment of fire to the moment when the fire is extinguished, this is a question of time series. The following is a discussion of the experimental dimensions of each scholar and the heat flux and temperature at the time of flash fire:

According to NFPA265-2007, the following five items are provided as indicators of flashover. Conforms to the two to be possible to determine the flashover occurrence:

1. Heat release rate is greater than 1MW
2. The heat flux of the floor surface reaches 20kW/m²
3. The temperature of the hot smoke layer above the space is above 600°C
4. The fire has been burned to the emergency entrance
5. The inflammable in the space reaches the lower limit of autoignition.

Time-temperature curve diagram of the sheet metal roof after fire-fighting intervention (figure 7). At the temperature of "No opening on the roof", the roof temperature exceeds the flashover condition of 600°C. According to Chen (2014) [3], etc. The research on the steel skeleton structure of steel structural members up to 538°C above the heat resistance, the steel reinforce is easy to be hot bending, the entire sheet metal house will be unstable due to the center of gravity, lost balance and collapse.

4. Conclusion

The main reason is that in the simulation of lightweight steel structure building fires, the distribution of smoke heat is the main point of analysis for the flashover temperature and the temperature of the steel thermal declination temperature. The safety time of personnel and buildings is shown in figure 8:

1. According to the fire investigation data, in the situation no opening on the roof of the original case, the temperature of the sheet metal roof "2 meters next to the road" reaches 603°C at 451 seconds, and the temperature of "7.5 meters next to the road " reaches 606°C at 568 seconds. "12 meters next to the road " reached 609°C at 625 seconds.
2. Simulate fire safety equipment on each floor to set the Smoke Vent. After the fire-fighting intervention, the temperature of the sheet metal roof is about 400°C. The structure of the lightweight steel is relatively stable and not easy to collapse, but if the firefighters arrive at the scene of the fire. After more than 510 seconds, the temperature of the iron sheet began to rise, and the strength of the steel structure began to be challenged by high temperatures, posing a risk of collapse.

![Figure 8. Temperature curve diagram and flashover temperature of each module roof.](image)

The situation temperature of "no opening on the roof" is higher than the other two scenarios. Repeatedly exceeding the flash point of 600°C and the steel softening temperature of 538°C, the impact on the lightweight steel structure is the most serious, easily lead to collapse of buildings, endangering the safety of fire rescue personnel. The decorate, the packaging materials of the products and the large space high-capacity machines placed in the studio space cause high fire load in the building and high use of fire to form a highly dangerous place. In order to improve the fire safety of buildings, firewalls, fireproof floor and fireproof windows and door should be used to divide the partitions, and the basic fire compartment should be used to reduce the burning speed of the fire.

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