



Burning behavior of two adjacent pool fires behind a building in a cross-wind

Zhibin Chen^{a,b,*}, Kohyu Satoh^b, Jennifer Wen^a, Ran Huo^b, Longhua Hu^b

^a Centre for Fire and Explosion Studies, Faculty of Engineering, Kingston University, Friars Avenue, Roehampton Vale, London SW15 3DW, United Kingdom

^b State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, Anhui 230026, PR China

ARTICLE INFO

Article history:

Received 10 November 2008

Received in revised form

9 June 2009

Accepted 15 June 2009

Available online 4 July 2009

Keywords:

Fire swirling

Fire merging

Mass loss rate

Critical velocity

ABSTRACT

With the global move towards performance based fire design, fire safety assessment in and around buildings becomes increasingly important. However, key knowledge gaps still exist concerning the behavior of fire swirling, which may be generated if one or more accidental fires are in the passage of the vortices behind an adjacent tall building. The present study is focused on the experimental investigations of the burning behavior of two pool fires behind 1/50 scaled tall buildings with heights varying from 0.565 to 1.165 m in a cross-wind. The objective is to gain insight of the effect of the distance between the two fires (D_2), the distance between the fires and the building (D_1), wind speed (V), and the height of the scaled building (H) on the burning behavior. Important conclusions have been drawn about the influence of D_1 and D_2 on the fuel mass loss rate, the influence of D_1 on fire swirling, the influence of D_2 on the possible merging of the two fires and the effect of wind speed on the mass loss rate. The results suggested the existence of a critical velocity for the cross-wind on the initiation of fire swirling and an approximate value was identified for the conditions in the tests. The investigations also covered the effect of height of the scaled building on the fuel mass loss rate and the occurrence of fire swirling. This relationship was found to be also dependent on the wind speed. Analysis of the results has led to some important recommendations to enhance the fire protection of tall buildings.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Increasing number of tall buildings are being constructed across the world. In the event of fire, safe evacuation of occupants in and away from the immediate vicinity of such buildings is a major concern. Fire safety assessment in and around these tall buildings is of significant importance. Previous studies [1,2] in this context have addressed the issues of fire spread, smoke movement and control, evacuation of occupants, and building structural analysis against fires. One example was the recent investigations on the collapse of the World Trade Center carried out by NIST [3]. Some other studies have identified the possible formation of fire swirling, which may be generated in city fires due to the complexity of air flow patterns in the vicinity of tall buildings [4–6].

When fluid flow is disturbed by an object, a so-called Karman Vortex Street may form behind this object and propagate downstream. If a fire exists in the passage of these vortices, it may develop into fire swirling due to accelerated fire growth from the rapid entrainment of air into the combustion zone. In a dense

urban area, buildings of varying heights are often constructed with small gaps between them. If an accidental fire in one building happens to be in the passage of the vortices behind an adjacent tall building, fire swirling could develop in this process. Such fire swirling will not only intensify the burning of the original fire but may also cause secondary fire in the tall building as the elongated flame would tilt against the wind direction and towards the tall building as shown in Fig. 1. This phenomenon can lead to rapid fire spread from one building to another and escalate fire accidents in dense urban area. It is therefore of great importance to gain insight into such phenomena and devise measures to prevent and mitigate related accidents. However, few studies [7,8] have been carried out in this context. In-depth understanding about the generation and behavior of such fire swirling is still lacking. There are also knowledge gaps on the mutual influence of adjacent fires, wind condition and relative distances between the fires and buildings.

In the present study, experimental investigations have been carried out to investigate the fire behavior. The generic scenario of two pool fires behind a tall building is considered while the distances between the two pool fires and their relative distance to the building were systematically varied. In the following, the general behavior of two pool fires will be presented. Detailed analysis about the effect of key parameters, such as the distance between the two pools, wind speed, and height of the building, will also be analyzed.

* Corresponding author. Centre for Fire and Explosion Studies, Faculty of Engineering, Kingston University, Friars Avenue, Roehampton Vale, London SW15 3DW, United Kingdom.

E-mail address: baronchenzb@gmail.com (Z. Chen).

Nomenclature

$D1$	the distance between the fires and the building, m
$D2$	the distance between the two fires, m
V	wind speed, m/s
H	the height of the scaled building, m
m	total fuel mass, kg

Abbreviations

HSV	High Speed Video
FPS	Frames Per Second

2. Experiments

Experiments were conducted in the combustion wind tunnel (6 m long, 1.8 m wide, and 1.8 m high), of State Key Laboratory of Fire Science (SKLFS), University of Science and Technology of China (USTC). The ambient temperature was about 16 °C. Fresh air was blown into the wind tunnel from right to left (Fig. 2) in order to produce uniform velocity on the tunnel cross-section. The key parameters in the experiments are listed in Table 1. In each test, a 1/50 scale building (0.48 m long and 0.26 m wide) with varying heights from 0.565 to 1.165 m at 0.2 m interval was set in the upstream direction. The wind speed (V) controlled from 0 to 2.0 m/s was chosen based on Froude-number [2] to ensure that the corresponding velocity range (0–14 m/s) is of practical interest in the real scale. The gasoline fuel was contained in two square trays of size 0.1 m × 0.1 m placed at equal distance behind the scaled building and equal distance to its centerline as shown in Fig. 2. The distance between the trays' centre and the nearest rim of the scaled building, $D1$, was varied from 0.12 m or 0.24 m, while the distance between the two trays ($D2$, rim to rim) was varied from 0.15 m or 0.30 m. In Cases 1–12, the total fuel mass (m) in each tray was about 0.1 kg for the analysis of the effect of $D2$ and $D1$ on the burning behavior only, while in Cases 13–32 this was about 0.2 kg to make the duration of quasi-steady combustion be sufficient for the comparative study with concern of probably positive effect of wind speed on combustion.

A digital scale (0.01 g accuracy) was employed to measure the transient fuel masses of the two trays to estimate the fuel mass loss rates during the quasi-steady period. A High Speed Video (HSV) camera manufactured by the Photron Limited Company, offering high-speed recording from 60 to 2000 Frames Per Second (FPS), was placed outside the wind tunnel to record variations of flame structure and the fire swirling phenomena. For the protection of the HSV lens, photos were taken in the direction perpendicular to wind speed as shown in Fig. 2. In the experiments, the recording rate was set as 1000FPS. A Charge

Coupled Device (CCD) camera located inside the wind tunnel was used to record fire merging and swirling phenomena from the front view.

3. Results and discussions

Fig. 3 describes the schematic of the flow around the scaled building in the wind tunnel. Two rows of air vortices with different swirling directions (clockwise and anti-clockwise) can be generated as shown in this figure. When the two pans located on two sides behind the building are ignited, the vaporized fuel gas above the pool surface mixes with the swirling air following its spinning direction, resulting in swirling flame in the same circulation direction as the local vortices. The typical characteristic of swirling flame is its elongated shape, which is used to define whether swirling phenomena happens or not. The measured instantaneous flame shape (Fig. 4) got from Case 18, in which $D2$ and $D1$ were 0.24 and 0.15 m, respectively, the wind speed 0.5 m/s and the scaled building 0.765 m, are taken as example to display this phenomenon.

It is also seen in Fig. 4 that the two flames are showing a tendency to merge at one point. This could possibly be due to the pressure drop in the space between the two flames [9]. Note that a pool fire is sustained by entraining fresh air into the combustion zone. In the region between the two fires, the flames compete to entrain limited amount of air to sustain combustion. The air entrainment rates on the outer edges of the two pool fires are therefore much bigger than the inner sides, and this has a positive effect to push the two flames together.

3.1. General behavior of the flames

Case 18 was also chosen as an example and the HSV recordings are presented in Fig. 5 with a time interval of 0.012 s between the frames. The images in Figs. 5(a–w) are taken by the HSV camera located as shown in Fig. 2. The left pool tray corresponds to Tray2 in Fig. 4. It is seen that during the initial phase, the flame heights above the two trays are almost the same (Fig. 5a) and then the flame height above Tray2 decreases while that above Tray1 increases with time. Then, the flame height above Tray2 starts to increase after it reaches the minimum height (Fig. 5c). Further on, the flame above Tray1 starts to decrease in height (Fig. 5d) while that above Tray2 continues to increase. After a while, the flame height above Tray1 starts to increase (Fig. 5f) while that above Tray2 continues to increase. After the flame above Tray2 reaches its maximum height (Fig. 5i), its height starts to decrease while the flame above Tray1 continues to climb higher. After the flame above Tray1 reaches its maximum height (Fig. 5m), it begins to decrease in height along with the flame above Tray2. Then, after the flame above Tray2 reaches its minimum height (Fig. 5r), it begins to increase in height while the flame height above Tray1 continues to decrease. Finally, the flame heights above both trays become almost the same (Fig. 5w) again.

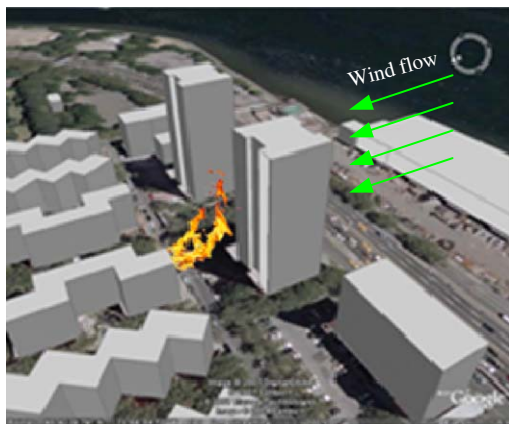


Fig. 1. Schematic of fire behavior behind a tall building in the cross-wind.

Download English Version:

<https://daneshyari.com/en/article/270289>

Download Persian Version:

<https://daneshyari.com/article/270289>

[Daneshyari.com](https://daneshyari.com)