WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA
Advancing Timber for the Future Built Environment

BURNABILITY OF WOODEN LOUVERS AND ITS FACTORS: FLAME-SPREAD EXPERIMENTS ALONG PARALLEL WOODEN BOARDS

Ryo Takase[1], Daisuke Kamikawa[2], Masatoshi Nakamura[3]

ABSTRACT: A series of simple flame-spreading tests along a channel was conducted to investigate fire risks of wooden vertical louvers. A pair of wood boards (either MDF or sugi) were burnt facing each other, and flame spread was observed. It was found that flames do not extinguish within the height of 6 times the source of the flame if blades 112 mm wide are aligned approximately every 100mm or closer. Over 6kW/m^2 of incident heat flux was observed even at the region higher than 1.5L_f' (flame height). This value was considerably higher compared to a flat wall configuration. It was also found that the increase in heat flux values in L_f' < H region was well estimated from radiative heat flux from the opposing blade. Louvers attached to inorganic walls are certainly safer than the "mirrored" configuration, as the heat loss towards a backing wall becomes significant either in unsteady flame propagation or for small entities.

KEYWORDS: timber, lining, louver, flame spread

1 – INTRODUCTION

Wooden porous designs are often applied to partition walls and exterior claddings in architecture. However, these linings are likely to enhance flame spread, due to an increase in surface area and preheating. In this study, the increase in fire risk is evaluated via a series of simple flame-spreading tests.

2 – BACKGROUND

2.1 LITERATURE REVIEW

As shown in Figure 1, there is a threshold above which a wood wall can sustain flame spread. This value is reported to be around 6 kW/m^2 if the incident heat flux is uniform [1-4]. In LIFT procedures, where the materials are exposed to a heat source that attenuates exponentially with distance, wooden materials tend to extinguish at the location that the external heat becomes less than 5kW/m^2 [5]. The opposing blade in a louver might be a one of non-uniform heat source that may preheat the unburnt surface to enhance flame spread.

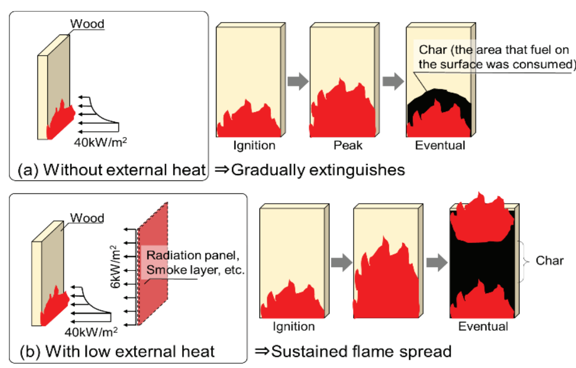

Figure 1: Literature review of sustained flame spread

[1] Ryo Takase, Dept. of Wood Improvement, Forestry and Forest Products Research Institute, Tsukuba, Japan, ryotakase@ffpri.affrc.go.jp

[2] Daisuke Kamikawa, Dept. of Wood Improvement, Forestry and Forest Products Research Institute, Tsukuba, Japan, daikami@ffpri.affrc.go.jp

[3] Masatoshi Nakamura, Dept. of Technology&Solution, Taisei Corporation, Yokohama, Japan, nkmmst00@pub.taisei.co.jp

 https://doi.org/10.52202/080513-0434

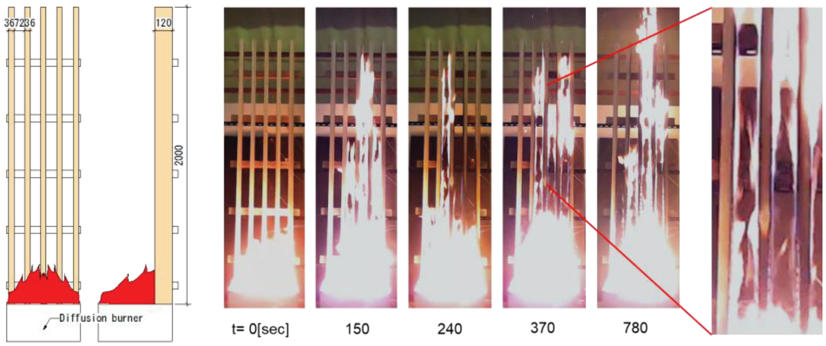

Figure 2: Preliminary test for observation

2.2 PRELIMINARY OBSERVATION

Prior to quantitative studies, issues had to be specified through a realistic burning experiment, as shown in Figure 2. Louvers comprising five blades made of sugi (Japanese cedar, *Cryptomeria japonica*) were aligned at a 72 mm spacing. A diffusion burner, 0.5 × 0.5 m in size, was placed at the bottom. Propane-based gas was supplied so that the theoretical heat release rate was 40 kW. The experiment's duration was 30 minutes. From this experiment, the following was observed;

1. it is difficult to derive quantitative evaluation from realistic fire experiments, as the flame propagates at various rates and times among the channels,

2. flames far from the source emerge mainly at the sides facing towards the channels, so the burning of other facets becomes a minor cause for the occurrence of sustained flame spread.

3 – PROJECT DESCRIPTION

Based on the observation, simple flame-spreading tests along a channel were designed, as shown in Figure 3. In all experiments, the back faces of the blades were insulated as to replicate one channel of a louver wall. Following two sets of experiments were conducted as per their interests.

4 – EXPERIMENTAL SETUP

4.1 SERIES 1: SPACING

Spacing between blades certainly plays a major role in louver burnability for the increase in surface area and preheating. In this series, the channel depth was 112 mm. Only the spacing distance varied from 48 to 180 mm.

As shown in Figure 3, a pair of specimens with a size of 1700×112×18 mm and steel supporting members were aligned at designated spacing (48, 72, 96 and 180 mm). Specimens were either MDF or sugi. The cases are named after their specimen types and spacing dimensions (i.e. M-48 or C-48).

We assumed that external heat from the opposing blade can be approximated with heat radiation. To evaluate this interaction, K-CA type thermocouples (ϕ0.32 mm) were aligned vertically on the surface of one blade, and heat-flux transducers (Gardon type, 0.15 mV/kW) were likewise aligned on the other. Flame spread was analysed from video recordings. Part of the result was published previously [6].

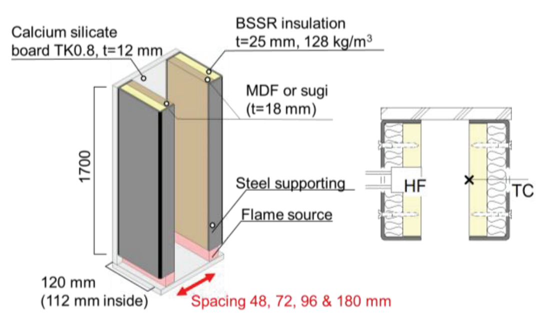

Figure 3: The apparatus for Series I

4.2 SERIES 2: WALL PRESENCE

Louvers are commonly designed to be either attached to a wall or apart from a wall. Conventional studies dealing with a steady plume against a wall yield that the plume temperature against the wall tends to be higher compared to the empirical result of its "mirrored" case [7], as the plume becomes narrower when a wall is present. Likewise, burning of the louvers in a semi-infinite space is theoretically eqivalent to louvers cut in half against their plume centreline [8]. Using the same apparatus of series I, this "mirroring" analogy was verified (Figure 4).

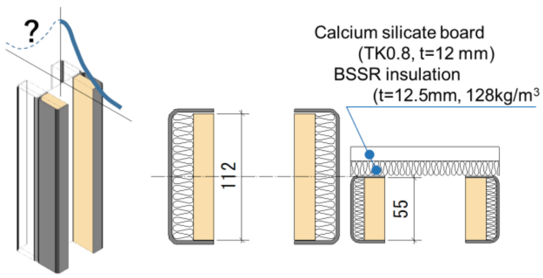

Figure 4: The apparatus for Series II

This time, MDF was applied, for specimens to match thermal characteristics between experiments. BSSR wool was attached to the wall surface to minimize heat loss. Horizontal temperature distribution was evaluated by thermocouples distributed at three points for each height.

4.3 FLAME SOURCE

The type of the flame source differed between series I and II. Wicks were employed in series I (Figure 5), while line burners were employed in series II (Figure 6). Although the flame extinguishes in 7 minutes in wick cases, hardly any difference was found.

For series I, a piece of BSSR insulating wool was placed below each blade to create a line flame, and butanol was contained within. The five facets (all except the burning facet) were covered with alminum tape. Preliminary measurement using a cone carolimeter found that the burning of the wick lasted for approximately 7 minutes, and that the heat release rate (HRR) was 12.8kW/m on average.

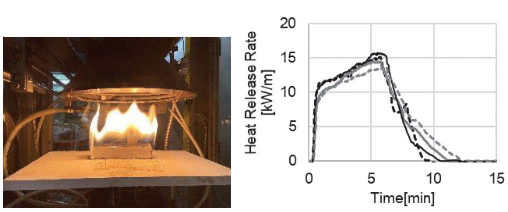

Figure 5: HRR of the wick flame

Figure 6: Line-burner setup

4.4 FLAME HEIGHT MEASUREMENT

In order to systematically evaluate the pyrolysis front X_p', average flame height L_f' and flame tip L_m', the following procedures were performed in this study (Figures 7, 8). Five frames chosen within the puffing frequency of the flame were captured from video recordings every 5 seconds. The images were then converted into multi-TIFF files, and the coordinate of the flame tip was analysed using an image processing program (ImageJ by NIH Image). The difference between L_f measured by the conventional method [9] and the L_f' by the above method was as small as 2%.

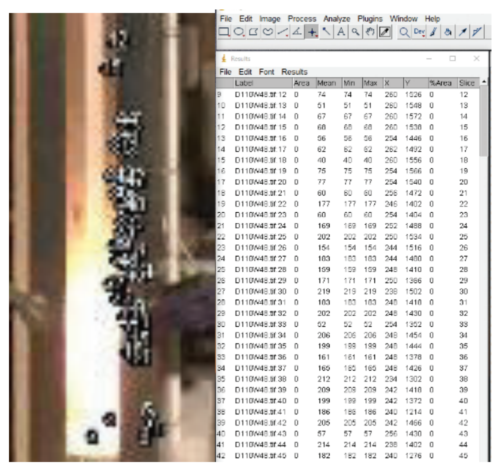

Figure 7: Flame height measurement by ImageJ

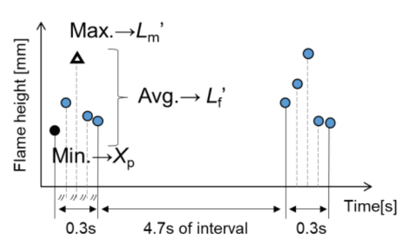

Figure 8: Analysing procedures of flame height

https://doi.org/10.52202/080513-0434

5 – RESULTS AND DISCUSSION

5.1 SPACING AND FLAME HEIGHTS

Figure 9 shows an example of the acquired datasets. The label “Ext.” indicates that flame was extinguished below that height. Flame heights (L_f’) for all cases are shown in Figure 10. In most conditions, flame height exponentially increased with time, and the flame height L_f’ reached the top end of the specimen in the cases M-48, M-72, C-48 and C-72. In sugi cases, flame stops propagating with even narrower spacing, 96 mm, though the flame spread itself became faster. Thermal character ristics and the amount of combustibles are presumable causes for these behaviors.

5.2 HEAT FLUX AND TEMPERATURE

Heat flux distributions in the MDF cases are plotted against the normalized height in Figure 11. Different symbols indicates different times. It is notable that some values measured below the pyrolysis front exceeded 70 kW/m^2, which is quite high for this narrow channel. Also, high values of more than 6kW/m^2 were observed even at the region > 1.5 L_f’. These values are considerably higher compared to those observed in flat wall configuration (literature [8] and Eq. (1)). This increase was almost identical with the radiative heat flux estimated from the temperature distribution of the opposing blade.

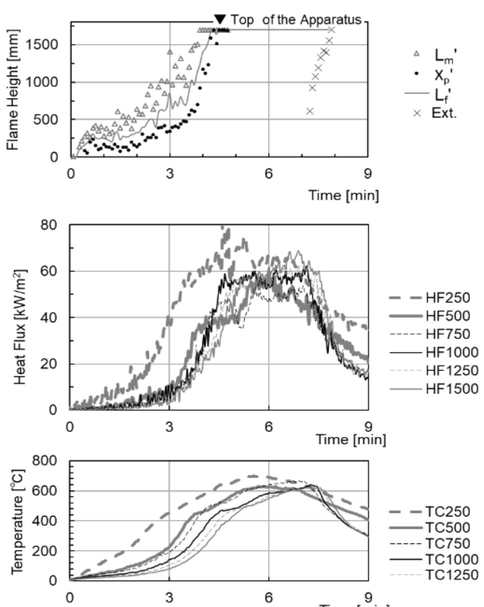

Figure 9: Example of acquired data (M-48)

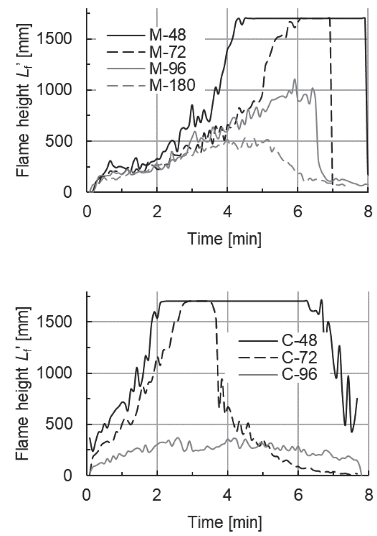

Figure 10: Comparison of flame height

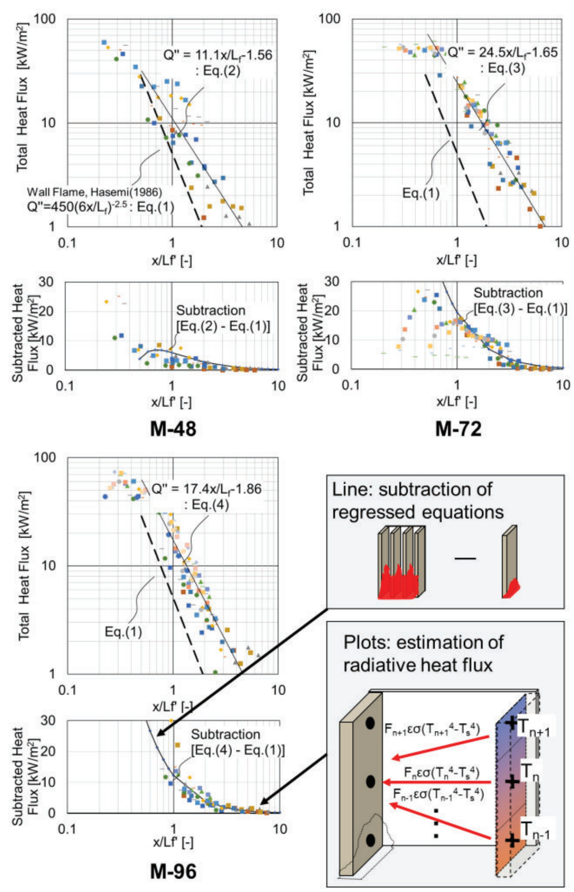

Figure 11: Normalized heat flux distribution

https://doi.org/10.52202/080513-0434

5.3 WALL PRESENCE

Flame heights measured on four conditions (48 mm spacing with and without a wall, 72 mm spacing with and without a wall) are shown in Figure 12. In both cases, flame propagation was suppressed to nearly 2/3 in the cases with walls. To see the detailed tendency, horizontal temperature distribution was compared. Figure 13 shows the exemplified results of the two cases with 72 mm spacing. As seen in the figure, temperature values near the insulated wall are especially low.

Results normalized by the temperature on the plume centerline are demonstrated in Figure 14. If the temperature on the centerline is highest, no $\Delta\theta_C / \Delta\theta_B$ value exceeds 1. Cases without the wall basically agree with this hypothesis. In contrast, $\Delta\theta_C / \Delta\theta_B$ values often exceed 1 in the cases with walls.

Conventional studies dealing with a steady plume against a wall yield that the plume temperature against the wall tends to be higher compared to the empirical result of its "mirrored" case, as the plume becomes narrower when a wall is present. The difference in these behaviors suggests that heat loss by a wall becomes significant in either unsteady flame propagation or small entities. Practically, louvers attached to an inorganic wall are should be safer than their "mirrored" situation.

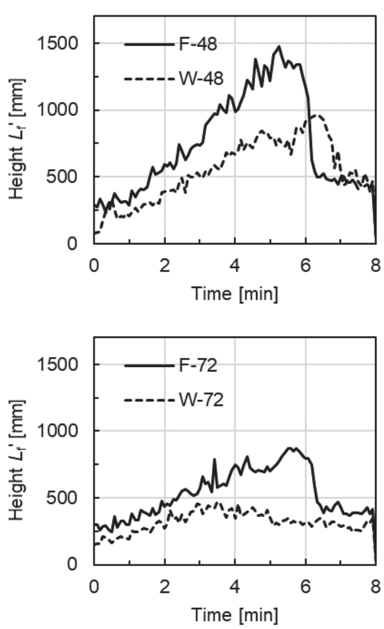

Figure 12: Comparison of flame height

6 – CONCLUSION

A series of simple flame-spreading tests along a channel was conducted to investigate fire risks of wooden vertical louvers. Consequently, the following conclusion was reached;

1. flames do not extinguish within the height of 6 times the source flame if blades 112 mm wide are aligned approximately every 100 mm or closer,
2. in louver configuration, over 6 kW/m^2 of incident heat flux was observed even at the height > 1.5 L_f'. This value is considerably higher compared to a flat wall configuration,
3. the increase in heat flux values in the L_f' < H region was well estimated by radiative heat from the opposing blade,
4. heat loss towards a backing wall becomes significant in either unsteady flame propagation or small entities. As a result, louvers attached to an inorganic wall should be safer than their "mirrored" configuration.

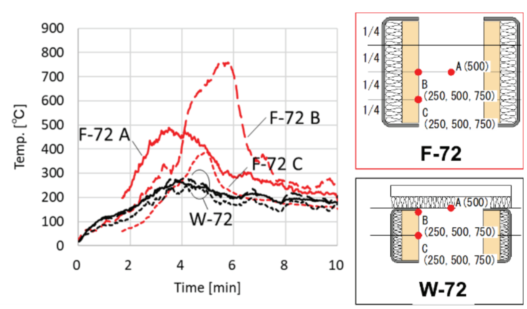

Figure 13: Temperature at 500 mm height

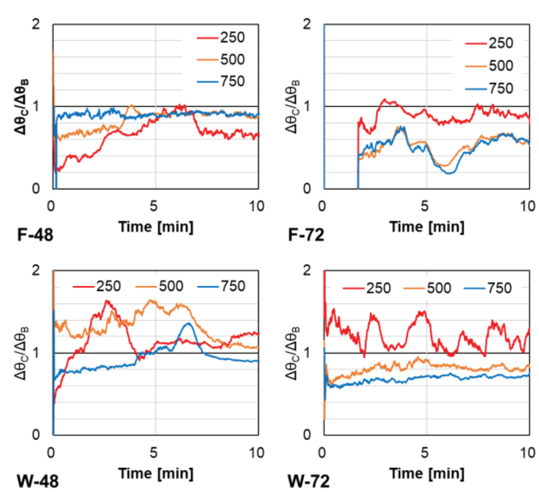

Figure 14: Normalized temperature

https://doi.org/10.52202/080513-0434

7 – REFERENCES

[1] Y. Hasemi and M. Yoshida: Upward flame spread along a vertical solid for transient local heat release rate, Proceedings of the 4th International Symposium of Fire Safety Science, 385-396 (1994)

[2] E.G. Brehob and A.K. Kulkarni: Experimental measurements of upward flame spread on a vertical wall with external radiation, *Fire Safety Journal*, 31, 181-200 (1998)

[3] Y. Yokobayashi, Y. Hasemi, M. Yoshida and T. Wakamatsu: Flame heat transfer correlations and concurrent flame spread in a ceiling fire, *Journal of Architecture and Planning* (Transactions of AIJ), 64 (519), 1-7 (1999)

[4] M. Seki, K. Kagiya, N. Yasui, Y. Hasemi and T. Takayama: Evacuation safety design of a large enclosure with wooden lining through the limitation of the fire growth (part 2) experimental research about catching fire and flame spread of wood wall in smoke layer, Proceedings of AIJ annual meeting, 33-34 (2017)

[5] G. Merryweather and MJ. Spearpoint: Flame spread measurements on wood products using the ASTM E 1321 LIFT apparatus and a reduced scale adaptation of the cone calorimeter, *Fire and Materials*, 34 (3), 109-136 (2010)

[6] R. Takase, K. Suzuki, D. Kamikawa, Y. Hasemi and K. Matsuyama: Flame spread along wooden louvers and the fire suppressing measures, *Journal of Environmental Engineering* (Transactions of AIJ), 85(772), 401-411 (2020)

[7] Y. Hasemi and T. Tokunaga: Some experimental aspects of turbulent diffusion flames and buoyant plumes from fire sources against a wall and in a corner of walls, *Combustion Science and Technology*, 40, 1-18 (1984)

[8] M. Nakamura and R. Takase: FDS analysis of flame spread along two opposing inside surfaces of wooden louver walls, Proceedings of AIJ annual meeting, 47-48 (2024)

[9] Y. Hasemi: Thermal modelling of upward flame spread along a vertical combustible solid: Part I - Mathematical formulation of a flame spread process and experimental heat transfer correlations for the spontaneous flame spreadine process, Journal of Structural and Construction Engineering (Transactions of AIJ), 359, 117-124 (1986)

ACKNOWLEDGEMENT

Part of this work was supported by JSPS KAKENHI Grant Number JP24K17410. The work is based on a research leaded or supported by Dr. Eng/Prof. Yuji Hasemi, Ph.D./Prof. Ken Matsuyama and Mr. Kentaro Suzuki.