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Firebrands generated from a full-scale structure burning under well-controlled laboratory conditions

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ABSTRACT

Firebrand production from a real-scale structure under well-controlled laboratory conditions was investigated. The structure was fabricated using wood studs and oriented strand board (OSB). The entire structure was placed inside the Building Research Institute's (BRI) Fire Research Wind Tunnel Facility (FRWTF) in Japan to apply a wind field of 6 m/s onto the structure. As the structure burned, firebrands were collected using an array of water pans. The size and mass distributions of firebrands collected in this study were compared with sparsely available firebrand generation data from actual full-scale structure burns, individual building component tests, and historical structure fire firebrand generation studies. In this experiment, more than 90% of firebrands were less than 1 g and 56% were less than 0.1 g. It was found that size and mass of firebrands collected in this study were similar to the literature studies, yet differences existed as well. Different experimental conditions, as well as varied firebrand collection strategies, were believed to be responsible for the differences in firebrand size and mass measured in the present work, and those in the literature. The present study has provided much needed data on firebrand generation from structures.

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1. Introduction

Firebrands are a critical mechanism of fire spread in large outdoor fires, such as urban fires in Japan and wildland–urban interface (WUI) fires common in Australia, Southern Europe, and the USA. While firebrands have been studied for some time [1], most of these studies have focused on spotting distance [2–12]. Unfortunately, very few studies have been performed regarding firebrand generation [13–15] and the subsequent ignition of building materials or vegetative fuels by firebrands [16–19]. To develop scientifically based mitigation strategies for urban/WUI fires, such as hardening structures to make them more ignition resistant, it is necessary to understand the firebrand generation process from structures.

Sparse data exist with regard to fire size distributions from actual structures or WUI fires [20–23]. It is believed that in WUI fires, the structures themselves may be a large source of firebrands, in addition to the vegetation. Yet, due to lack of quantitative information available on production of firebrands from structures, it cannot be determined if firebrand production from structures is a significant source of firebrands in WUI fires. Detailed studies are needed to address this question.

For completeness, prior firebrand generation studies from structures are reviewed. Vodvarka [20] measured firebrand deposition by laying out 3 m × 3 m sheets of polyurethane plastic downwind from five separate residential buildings burned in full-scale fire experiments. Three of the structures were standard frame construction with wood siding. The fourth was asphalt siding applied over sheet rock which covered the original shiplap. The fifth structure was a brick veneer over a wood frame. The total number of firebrands collected from these structure fires was 4748. Very small firebrands dominated the size distribution with 89% of the firebrands less than 0.23 cm^2.

Vodvarka [21] measured the fire spread rate radiant heat flux, firebrand fallout, buoyancy pressures, and gas composition from eight separate buildings. Firebrands were collected by laying out sheets of polyurethane plastic downwind from three of eight experiments. Two of the buildings were all wood construction, one was cement-block construction, and had wooden floors and asphalt shingles over wood sheathing. In total, 2357 firebrands were collected. More than 90% of the firebrands had a projected area less than 0.90 cm^2 and 85% of the firebrands were less than 0.23 cm^2 in projected area. Only 14 firebrands had projected areas larger than 14.44 cm^2 in three experiments.

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Yoshioka et al. [24] measured the size and mass of firebrands from the real-scale wooden house in the Building Research Institute's (BRI) Fire Research Wind Tunnel Facility (FRWTF) in Japan. This is the only full-scale structure experiment under laboratory conditions with a controlled applied wind field the authors are aware of in the literature. The FRWTF is a remarkable wind tunnel because it was designed specifically with fire testing in mind. Two square pans, both 1 m × 1 m, were placed 2 m from the house to collect firebrands: one was filled with water (wet pan) and the other without water (dry pan). The total number of firebrands collected in their study was 430; 368 from a wet pan and 62 from a dry pan. It was reported that 83% of the firebrands in the wet pan were between 0.25 cm^2 and 1 cm^2 projected area while 53% of those from the dry pan were between 0.25 cm^2 and 1 cm^2 projected area. Only 1 of 368 in the wet pan and 4 of 62 in the dry pan were larger than 4 cm^2 projected area. It was pointed out that the reason why a dry pan had far less firebrands with projected areas between 0.25 cm^2 and 1 cm^2 was that they simply burned in the dry pan. The work is very important; nevertheless since construction practices in Japan are very much different than those in the USA, it is not clear how applicable this data is in terms of the WUI fire problem in the USA.

Suzuki et al. [25] collected firebrands from a two story house located in Dixon, CA. Debris piles were used to ignite the structure and it took approximately two hours after ignition for complete burn down. A large amount of water was poured onto the structure several times to control the fire since the house was located in a populated section of downtown Dixon. Firebrands were collected with a series of water pans placed near (4 m) the structure and on the road about 18 m downwind of the structure. For the data collected from the full-scale structure burn by Suzuki et al. [25], 139 firebrands were collected at the two measurement locations. All the firebrands collected from the burning house were less than 1 g and almost 85% of the firebrands collected 18 m from the structure, and 68% of firebrands 4 m from the structure, were less than 0.1 g. In terms of the projected area, most of the firebrands, 95% of those from 18 m downwind from the structure, and 96% of those 4 m from the structure, were less than 10 cm^2 in projected area.

Most recently, Suzuki et al. [26] investigated firebrand production from real-scale building *components* under well-controlled laboratory conditions using BRI's FRWTF in Japan. Specifically, wall and re-entrant corner assemblies were ignited and during the combustion process, firebrands were collected to determine the size/mass distribution generated from such real-scale building components under varying wind speed. The purpose of those experiments was to determine if useful information regarding firebrand generation may be obtained from simple components tests. Components experiments are far simpler than full scale structure experiments. It was observed that similar mass classes of firebrands were observed from components to the available full scale structure tests in the literature. The results of Suzuki et al. [26] are compared to the experiments outlined in this paper and are presented below.

Finally, it is worth mentioning that Manzello and Foote [23] examined the size distribution of firebrand exposure during the Angora fire, a severe WUI fire in California, USA in 2007. In that study, a trampoline, which was exposed to wind-driven firebrands during the fire, was collected for analysis. The burn areas of the round trampoline base were assumed to be generated from firebrands and measured by digital image analysis. The trampoline section that was analyzed had an overall area of 10.5 m^2 with 1800 burn holes. The single largest hole in the trampoline base had a 10.25 cm^2 burned area. It was observed that more than 85% of the burned areas from firebrands were less than 0.5 cm^2 and more than 95% of them were less than 1.0 cm^2. In addition to the trampoline data, burn patterns on building materials and plastic outdoor furniture were observed at 212 individual locations on or near numerous buildings in the Angora Fire. A large majority of these firebrand indicators were less than 0.40 cm^2 with the largest being 2.02 cm^2 or 0.64 cm × 3.18 cm. Most of the burn patterns on building materials consisted of shallow scorch or char marks on wooden or composite lumber decks.

To this end, firebrand production from real-scale building under well-controlled laboratory conditions was investigated. The structure was fabricated using wood studs and oriented strand board (OSB). A sofa was placed inside the structure and this sofa was ignited using a remotely controlled electric match (matchbook coupled to resistive wire; electrical current provide by battery box). The door opening was sized to allow flashover to occur inside the structure. The entire structure was placed inside the BRI's FRWTF in Japan in order to apply a wind field of 6 m/s onto the structure. As the structure burned, firebrands were collected using an array of water pans positioned downstream of the structure. The size and mass distributions of firebrands collected were compared with firebrand generation data from actual full-scale structure burns, individual building component tests, and historical firebrand generation studies from structures. This study provides data for the beginning of a database on firebrand generation data from structures that is being developed by Manzello and co-workers. Temperatures and mass loss measured during the experiment are also reported in this paper.

2. Experimental description

A full-scale structure was constructed for the experiments. The overall dimensions of the structure were 4 m long by 3 m wide by 4 m high. Fig. 1 displays an image of the structure. The wall framing was constructed of wood studs (wood cross section 3.8 cm by 8.8 cm) spaced 406 mm on center (16.0″). King post trusses were used for the roof assembly with a roof pitch of 20° as these are thought to be one of the simplest trusses for roof assemblies with overhang used in the USA. The supporting structure for the roof assembly was constructed with wood studs (wood cross section 3.8 cm by 14.0 cm). Oriented strand board (OSB) with a thickness of 11 mm was applied to the exterior walls and roof. The moisture content of the building materials was nominally 10% (dry basis). A schematic drawing is shown in Fig. 1. The entire structure was placed on load cells to determine the temporal variation of mass loss. The total mass of the structure at

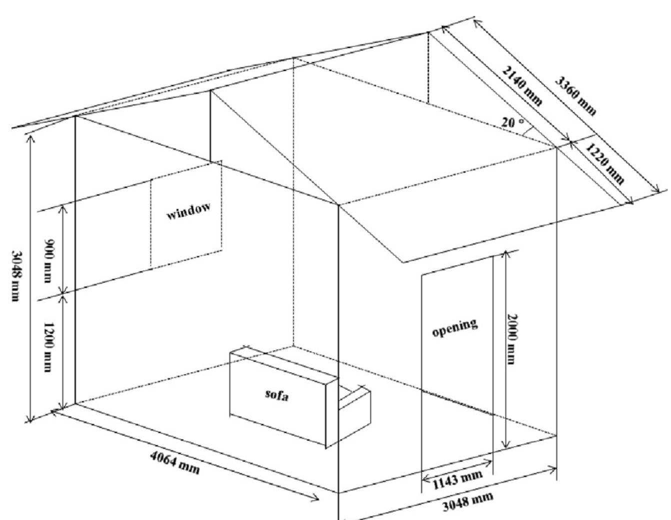

Fig. 1. Schematic of the structure.