REPORT ON A RECENT FIRE IN A NEW CURTAIN-WALLED BUILDING IN DOWNTOWN DALIAN

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ABSTRACT

This is a short note on reporting a fire in a curtain-walled building complex in a developed city of China. The fire was briefly described with photographs taken at the burning site. Combustibles stored in the building were estimated by empirical equations by considering the geometry and ventilation factors.

1. INTRODUCTION

A big fire broke out at the construction site of a 12-storey multi-purpose building, i.e. the Dalian Kaixuan Plaza in downtown Dalian on September 18, 2005 at about 11:30 a.m. The fire was observed by the two authors after a business tour. It is worthwhile to report on the fire and estimate the possible fire environment by simple empirical equations.

Dalian is a big city in the coastal area of the northeast Liaoning Province of China as in Fig. 1. The building concerned is 60 m tall with ten levels above ground and two levels underground. It is a glass curtain-walled building complex for shopping mall, offices and residence. The height of each storey is about 6 m. The main structure and the external glass façade have been completed. Part of the external decoration was still under construction. Piles of decorating materials were stored inside the building.

2. THE FIRE

The fire was suspected to start from welding activities, igniting the combustibles piled at the top level, as reported in the news [1]. Heavy black smoke was observed throughout the city. Flames came out from windows in the top five storeys. Many burning materials dropped from the external wall with flame. The fire 'spread' down to the fifth storey from the top within 20 minutes. A sequence of the pictures taken by the authors is shown in Fig. 2.

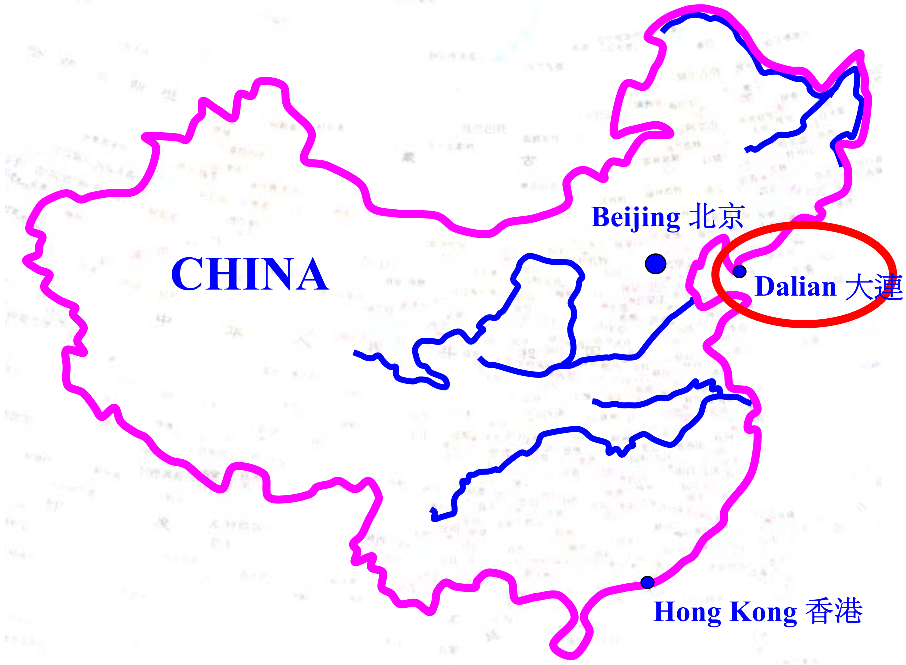
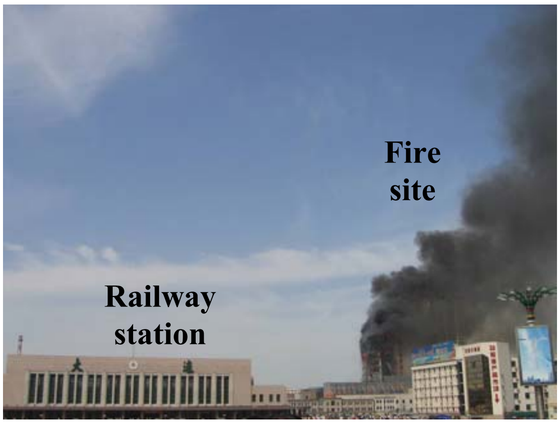
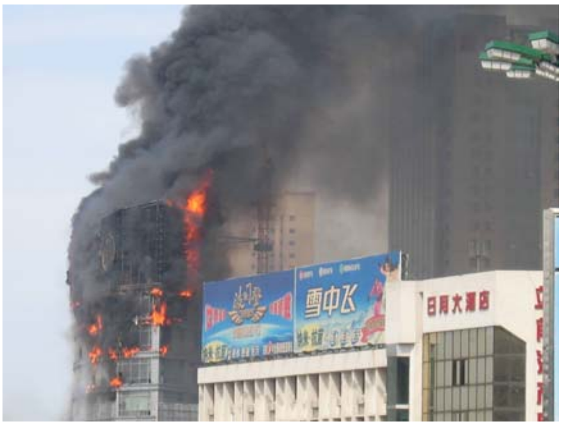


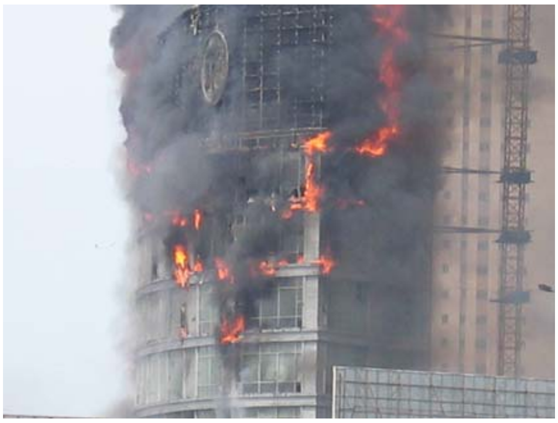
Fig. 1: Location of Dalian



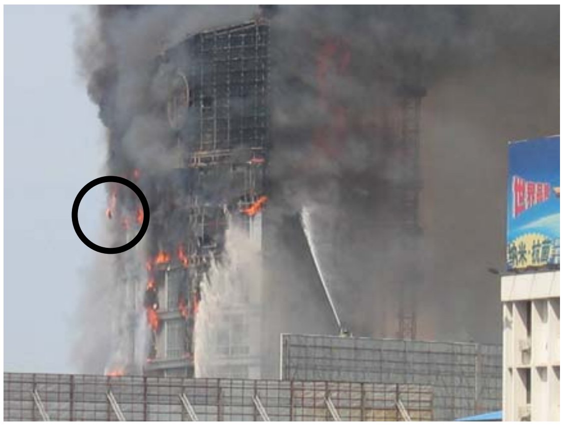
(a) Building next to a Railway station



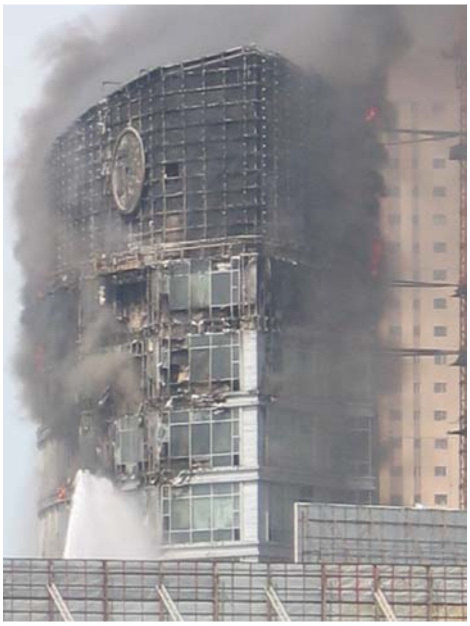
(b) Zoomed-up view



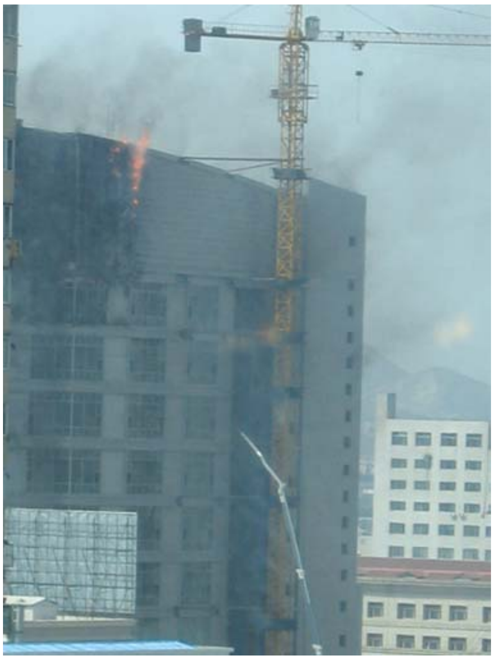
(c) Fire broken out



(d) Burning object fell down



(e) Almost controlled



(f) Controlled

Fig. 2: Big fire in a commercial building in Dalian

Five minutes after the fire had started, firemen arrived at the site with over 10 fire engines. They were blocked by the fencing walls as the building was still under construction. Fire ladder could only set up to reach the eighth storey. Over 30 fire engines arrived later and a 70 m fire ladder was eventually set up after pulling the fencing walls down. Firemen then rushed into the building for fighting the fire inside. The fifth floor of the building wing was used to house the water gun. The fire was finally put out at about 1:00 p.m.

3. PRELIMINARY INVESTIGATION

Preliminary investigation [2] was reported on the following day. The fire might be started from electric welding. Piles of decorative materials were ignited afterward. Those decorative materials were mainly aluminum composite boards. The metal surface decoration was not combustible. However, the core combustible material inside was exposed to the fire by the holes drilled at the surface. The core material was ignited by electric spark and involved in burning.

Almost all the decorative combustible materials were burnt eventually to give a very vigorous fire. Damages were still unknown, though the exterior decoration of the building was burnt out. Rough estimation reported in the news gave a loss of at least 0.4 million RMB. The structure itself had not yet been inspected for possible damages.

4. ESTIMATION OF THE FIRE LOAD DENSITY

The fire was fully developed at the upper levels (level 10) and lower levels (level 5). The burning duration was about 90 minutes. A point of major concern is the amount of combustibles (or fire load density) inside the building. For example, an upper limit of fire load density of 1,135 MJm^{-2} was imposed in places like Hong Kong [3].

For burning hydrocarbon polymers $C_xH_yO_z$, a balanced chemical equation for the combustion with air can be written as [4]:

$$C_xH_yO_z + wO_2 + w\left(\frac{79}{21}\right)N_2 \rightarrow xO_2 + \frac{y}{2}H_2O + w\left(\frac{79}{21}\right)N_2 \quad (1)$$

The value w is given by:

$$w = \frac{2x + \frac{y}{2} - z}{2} \quad (2)$$

Burning 1 kg of fuel completely would require r kg of air with r given by:

$$r = \frac{(w + 3.76w)28.97}{12.01x + 1.00y + 16.00z} \quad (3)$$

For common polymers like polymethyl methacrylate $C_5H_8O_2$, polycarbonate $C_{16}H_{14}O_3$, polyethylene C_2H_4, polypropylene C_3H_6, and polystyrene C_8H_8, the values of r for burning per kg of fuel would be 8.27 kg air, 9.77 kg air, 14.76 kg air, 14.76 kg air, and 13.25 kg air respectively.

The air intake rate m_a (in kgs^{-1}) was found to be proportional to the ventilation factor of the opening $A_v\sqrt{h}$, where A_v is the surface area of ventilation (in m^2), A_T is the total area of wall (in m^2), and h is height of the opening (in m) (e.g., Fire Protection Engineering Handbook [5]):

$$m_a = 0.52A_v\sqrt{h} \quad (4)$$

The amount of fuel would be burnt at a rate m_B (or m_a / r) if there is only one type of fuel.

The burning rate of wood m_B is given by the equation [e.g. 6] as r is 5.7 kg air/kg used:

$$m_B = 0.09A_v\sqrt{h} \quad (5)$$

The burning rate m_B of polymethyl methacrylate, polycarbonate, polyethylene, polypropylene and polystyrene are 0.062, 0.053, 0.035, 0.035 and 0.039 of $A_v\sqrt{h}$ respectively.

For ventilation openings with a height h of 2.5 m and an area A_v of 25 m^2 as in the above building, m_a is 21 kgs^{-1}, giving an intake air speed of 0.65 kgs^{-1} through the windows. Burning for 90 min meant that the total mass of polymethyl methacrylate, polycarbonate, polyethylene, polypropylene, and polystyrene burnt would be 13234 kg, 11313 kg, 7471 kg, 7471 kg, and 8325 kg; giving a fire load density of at least 662 MJm^{-2}, 672 MJm^{-2}, 766 MJm^{-2}, 766 MJm^{-2}, and 738 MJm^{-2}, respectively.

Another equation was reported by Raes [7] relating the possible equivalent duration of a fire t_B (in minutes) to the fire load density (FLD) (in MJm^{-2}) burnt, and the floor area A_f (in m^2):

$$t_B = \frac{0.067A_f FLD}{(A_T\, A_v\, h)^{1/2}} \quad (6)$$

This equation was derived by burning all the combustible items in the building at a known burning rate which is proportional to the ventilation factor. This equation was applied to estimate the amount of materials burnt in the building.

Taking a level of 50 m by 10 m as an example for the analysis. The floor area A_f is 500 m^2; the total wall area A_T is 600 m^2 for a ceiling height of 5 m; and the duration of fire t_B was observed to be 90 min. Putting the numerical figures into equation (6) gives:

$$FLD = 66\,(A_v * h)^{0.5} \qquad (7)$$

Suppose the broken openings were of height 2.5 m and width 10 m, the ventilation area is 25 m^2 and so $(A_v * h)^{0.5}$ becomes 7.9 $m^{3/2}$, giving an FLD of 520 MJm^{-2}. Again, this value is less than the upper limit of some codes, say 1135 MJm^{-2} as in Hong Kong [3].

Results are consistent with those predicted using equation (7). All these values of fire load density are lower than the FSD limit of 1135 MJm^{-2}.

5. CONCLUSIONS

There are also fire safety concerns on glass curtain-walled buildings. Reporting on accidental fires might be interesting to the industry. One part of this study was related to the estimation of fire load density as reported before in the big Garley Building fire [8]. Observing the duration of the fire would indicate the amount of combustible materials burnt. Whether the stored combustibles denoted by fire load density exceeded the limit of 1135 MJm^{-2} of some standards can be estimated [3].

About a month later, another fire occurred at the construction site of a residential building in Hong Kong [9,10]. The fire occurred also at the top level, and 'spread' down to the lower levels due to burning combustible objects falling down. However, the fire was no serious as the one in Dalian. A possible reason is that not much combustibles (amount not announced) were stored. This might be good for isolating the construction site and will be reported later.

ACKNOWLEDGEMENT

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