INFLUENCE OF CAVITY FIRES ON COLD FORMED STEEL MODULAR CONSTRUCTION SYSTEMS

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Thesis submitted in partial fulfillment of the requirements for the degree

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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 02.03.2026

The above candidate has carried out research for the PhD thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

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Signature of the Supervisor: Date: 09.06.2026

DEDICATION

To my beloved parents, brother and sister, for their unconditional love and unwavering support throughout my life.

To my mentors and teachers, whose guidance and wisdom shaped the person I am today.

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ABSTRACT

Fire safety challenges associated with continuous intermodular cavities have raised concerns about fire/heat and smoke spread in modular buildings. However, their interaction with steel modular buildings remains unexplored, contributing to uncertainty in fire safety design. Therefore, this research investigates the influence of cavity fire on fire safety and structural response of cold-formed steel (CFS) columns in modular buildings through experimental testing and validated numerical simulations. Results highlighted that even narrow, non-combustible cavity widths of 25–50 mm compromise upper-level safety, enabling vertical flame to spread up to 9 times and smoke spread up to twice that of non-cavity fires. Structural analysis demonstrated that such cavity fire exposure causes complex column behaviour, including restrained thermal expansion, thermal bowing, and buckling, contributing to reducing the axial load capacity by 2.4% to 35%. The observed failure modalities included global-local buckling interaction and local buckling. The quantified axial load increment due to restrained thermal expansion further revealed the requirement to consider additional service loads of 52% at intermodular connections and the column. Cavity widths of 25–50 mm were identified as the most vulnerable for fire resistance, with unprotected columns often failing to meet the 60 – 120 minute fire resistance requirements. Fire resistance improvement strategies were evaluated in terms of both performance and spatial efficiency. For cavity fire intensities up to 30 kW, reducing cavity width was found to be effective, while intensities between 30 – 60 kW necessitate plasterboard protection. In conclusion, this research demonstrates the critical impact of narrow intermodular cavities on the fire safety of steel modular buildings. The presented insights on critical cavity width, fire resistance levels and critical temperature levels contribute to advancing fire safety standards and practices for steel modular buildings.

Keywords: Modular construction; Cold-formed steel; Intermodular cavities; Fire safety; Structural fire resistance; Cavity fire; Thermal bowing; Restrained thermal expansion; Buckling; Plasterboard protection; Design charts.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AL 45	Aluminium Composite Cladding
ANN	Artificial Neural Network
CA	Cavity configuration with three closed boundaries
CB	Cavity configuration with closed bottom boundary
CF	Cold Flange
CFD	Computational Fluid Dynamics
CFS	Cold-formed steel
CO	Carbon Monoxide
CS	Cavity configuration with closed side boundaries
COV	Coefficient of variation
DOF	Degrees of freedom
EPS	Expanded Polystyrene
FDS	Fire Dynamics Simulator
FEA	Finite element analysis
FE	Finite element
FEM	Finite element model
FRL	Fire resistance level
HCN	Hydrogen cyanide
HF	Hot Flange
HRR	Heat release rate
LP	Liquid petroleum
LR	Load ratio
ML	Machine learning
MW	Mineral wool
NCC	National Construction Code
O	Fully opened cavity configuration
PIR	Polyisocyanurate
SHS	Square hollow sections
SIP	Structural insulated panels
TSC	Thin skin calorimeter

LIST OF APPENDICES