INVESTIGATING WIND DRIVEN FIREBRAND PENETRATION INTO BUILDING VENTS

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1. ABSTRACT

Evidence suggests that wind driven firebrand showers are responsible for a majority of structure ignitions in Wildland-Urban Interface (WUI) fires in the USA and urban fires in Japan. This study is aimed at extensively quantifying firebrand penetration through building vents using the NIST Firebrand Generator (NIST Dragon) coupled to BRI's Fire Research Wind Tunnel Facility (FRWTF). Mesh size was varied to determine if mesh alone can retard firebrand penetration into building vents.

2. INTRODUCTION

To attempt to design structures to be more resistant to firebrand bombardment, it is imperative to quantify key vulnerabilities where firebrands may easily enter structures. Until recently, attempting to experimentally quantify the vulnerabilities of structures to firebrand showers has remained elusive. The partnership of BRI and NIST facilities as well as expertise in WUI and urban fires has provided the first quantification of structure vulnerabilities to firebrand showers [1-2].

Prior collaborative work by Hayashi of BRI and Manzello of NIST [1], have shown the vulnerabilities that exist when using certain sizes of metal mesh screens behind building vents. The present investigation is aimed at extensively quantifying firebrand penetration through building vents using full scale tests at BRI. In these experiments, six different mesh sizes were considered as well as four different types of ignitable material placed inside the structure, behind the mesh. Mesh size was varied to determine if mesh alone can retard firebrand penetration into building vents.

3. EXPERIMENTAL DESCRIPTION

A detailed description of the NIST Firebrand Generator (NIST Dragon) is not provided here since the device, as well as the mulch type used in this experimental campaign, was identical to those used by Manzello *et al.* [2]. The only difference was the mulch loading was fixed at 2.1 kg in the present experiments.

The NIST Dragon was installed inside the test section of the FRWTF at BRI. The facility used a 4.0 m diameter fan to produce the wind field and was capable of producing a flow of 10 m/s. To track the evolution of the size and mass distribution of firebrands produced, a series of rectangular pans (water-filled) were placed downstream of the NIST Dragon. The firebrands were subsequently dried in an oven at 104 °C for eight hours. The firebrand sizes were then measured using precision calipers (1/100 mm resolution). Following size determination, the firebrands were then weighed using a precision balance (0.001 g resolution).

The overall dimensions of the target structure, placed 7.5 m downstream of the NIST Dragon, were 3.06 m in height, 3.04 m in width, and 3.05 m in depth. The structure was constructed of calcium silicate (non-combustible) board. A generic building vent design, consisting of only a frame fitted with a metal mesh, was used. The vent opening was fitted with six different types of metal mesh: 4 x 4 mesh x 0.65 mm wire diameter, 8 x 8 mesh x 0.43 mm wire diameter, 10 x 10 mesh x 0.51 mm wire diameter, 14 x 14 mesh x 0.23 mm wire diameter, 16 x 16 mesh x 0.23 mm wire diameter, and 20 x 20 mesh x 0.23 mm wire diameter. These mesh sizes corresponded to opening sizes of: 5.72 mm (4 x 4), 2.74 mm (8 x 8), 2.0 mm (10 x 10), 1.55 mm (14 x 14), 1.35 mm (16 x 16), and 1.04 mm (20 x 20). Mesh was defined, per the manufacturer, as the number of openings per 25.4 mm (1”).

Prior to conducting the experiments, computer simulations were conducted using the NIST Fire Dynamics Simulator (FDS) to visualize the flow around the structure in the FRWTF. As a result, the placement of the mesh assembly, on the front face of the structure, was intentionally selected to provide for an intense exposure of firebrand showers from the NIST Dragon.

Behind the mesh, four different materials were placed to ascertain whether the firebrands that were able to penetrate the building mesh assembly could ignite these materials. The materials were shredded paper, cotton, crevices constructed with oriented strand board (OSB) and wood (to form 90° angle). For the crevice tests, experiments were conducted with the crevice filled with or without shredded paper. The purpose of using the crevice was to determine if firebrands that penetrated the mesh were able to ignite building materials. Paper in the crevice was intended to simulate fine fuel debris.

4. RESULTS AND DISCUSSION

The NIST Dragon was designed to be able to produce firebrands characteristic to those produced from burning trees [1-2]. In this study, the input conditions for the NIST Dragon were intentionally selected to produce firebrands with masses as large as 0.2 g [2]. The total mass of firebrands produced was also determined based on repeat experiments. With mulch loadings of 2.1 kg, an average of 196 g (varied from 192 g to 200 g) of glowing firebrands were produced.

For the full scale tests, the wind tunnel speed was fixed at 7 m/s (± 10 %). The velocity behind the mesh varied from 7 m/s (4 x 4 mesh; 5.72 mm opening) to 5 m/s (20 x 20 mesh; 1.04 mm opening). The uncertainty in these measurements is ± 10 %.

Three repeat experiments were conducted for each of the four ignitable materials considered and the results are tabulated in Table 1. The acronyms in the table are as follows: NI – no ignition; SI – smoldering ignition; FI – flaming ignition.

When shredded paper was used, a repeatable SI was observed for all mesh sizes up to 16 x 16 (1.35 mm). As for the smallest mesh size tested (20 x 20) (1.04 mm), SI was observed in only one experiment out of three. For cotton, the ignition behavior was similar for all mesh sizes. The firebrands would deposit into the cotton bed and simply burn holes into the cotton.

The bare wood crevice experiments resulted in SI in the OSB layer for the 4 x 4 (5.72 mm) and 8 x 8 (2.74 mm) mesh sizes. As the mesh size was reduced to 10 x 10 (2.0 mm), the firebrands were not able ignite the bare wood crevices. When the crevices were filled with shredded paper, SI followed by FI occurred in the paper for mesh sizes up 10 x 10 (2.0 mm). The OSB layer was then observed to ignite by SI and subsequently produced a self sustaining SI that continued to burn holes into the OSB. For the smallest mesh sizes tested (16 x 16 and 20 x 20), NI was observed in the paper and consequently NI in the crevice.

These experiments found that firebrands were not quenched by the presence of the mesh and would continue to burn until they were able to fit through the mesh opening, even down to 1.04 mm opening (see Figure 1). While mesh size reduction did mitigate ignition of bare wood crevices, the presence of fine fuels would be expected in attic spaces.

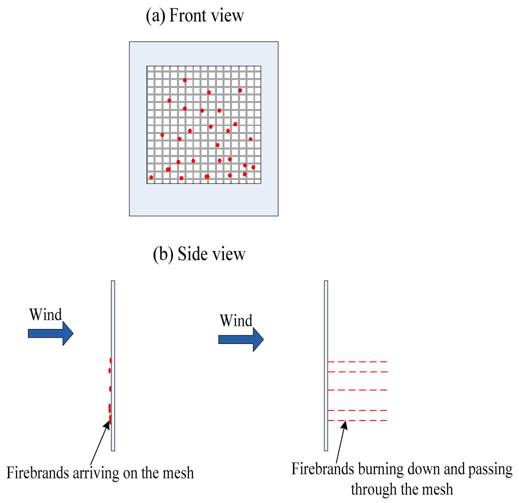

Figure 1 Firebrand penetration through mesh.

Table 1 Summary of ignition results; all materials were oven dried.

Mesh	Paper	Cotton	Crevice	Crevice with paper
4 x 4 (5.72 mm)	SI to FI	SI	SI	SI to FI (paper) SI (OSB)
8 x 8 (2.74 mm)	SI to FI	SI	SI	SI to FI (paper) SI (OSB)
10 x 10 (2.0 mm)	SI to FI	SI	NI	SI to FI (paper) (SI OSB)
14 x 14 (1.55 mm)	SI	SI	NI	SI (paper) SI (OSB)
16 x 16 (1.35 mm)	SI	SI	NI	NI
20 x 20 (1.04 mm)	NI (twice) SI (once)	SI (twice) NI (once)	NI	NI

5. SUMMARY

The experiments demonstrate that mesh was not effective in reducing ignition for the fine fuels tested and firebrand resistant vent technologies are needed. These full scale tests have just been compared to a newly developed reduced scale test method constructed at NIST [3].

6. REFERENCES

1. Manzello, S.L. *et al.*, *Proceedings of the 11th International Conference on Fire Science and Engineering (INTERLFAM)*, Interscience Communications, London, pp. 861-872, 2007.
2. Manzello, S.L. *et al. Fire Safety Journal* 45, 35-43, 2010.
3. Manzello, S.L. *et al. NIST Technical Note 1659*, 2010.