

ANALYSIS ON THE EFFECT OF WIND ON FIREBRAND ACCUMULATION IN FRONT OF OBSTACLES

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1. INTRODUCTION

Wildfires that spread into communities, referred to as Wildland-Urban Interface (WUI) fires, have destroyed communities throughout the world. Japan does not have an issue of fires spreading from the wildlands to communities [1]. Rather, Japan experiences urban fires. Since most Japanese cities are densely populated, severe fire spread occurs within these urban areas [1].

An interesting similarity, that is a major factor in both WUI and urban fire spread, is firebrand production. When vegetation and structures burn in these fires, pieces of burning material, known as firebrands, are generated, become lofted, and are carried by the wind. This results in showers of wind-driven firebrands.

As structures are exposed to wind, stagnation planes are produced around structures. In a prior scoping study, the authors demonstrated that firebrands may accumulate in these stagnation planes [2]. This paper describes a more in depth analysis of this phenomenon. Specifically, new insights have been made possible by an improved experimental design to generate continuous wind-driven firebrand showers. While these experiments have been presented before [3], no analysis was offered to the observed results until now.

2. EXPERIMENTS

Experiments were performed by using the full-scale Continuous-Feed Firebrand Generator. The full-scale wall with varied size was placed downstream of the device and the wind speed was varied in increments of 2 m/s up to 10 m/s. Specifically, two walls with dimensions of 1.32 m (H) by 2.44 m (W), and 2.44 m (H) by 2.44 m (W) were used. Different dimensions were intentionally selected to determine the influence of the obstacle profile on potential firebrand accumulation zones. These were located at a distance of 7.5 m from the Continuous-Feed Firebrand Generator to visualize the transport process. The experiments were conducted in the Building Research Institute's Fire Research Wind Tunnel Facility (FRWTF).

For all experiments, Douglas-fir wood pieces, shown in **Fig. 2**, machined to dimensions of 7.9 mm (H) by 7.9 mm (W) by 12.7 mm (L) were used

to produce firebrands. Firebrands generated from these sized wood pieces have been shown to be commensurate to firebrand sizes measured from burning vegetation, as opposed to those quantified from burning structures (see authors second paper in these JAFSE proceedings for more information).

In all experiments, the same amount of wood pieces was fed into Dragon so that all the walls were attacked by firebrand showers for the same duration. In total, 10 minutes of feeding, which corresponds to 8 kg of wood pieces, was provided.

3. RESULTS & DISCUSSIONS

Experimental results were compared with a simple analysis on the wind effect on firebrand accumulation. In total, 8 conditions (2 configurations for 4 different wind speeds) were considered for this experimental series.

3.1. Experimental Results

Figure 1 (Left) displays images of the experiments conducted with 2.44 m (H) by 2.44 m (W) obstacle placed downstream of firebrand showers (6 m/s and 10 m/s are shown). At a wind speed of 4 m/s (not shown), the firebrands were unable to accumulate into compact zones. At 6 m/s, the most significant accumulation was observed. Little accumulation was observed at the highest wind speed used (10 m/s).

Figure 1 (Right) displays images of the experiments conducted with 1.32 m (H) by 2.44 m (W) obstacle placed downstream of firebrand showers (6 m/s and 10 m/s are shown). Similar to the experiments with the 2.44 m by 2.44 m wall, at a wind speed of 4 m/s (not shown), the firebrands were unable to accumulate into compact zones. At 6 m/s, the most significant accumulation was observed. No accumulation was observed at the highest wind speed used (10 m/s). For both obstacles, it is believed that at the highest wind speed of 10 m/s, little or no firebrand accumulation was observed due to the enhanced flow recirculation present afforded by the higher wind speeds.

3.2. Analysis

A simple analysis was performed in order

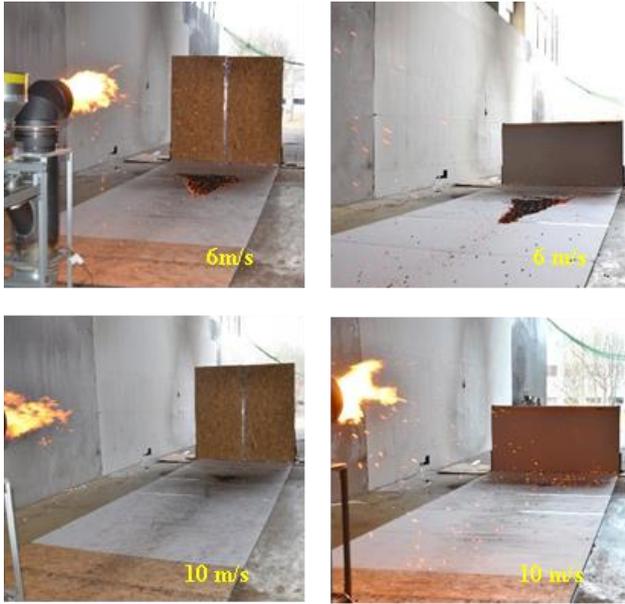


Figure 1 Firebrand accumulations. Left: 2.44 m (H) by 2.44 m (W) obstacle and Right: 1.32 m (H) by 2.44 m (W) obstacle. Top: 6 m/s and Bottom: 10 m/s

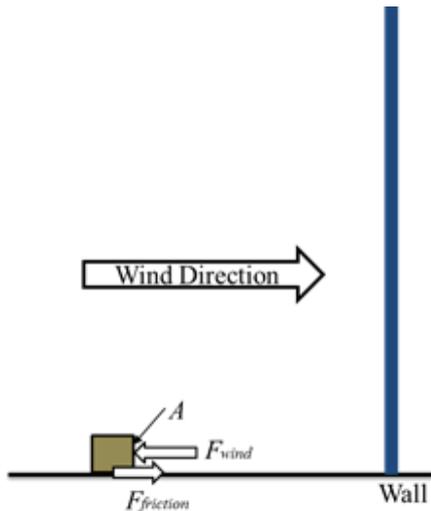


Figure 2 Schematic of force balance on a firebrand

to investigate the effect of wind on firebrand accumulation. The force by wind on a firebrand (F_{wind}) should be balanced with the friction force between the firebrand and the floor (gypsum board). ($F_{friction}$) (see **Figure 2**).

$$F_{friction} = F_{wind} \quad (1)$$

Here,

$$F_{friction} = \mu m_{firebrand} g \quad (2)$$

$$F_{wind} = \frac{1}{2} \rho_{air} v^2 \times A \quad (3)$$

Therefore, μ is the friction coefficient between gypsum board and smoldering firebrands, $m_{firebrand}$ is mass of a firebrand, ρ_{air} is the air density, g is gravitation acceleration, v is wind speed on a firebrand, and A is an area of firebrand facing a wind.

$$\mu m_{firebrand} g = \frac{1}{2} \rho_{air} v^2 \times A \quad (4)$$

There is no study on friction coefficient between gypsum board and smoldering firebrands (or any burning wood) so we assume $\mu = 0.5$ based on the friction coefficient data between wood [3]. Also, we measured $A = 0.78 \text{ cm}^2$ and $m_{firebrand} = 0.05 \text{ g}$ as the average projected area, and average mass of firebrands, respectively. Eventually v is calculated to be 2.3 m/s. A wind speed of 2.3 m/s may be considered a critical value for a firebrand to remain in front of an obstacle. As shown, for 10 m/s wind, with 1.32 m wall (H), and 2.44 m wall (H), different behaviors of firebrand accumulation were observed. The possibility of flow near the critical wind speed, for 10 m/s applied wind to these obstacles, was investigated by simulating BRI's FRWTF using FDS with a grid size of 10 cm [5].

FDS simulations (10 m/s) confirmed the experimental findings: no accumulation was observed in front of a wall of 1.32 m (H), since velocities there were higher than the critical wind speed (2.3 m/s). Accumulation was possible for 2.44 m (H) wall, since simulations showed the critical wind speed was not exceeded.

4. SUMMARY

A simple analysis was performed to investigate critical wind speed for firebrands to accumulate in the stagnation zone and the same behavior was confirmed by wind profile using FDS simulation.

5. ACKNOWLEDGEMENT

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6. REFERENCES

- [1] Manzello, S.L., Fire Saf. J., 59 (2013) 122-131.
- [2] Manzello, S.L., et al., Fire Saf J. 46(2011) 568-578.
- [3] Manzello, S.L., and Suzuki, S., Fire and Materials Conference, San Francisco, CA, 2015.
- [4] Japanese Society of Mechanical Engineers, JSME Mechanical Engineers' Handbook, Alpha2, (2004), Maruzen (in Japanese).
- [5] McGrattan K, et al., (2013) Fire dynamics simulator 6, Technical Note.