Investigating Firebrand Accumulation over Various Scales

SUZUKI, Sayaka[1*], MANZELLO, Samuel, L.[2]

[1] *National Research Institute of Fire and Disaster, 4-35-3 Jindaiji-higashimachi, Chofu, Tokyo, 182-8508, Japan*
[2] *National Institute of Standards and Technology, 100 Breau Dr. Gaithersburg, MD, 20899, USA*

Abstract : As structures are exposed to wind, stagnation planes are produced around structures. Using full-scale experiments, the authors demonstrated that firebrands may accumulate in these stagnation planes. In a subsequent full-scale study performed by the authors that made use of firebrand showers of longer duration, experiments revealed that wind speed influences not only the spatial location and extent of the accumulated firebrands in the stagnation plane in front of the obstacle, but also the nature of the smoldering combustion intensity of the accumulated firebrands. All of the prior work was limited to firebrand distributions similar to burning vegetation conducted using full-scale experimental facilities. Here, the firebrand distributions were varied to simulate *both* burning structures and vegetation, and conducted using reduced-scale experimental facilities to determine if simpler experiments may provide insights into this complex problem.

Keywords : Firebrand, Accumulation, Large Outdoor Fires, WUI Fires

1. Introduction

Wildfires that spread into communities, referred to as Wildland-Urban Interface (WUI) fires, are a dilemma throughout the world. Japan has experienced large urban fires after strong earthquakes, such as 1997 Hanshin-Awaji Earthquake. When earthquakes hit densely-populated urban areas, the resulting urban fires are difficult to cope with.

A major factor in both WUI and urban fire spread, is firebrand production [1]. When 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. These spot fires overwhelm firefighting resources after such earthquakes [1].

In Japan, several city fire spread models were developed for damage estimation. These models were based on the past city fire damages and use empirical formula under limited situations [2]. There is a lack of scientific and reliable data needed to advance such models further; especially for firebrand accumulation.

As structures are exposed to wind, stagnation planes are produced around structures. The authors demonstrated that firebrands may accumulate in these stagnation planes [3]. In a subsequent study performed by the authors [4], a series of full-scale experiments revealed that wind speed influences not only the spatial location and extent of the accumulated firebrands in the stagnation plane in front of the obstacle, but also the nature of the smoldering combustion intensity of the accumulated firebrands. This paper describes an in depth study of this phenomenon at reduced-scale to determine if useful insights may be obtained from simpler experiments. The firebrand distributions were varied to simulate *both* burning structures and vegetation, as prior studies were focused on vegetative firebrands [3-4].

2. Experimental Descriptions

A reduced-scale continuous firebrand generator was used to generate firebrand showers (Fig. 1) Details of this facility were presented in this conference last year [5]. The following experimental description follows the facility closely.

The reduced-scale continuous-feed firebrand generator consisted of two parts; the main body and continuous feeding component. The capability of a smaller-sized firebrand generator to develop continuous firebrand showers has been described [5]. Japanese Cypress wood chips and Douglas-fir wood pieces were used to produce firebrands. The Japanese Cypress wood chips had dimensions of 28 mm ±7.5 mm (L) by18 mm ± 6.3 mm (W) by 3 mm ± 0.8 mm (H) (average ± standard deviation), respectively, before combustion. These were provided from a supplier and filtered to remove really small wood chips by using a 1 cm mesh. Douglas-fir wood pieces were machined to dimensions of 7.9 mm (H) by 7.9 mm (W) by 12.7 mm (L).

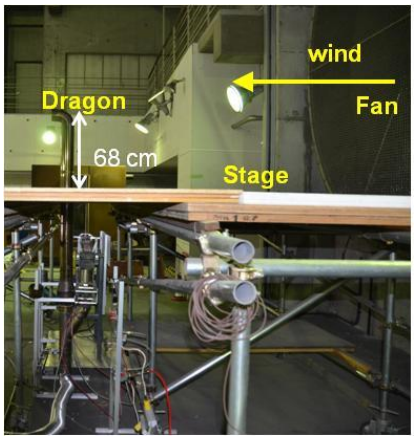

Figure 1 Experimental Setting in NRIFD's wind facility

The obstacle was placed downstream of the firebrand generator and the wind speed was varied at 4 m/s, 6 m/s, 8 m/s and 9 m/s. Specifically, the obstacle used in this study had the dimensions of 660 cm (H) by 1275 cm (W) and was located at a distance of 3 m from the device to visualize the transport process.

3. Results and Discussions

Figure 2 displays images of experiments with a 660 cm (H) x 1275 cm (W) obstacle with different wind speeds (4 m/s and 8 m/s) and feeding materials (Japanese Cypress chips and Douglas-fir wood pieces). Images shows that firebrands made from Japanese Cypress wood chips and from Douglas-fir wood pieces accumulated differently in front of the same obstacle.

Under a 4 m/s wind, it was observed that firebrands were unable to accumulate into one compact zone, rather scattered. As a wind speed increases, firebrands accumulated more in one zone. It was observed that firebrands made from Japanese Cypress wood chips managed to accumulate in front of the obstacle up to 10 m/s while those made from Douglas-fir wood pieces did not accumulate under 8 m/s and 10 m/s wind.

The accumulated area was measured using image processing software. Based on repeat measurements of different areas, the standard uncertainty in determining the projected area was ±10%. It is also important to mention that the obstacle was exposed to firebrand showers for the same duration.

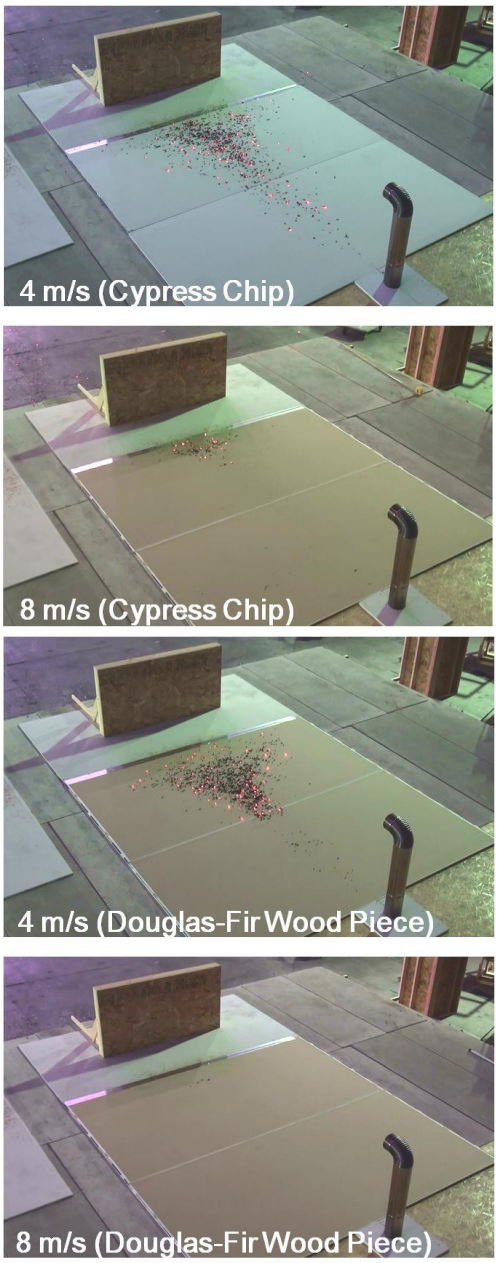

Figure 2 Images of experiments with a 660 cm (H) by 1275 cm (W) obstacle under different wind speeds -4 m/s and 8 m/s, with different feeding materials –Japanese Cypress wood chips and Douglas-fir wood pieces

Figure 3 displays the measured area of the accumulated firebrands as a function of wind speed. As the wind speed was increased, the area of accumulated firebrands was reduced significantly. It is obvious in Fig. 3 that firebrands from Douglas-fir wood pieces accumulated to smaller areas than those from Japanese Cypress wood chips.

Comparison was made in order to investigate the difference of accumulation behaviors of firebrands. Figure 4 displays the mass and size distributions of firebrands made from Japanese Cypress wood chips and Douglas-fir wood pieces under the same wind speed (6 m/s). Similar to the authors prior full-scale studies, firebrands made from Japanese Cypress wood chips have approximately double the projected areas at a certain mass, compared to firebrands generated from Douglas-fir wood pieces. It suggests that the difference of firebrand characteristics has effect on the accumulation behavior of firebrands in front of wall assemblies.

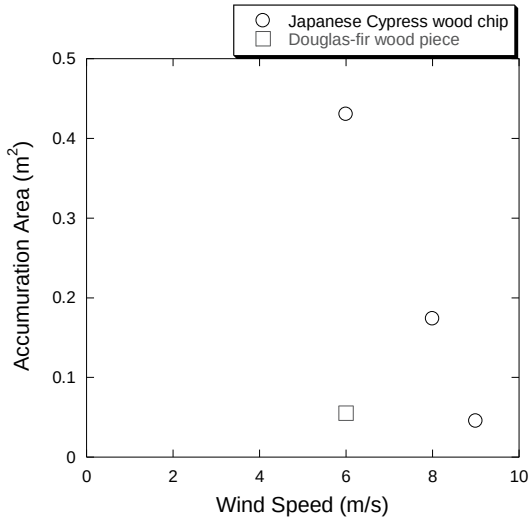

Figure 3 Measured accumulated area for various wind speeds.

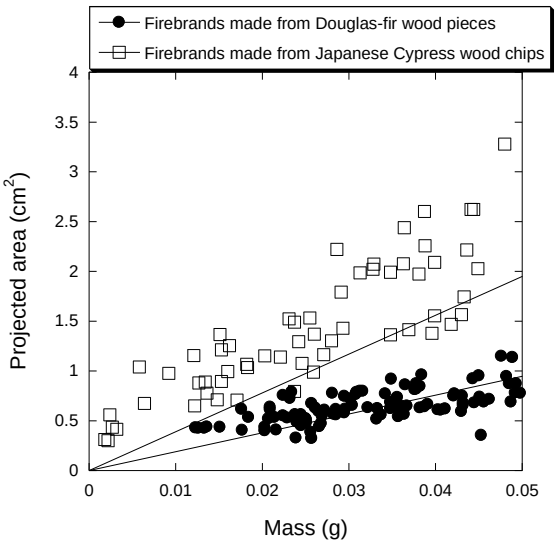

Figure 4 Mass and size distributions of firebrands made from Douglas-fir wood pieces and Japanese Cypress wood chips

4. Summary

A series of reduced-scale experiments were performed in order to investigate firebrand accumulation in front an obstacle using Japanese Cypress wood chips and Douglas-fir wood pieces. For a specified wind speed, it was found that the characteristics of firebrands has an effect of accumulation behavior of firebrands in front of an obstacle. An important qualitative similarity between the full-scale and reduced-scale vegetative firebrand studies is that increased wind speed resulted in decreased firebrand accumulation areas. Detailed investigation will be needed in the future for different obstacles placed downwind from the firebrand generator, as well as further full-scale experiments generating firebrands similar to structure production for comparison.

5. References

[1] Manzello, S.L., et al., Fire Saf. J. 59 (2013) 122-131.
[2] Iwami, T., et al., *Annual Meeting of Architectural Institute of Japan*, Tokyo, Japan, 2011. (in Japanese)
[3] Manzello, S.L., et al., Fire Saf J. 46 (2011) 568-578.
[4] Manzello, S.L, and Suzuki, S., *52nd Japanese Combustion Symposium*, Okayama, Japan, 2014.
[5] Suzuki, S., and Manzello, S.L., *53rd Japanese Combustion Symposium*, Tsukuba, Japan, 2015.