Influence of Glass Breakage on Ventilation and Fire Behaviour in Large Timber Compartments: A Numerical Simulation Study

FIRE RESEARCH & INNOVATION CENTRE

Presented at the Interflam conference, Royal Holloway, University of London, UK
30th June - 2nd July 2025

Deonisius Pradipta Aprisa*(NTNU, deonisius.aprisa@ntnu.no), Andreas Sæter Bøe (RISE Fire Research), Kathinka Leikanger Friquin (SINTEF), Anne Steen-Hansen(NTNU, RISE Fire Research), Lei Jiang (RISE Fire Research)

Introduction

The adoption of engineered timber as a construction material introduces a different fire risk due to its combustible nature. To understand the risk, many studies have been conducted to study the effects of exposed timber on compartment fire dynamics.

However, these studies were done with constant ventilation conditions, which may not represent realistic fire scenarios.

This study aims to numerically **evaluate the impact of varying ventilation conditions**, through glass breakage, **on the fire dynamics and HRR in large timber compartments.**

Methods

FDS 6.9.1 was used to construct three compartment models based on the #FRIC-02 studies [1,2].

Each compartment has a uniform dimension of 18.8 m (L) × 5.0 m (W) × 2.5 m (H), with exposed timber ceiling and back wall.

Variable fuel load is represented by a long continuous wood crib (15.5 m × 2.8 m × 0.2 m) and a short wood crib (1.0 × 2.8 × 0.2).

The Models investigated in this study are:

a) Model 1: Compartment with glass windows
b) Model 2: Compartment with open windows
c) Model 3: Compartment with closed windows

Model 1 used a glass-breakage model [3] to study the effect of varying ventilation conditions.

The glass-breakage model has **two parameters** for the removal of the glass:

a) Surface temperature > 447°C, or
b) Incident heat flux towards the surface > 35 kW/m^2.

An opening with a dimension of 3 m (W) × 1.95 m (H) on one of the long ends of the compartment was added to provide baseline ventilation in Model 1-3.

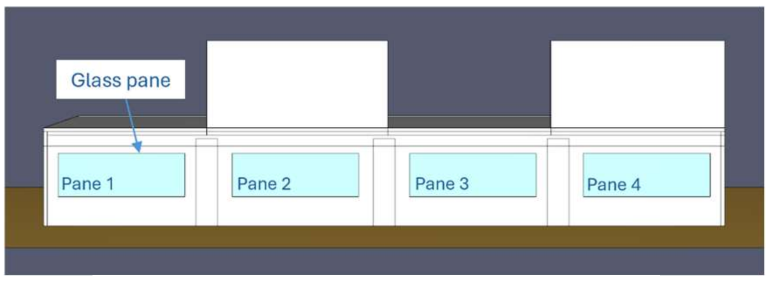

Figure 1. Front view of Model 1 with glass windows

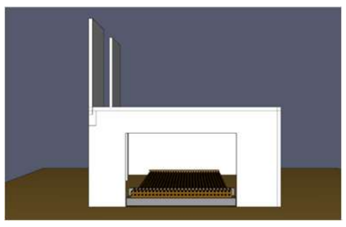

Figure 2. Additional opening at the end of the compartment

Results and Discussion

Ventilation Conditions

- The glass breakage (GB) of the pane 1-4 resulted in change of Opening Factor for Model 1. The events are marked as GB 1-4 in Figure 3.
- Complete glass breakage was achieved in approximately 50 s after the initial fracture at 121 s.
- Glass breakage introduced additional oxygen to support combustion in Model 1.

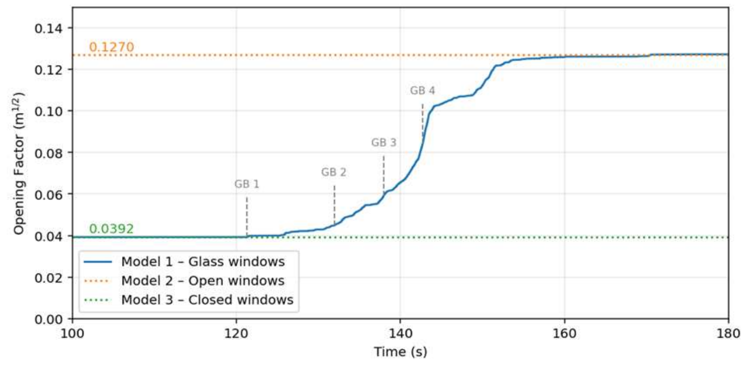

Figure 3. Opening Factor evolution of the models

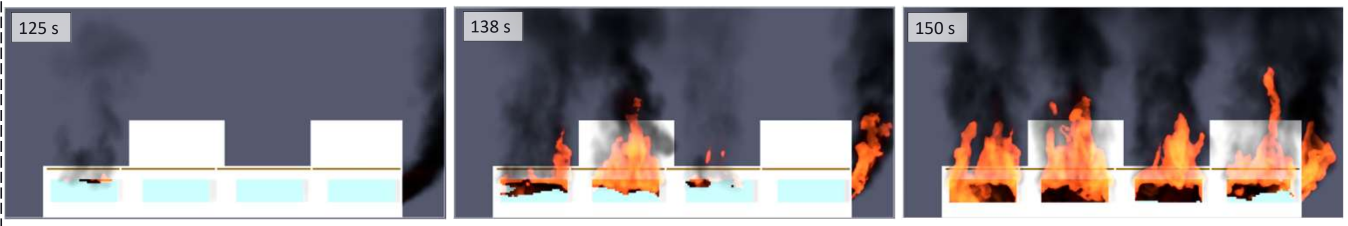

Figure 4. Glass breakage progression in Model 1

Heat Release Rate (HRR)

- Model 1 demonstrated the fastest HRR growth and highest overall HRR.
- The fast HRR growth in Model 1 is due to the exposed timber surfaces being preheated by the accumulated heat and smoke within the compartment; once the glass breaks, sudden introduction of oxygen accelerates the combustion process.
- Model 2 exhibited fuel-controlled fire behaviour, while Model 3 displayed ventilation-controlled fire behaviour.

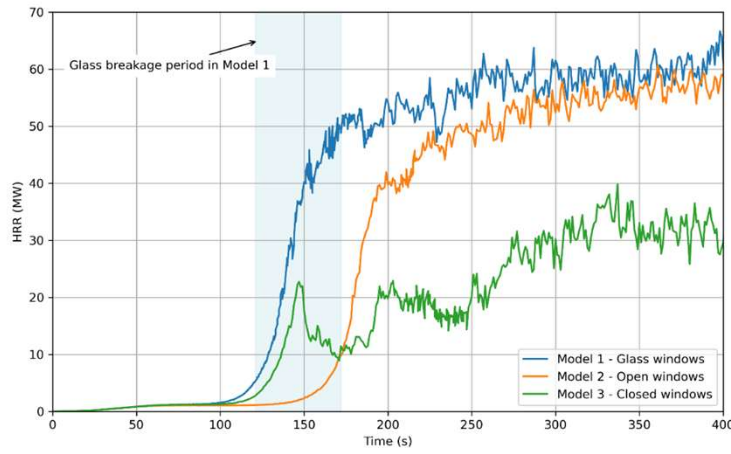

Figure 5. HRR evolution of the models

Temperature Profiles

- Model 1 and 2 showed clear thermal stratification within the compartment. Meanwhile, Model 3 displayed a more uniform temperature profile inside due to oxygen scarcity.
- Consistent with the HRR graph, the temperature profile in Model 1 shows faster increase and higher temperature compared to Model 2 at the chosen times.

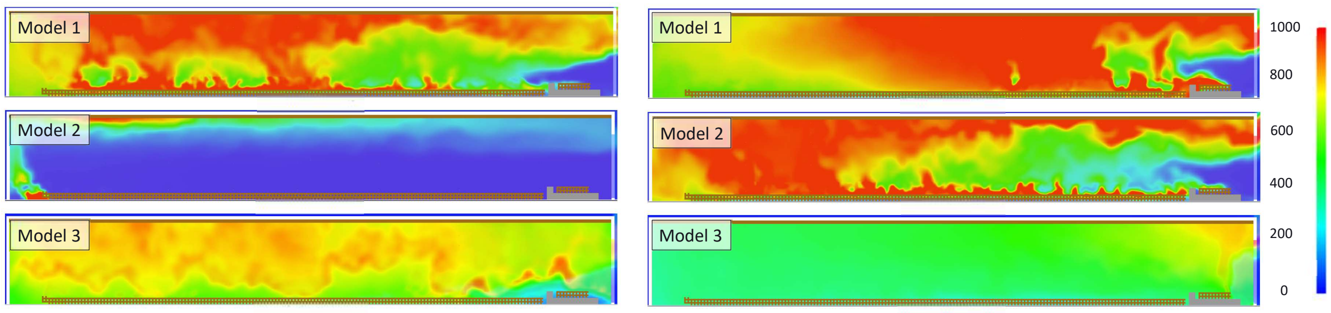

Figure 6. Longitudinal temperature profiles for the models at 150 s (left) and 200 s (right).
Scale is Temperature (°C)

Conclusions

- The three models with different ventilation conditions revealed significant differences in fire dynamics, HRR, and temperature profiles.
- Fastest fire growth and highest HRR, often considered to be the worst-case scenario, is observed in Model 1 with varying ventilation conditions due to glass breakage.
- The results highlight the importance of realistic ventilation consideration in predicting the fire behaviour of timber compartments.

References

[1] Bøe, A. S., Friquin, K. L., Brandon, D., Steen-Hansen, A. & Ertesvåg, I. S. 2023. Fire spread in a large compartment with exposed cross-laminated timber and open ventilation conditions: #FRIC-01 - Exposed ceiling. *Fire Safety Journal*, 140.
[2] Bøe, A. S., Friquin, K. L., Brandon, D., Steen-Hansen, A. & Ertesvåg, I. S. 2023. Fire spread in a large compartment with exposed cross-laminated timber and open ventilation conditions: #FRIC-02 - Exposed wall and ceiling. *Fire Safety Journal*, 141.
[3] Chu, T., Jiang, L., Zhu, G. & Usmani, A. 2024. Integrating glass breakage models into CFD simulation to investigate realistic compartment fire behaviour. *Journal of Building Engineering*, 82

RISE NTNU SINTEF

FRIC is funded by all the partners and a significant donation by the Gjensidige Foundation through the Research Council of Norway (the BRANNSIKKERHET programme, project number 294649).
https://fric.no/en