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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).

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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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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.

TABLE OF CONTENTS

Declaration	i
Dedication	ii
Acknowledgement.....	iii
Abstract	iv
Table of Contents	v
List of Figures	xi
List of Tables.....	xxiii
List of Abbreviations.....	xxvi
List of Appendices	xxvii
1 INTRODUCTION	1
1.1 Research Background.....	1
1.2 Research Problem.....	5
1.3 Research Objectives	7
1.4 Thesis Outline.....	9
2 LITERATURE REVIEW.....	11
2.1 Introduction	11
2.2 General Cavity fires.....	11
2.2.1 Research on Cavity Fire	11
2.2.2 Characteristics of Cavity Fire.....	14
2.2.3 Fire scenarios associated with cavity fire initiation	25
2.2.4 Associated risks in cavity fire	26
2.3 Steel Modular construction and cavity fires.....	28
2.3.1 Steel Modular Structural System	28

2.3.2	Intermodular cavity system	29
2.3.3	Cavity fire-related risks in modular buildings	31
2.3.4	Structural response of modular steel columns under fire	35
2.4	Cavity fire testing arrangements	44
2.5	Fire resistance level of steel columns	46
2.5.1	Fire resistance levels in modular construction	46
2.5.2	Fire resistance level achievement	49
2.6	Summary	51
3	FIRE AND SMOKE SPREAD CHARACTERISTICS THROUGH NARROW CAVITIES	55
3.1	Introduction	55
3.2	Experimental set-up	55
3.3	Numerical Simulation and Validation	57
3.4	Parametric analysis	64
3.5	Fire behaviour within cavity spaces compared to open fire scenarios	66
3.6	Effect of cavity width	69
3.6.1	Flame height	69
3.6.2	Incident radiative heat flux	72
3.6.3	Gas and surface temperatures	74
3.6.4	Smoke velocity and CO concentration	77
3.7	Effect of the heat release rate on fire behaviour	80
3.8	Severity levels	80
3.9	Summary	86
4	SENSITIVITY OF FIRE AND SMOKE SPREAD CHARACTERISTICS THROUGH NARROW CAVITIES FOR VENTILATION CONDITIONS	88
4.1	Introduction	88

4.2	Parametric analysis.....	88
4.3	Variations in fire behaviour under partially opened configurations.....	90
4.3.1	Flame height.....	90
4.3.2	Incident radiative heat flux.....	95
4.3.3	Gas temperature	98
4.3.4	Surface temperature	102
4.3.5	Carbon Monoxide concentration.....	109
4.3.6	Smoke velocity.....	111
4.4	Severity level variation.....	115
4.5	Summary	117
5	STRUCTURAL AND FIRE PERFORMANCE OF COLD-FORMED STEEL COLUMNS SUBJECTED TO CAVITY FIRE IN MODULAR BUILDINGS.....	120
5.1	Introduction	120
5.2	Fire Dynamics Simulation.....	120
5.2.1	Experimental program.....	120
5.2.2	Numerical model development and validation	125
5.3	CFS column structural fire simulation	129
5.3.1	Sequentially coupled thermo-mechanical simulation	129
5.3.2	Validation of modelling techniques	133
5.4	Parametric Analysis.....	134
5.4.1	Fire Scenario Analysis	135
5.4.2	Structural Response Analysis.....	137
5.5	Results and Discussion.....	138
5.5.1	Critical cavity fire scenario	138
5.5.2	Effect of ventilation conditions on column temperature.....	141
5.5.3	Heat transfer in the column.....	143

5.5.4	Structural response	144
5.6	Summary	162
6	FIRE RESISTANCE OF UNPROTECTED COLD-FORMED STEEL COLUMN POSTS UNDER CAVITY FIRE	164
6.1	Introduction	164
6.2	Experimental program	164
6.2.1	Column behaviour under ambient conditions	165
6.2.2	Column behaviour under cavity fire condition	176
6.3	Parametric analysis	211
6.4	Failure criteria	216
6.5	Fire resistance levels	219
6.6	Development of design guidance on the fire resistance level	225
6.6.1	Machine Learning model development.....	225
6.6.2	Explanation of the ML model	229
6.6.3	Development of design charts using the ML model	232
6.7	Critical cavity width	235
6.8	Critical temperature	238
6.8.1	Critical temperature metrics.....	238
6.8.2	Machine learning model on critical temperature	240
6.8.3	Development of design guidance on critical temperature using the ML model	243
6.9	Restrain/axial force development	248
6.10	Comparison with AS 4600	251
6.11	Summary	258
7	IMPROVEMENT OF THE FIRE RESISTANCE LEVEL OF COLD-FORMED STEEL COLUMNS SUBJECTED TO CAVITY FIRE	262

7.1	Introduction	262
7.2	Experimental test on a cold-formed steel column with fire protection exposed to cavity fire	262
7.2.1	Experimental setup and procedure	263
7.2.2	Experiment results.....	266
7.3	Numerical model development for structural behaviour of plasterboard protected column under cavity fire conditions.....	279
7.3.1	Computational fluid dynamics model	279
7.3.2	Structural FE model	281
7.4	Validation of numerical modelling technique used for structural fire behaviour under plasterboard protection.....	282
7.4.1	Fire dynamics simulation	282
7.4.2	Structural simulation	287
7.5	Parametric analysis.....	290
7.6	Fire resistance levels and effectiveness of plasterboard thickness variation	291
7.7	Development of design charts to identify protection layer thickness	301
7.7.1	Machine learning model development.....	301
7.7.2	Development of design charts.....	306
7.8	Critical temperature for protected columns under cavity fire exposure	311
7.9	Optimum FRL improvement method	315
7.10	Summary	318
8	CONCLUSIONS AND RECOMMENDATIONS	321
8.1	Key findings and implications.....	321
8.2	Recommendations for future studies	327
9	REFERENCES.....	329

APPENDIX A	346
APPENDIX B	351
APPENDIX C	354
APPENDIX D	356
APPENDIX E	361
APPENDIX F	377
APPENDIX G	389
APPENDIX H	394
APPENDIX I	398
APPENDIX J	408
APPENDIX K	418
APPENDIX L	438

LIST OF FIGURES

Fig. 1.1. Modular construction process [3].	1
Fig. 1.2. Structural formation of modular units [3].	2
Fig. 1.3. Types of steel modular units: a) four-sided, b) partially opened, c) opened [7, 8].	3
Fig. 1.4. Connection types in steel modular buildings [9].	3
Fig. 1.5. Cavities in modular construction (plan view) [4].	6
Fig. 1.6. Fire/heat spreads through intermodular cavities in fire accidents [29].	6
Fig. 2.1. Cavity fire research analysis - cavity geometries included in existing studies.	12
Fig. 2.2. Flame height data of different cavity types.	17
Fig. 2.3. Modular unit structural system	29
Fig. 2.4. Cavities in modular construction: (a) Typical intermodular cavity configuration [95], (b) Vertical intermodular cavity with a column within the cavity (source: AECOM).	30
Fig. 2.5. Cavity barriers in modular construction [26].	31
Fig. 2.6. Possible fire entry points into the intermodular cavity system.	33
Fig. 2.7. Risk-full practices in modular construction.	35
Fig. 2.8. Load-temperature relationship of an axially restrained uniformly heated steel column [111].	38
Fig. 2.9. Structural deformations under the thermal gradient [132].	42
Fig. 2.10. Schematic diagram of a parallel panel test setup used in ANSI/FM approvals 4880-2017 [137].	45
Fig. 3.1. Test setup used to simulate the cavity fire.	56
Fig. 3.2. Temporal variation of results obtained during the experimental test: (a) Gas Temperature (T_g); and (b) Wall Temperature (T_w) ($T_g 0.93 = T_g$ at 0.93 m height)..	57

Fig. 3.3. The numerical model for the experiment: (a) 3D view; (b) side view with mesh; and (c) top view with mesh.	59
Fig. 3.4. Mesh sensitivity analysis concerning the gas temperature in the middle of the 125 mm cavity at 1.45 m from the bottom of the cavity (62.5 mm = Mesh with 62.5 mm cells).....	60
Fig. 3.5. Comparison of temperature variations in the experiment and numerical model: (a) Gas temperature results; and (b) Wall temperature results.....	60
Fig. 3.6. Comparison of model results with the experimental results by Livkiss et al. [75] and the numerical model results by Livkiss et al. [158]: (a) Heat transfer coefficient; (b) Convective heat flux; (c) Incident heat flux; and (d) TSC temperature at 0.25 m.....	63
Fig. 3.7. HRR within a 50 mm non-combustible cavity space under a compartment fire.	65
Fig. 3.8. Positions of monitored data.	66
Fig. 3.9. Comparison of fire properties of cavity fire with open fire (w = cavity width (mm), Q = HRR (kW)): (a) Flame height; (b) Gas temperature; (c) CO concentration and (d) Flow velocity at the top of the cavity.	69
Fig. 3.10. Flame characteristics of cavity fire: (a) Flame height variation; (b) Flame geometry within the cavity, and (c) air entrainment per unit height values.....	71
Fig. 3.11. Flame height correlation between L_f/w (-) and $Q^{2/5}/w$ (kW ^{2/5} /m).	72
Fig. 3.12. Incident radiative heat flux (q_{inc}, rad'') data: (a) Incident radiative heat flux vs. Height; (b) Incident radiative heat flux vs. Height/Flame height (Z/L_f); and (c) Developed empirical equation.....	74
Fig. 3.13. Temperature profiles: (a) Gas temperature vs. Height; and (b) Surface temperature vs. Height.	75
Fig. 3.14. Temporal variation of inner wall surface temperature at 0.85 m: (a) 40 kW fire; and (b) 10 kW fire.	76
Fig. 3.15. Correlation of excess centreline gas temperature with flame height L_f (m), convective heat release rate Q_c (kW) and height z (m).	77

Fig. 3.16. Smoke behaviour within the cavity: (a) smoke velocity; (b) Carbon monoxide concentration; and (c) An empirical equation for smoke velocity.....	79
Fig. 3.17. Reference fire scenarios and related events to assess the overall cavity fire severity levels (P = probability of event).	81
Fig. 3.18. Cavity fire severity levels: (a) cavity fire severity with respect to fire parameters and (b) overall cavity fire severity.....	86
Fig. 4.1. Possible cavity boundary ventilation configurations during normal conditions and propagation during fire events.....	89
Fig. 4.2. Fully opened and partially opened cavity boundary conditions used for the study.....	90
Fig. 4.3. Flame height (L_f) variation against cavity width under different ventilation conditions: (a) 40 kW fire, (b) 10 kW fire.	92
Fig. 4.4. Flame behaviour for the 50mm cavity width and 10 kW fire under the CA partially closed cavity boundary condition.	94
Fig. 4.5. Applicability of flame height correlation identified for fully opened cavity spaces for partially opened cavities.....	95
Fig. 4.6. Incident radiative heat flux profiles during the 170 s to 180 s period; (a) O, (b) CA, (c) CB, and (d) CS.	96
Fig. 4.7. The percentages of variation of the incident radiative heat flux data of partially closed cavities for corresponding open cavities: (a) CA, (b) CB and (c) CS.	98
Fig. 4.8. Steady state gas temperature profiles; (a) O, (b) CA, (c) CB and (d) CS....	99
Fig. 4.9. The percentages of variation of the gas temperature data of partially closed cavities for corresponding open cavities: (a) CA, (b) CB and (c) CS.....	101
Fig. 4.10. Applicability of the gas temperature correlation for partially opened cavities.	101
Fig. 4.11. Surface/wall temperature profiles during the 170s to 180s period; (a) O, (b) CA, (c) CB and (d) CS.	103

Fig. 4.12. The percentages of variation of the surface temperature data of partially closed cavities for corresponding open cavities: (a) CA, (b) CB and (c) CS.....	104
Fig. 4.13. Temporal variation for maximum wall temperature variations for the open cavity scenarios.	105
Fig. 4.14. Surface temperature spatial distribution (10 kW 50 O = fire size of 10kW and 50 mm cavity width for ‘O’ cavity configuration).	107
Fig. 4.15. Steady-state CO concentration profiles; (a) O, (b) CA, (c) CB, and (d) CS.	110
Fig. 4.16. The percentages of variation of the CO concentration data of partially closed cavities for corresponding open cavities: (a) CA, (b) CB and (c) CS.....	111
Fig. 4.17. Average steady-state velocity at the top of the cavity against cavity width under different ventilation conditions: (a) 40 kW fire, (b) 10 kW fire.	114
Fig. 4.18. Applicability of the gas temperature correlation for partially opened cavities.	114
Fig. 4.19. Cavity fire severity levels: (a) cavity fire severity with respect to fire parameters and (b) overall cavity fire severity.....	117
Fig. 5.1. Test setup used to observe the cavity fire scenario (red circles show the positioning of thermocouples).....	122
Fig. 5.2. Observations from the experiment: (a) Evolution of the flame penetration, (b) The view of the plasterboard cracks at the end of the experiment.....	124
Fig. 5.3. Gas temperature (g_t) and wall/surface temperature (w_t) variation during the experiment.....	125
Fig. 5.4. Numerical model representation of the experimental setup.	126
Fig. 5.5. Comparison of gas temperature (g_t) and wall temperature (w_t) variations in the experiment and numerical model: (a) g_t fire compartment; (b) g_t adjacent compartment; (c) g_t cavity at 350 mm; (d) g_t cavity at 900 mm; (e) g_t cavity at 1200 mm; (f) w_t cavity at 780 mm; (g) w_t cavity at 1040 mm.	129
Fig. 5.6. Boundary conditions used in heat transfer analysis under the parametric study (section 5.4.2).....	131

Fig. 5.7. Boundary conditions used in the structural (sequentially coupled thermo-mechanical) analysis under the parametric study (section 5.4.2).....	132
Fig. 5.8. Comparison of the results of the numerical model with the experimental results of Balarupan [101]: (a) Load vs axial shortening of 65×65×3 section at 400 °C; (b) Load vs lateral deflection of 65×65×6 section at 600 °C, and (c) Failure mode of 65×65×3 section.....	134
Fig. 5.9. Design fire curve used for the fire simulation: (a) Heat release rate of the fire source; (b) Gas temperature at the mid-height of the fire compartment.	135
Fig. 5.10. Model geometries for the three cases selected: (a) case 1, (b) case 2, (c) case 3.....	137
Fig. 5.11. The gas temperature variations near the intermediate column exposed to the intermodular cavity.	139
Fig. 5.12. The gas temperature variations along the centre of the intermodular cavity: (a) Case 1; (b) Case 2; (c) Case 3.....	140
Fig. 5.13. The column temperature variations at the bottom (0 m) and the top (3 m) of the column under different ventilation scenarios.	142
Fig. 5.14. The surface temperature contours obtained for the cavity thermal conditions.	144
Fig. 5.15. The maximum surface temperature at the Cold Flange (CF) side and Hot Flange (HF) side with time.	144
Fig. 5.16. Relative restraining forces (P/P_0) vs time plots: (a) Typical structural response, (b) 65×65×3, (c) 89×89×3.5, (d) 100×100×3, (e) 125×125×4, (f) 150×150×5, (g) influence of load ratio (LL = load ratio, P = Pinned, F = fixed)....	148
Fig. 5.17. Maximum lateral displacement with time.	153
Fig. 5.18. Plastic strain distribution (for clarity, enlarged images capture the critical areas).....	158
Fig. 5.19. Load ratio vs maximum increment of restraint forces during the cavity fire heat exposure.....	162

Fig. 6.1. Experimental setup for load capacity test under ambient conditions: (a) schematic diagram, (b) three-dimensional images.....	166
Fig. 6.2. Block designed to enforce pinned boundary conditions.....	166
Fig. 6.3. Visual observations during the experiment	167
Fig. 6.4. Localised failure at the mid-height of the column.....	167
Fig. 6.5. Experimental results from column load test under ambient conditions: (a) Bottom displacement, (b) Lateral displacement, (c) Strain measurement	168
Fig. 6.6. True stress-strain curve used in structural modelling.	169
Fig. 6.7. Mesh geometry used in the structural model.	170
Fig. 6.8. Boundary condition enforcement.....	171
Fig. 6.9. Elastic buckling mode shapes used to incorporate geometric imperfections: (a) Global buckling mode, (b) Local buckling mode.....	172
Fig. 6.10. Comparison of load vs. lateral displacement results of the experiment and the finite element model.....	174
Fig. 6.11. Comparison of load vs. bottom displacement results of the experiment and the finite element model.....	174
Fig. 6.12. Comparison of strain results of the experiment and the finite element model.	175
Fig. 6.13. Comparison of failure mode observed in the experiment with FE model results: (a) global buckling failure, (b) web, (c) compression flange and (e) tension flange.....	176
Fig. 6.14. Experimental setup used to test column specimens under cavity fire conditions: (a)pictorial diagram, (b) schematic diagram	177
Fig. 6.15. Measurements related to fire conditions.....	179
Fig. 6.16. Measurements associated with structural behaviour	180
Fig. 6.17. The cumulative flow of LP gas during test 01 was measured from the diaphragm gas flow meter.....	181
Fig. 6.18. Flame height monitoring for test 1 over a 10-second duration.....	182

Fig. 6.19. Gas temperature (T_g) measured along the height of the cavity: (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.....	184
Fig. 6.20. The surface temperature of the hot flange ($T_{s, HF}$): (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.....	186
Fig. 6.21. Cold flange surface temperature ($T_{s, CF}$) along column height: (a) 600 mm and (b) 1200 mm	187
Fig. 6.22. Deformation of the column during the test: (a) test 01, (b) test 02, (c) test 03.....	190
Fig. 6.23. Lateral displacements measured during the experiments.	191
Fig. 6.24. Downward displacement measured at the top supporting block.	191
Fig. 6.25. Failure modes: (a) global buckling failure, (b) local buckling failure at the cold flange, (c) local buckling at the web (side flange).	193
Fig. 6.26. Workflow used to couple CFD and FE models.	195
Fig. 6.27. The geometry of the FDS model.	197
Fig. 6.28. Cross-sectional view of the FDS model at the bottom of the cavity.	197
Fig. 6.29. Mesh details of the FDS model.	199
Fig. 6.30. Boundary condition enforcement.....	201
Fig. 6.31. Gas temperature (T_g) results comparison between the experiment and the numerical model (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.	204
Fig. 6.32. Comparison of numerical model results for hot ($T_{s, HF}$) temperature with experimental results: (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) and 1500 mm.	206
Fig. 6.33 Comparison of Cold flange surface temperature ($T_{s, CF}$) results of the numerical model with experimental results: (a) 600 mm and (b) 1200 mm.	207
Fig. 6.34. Average cumulative heat release rate per unit volume along the centre of the flame from 290 s to 300 s.....	208

Fig. 6.35. Comparison of lateral displacement in the FE model with experimental results.	209
Fig. 6.36. Comparison of the final deformed shape from the FE model with experimental observations.....	209
Fig. 6.37. Time vs. support reaction (column load) obtained from the FE model. ..	210
Fig. 6.38. FE model visualisations for the cold flange local buckling failure.	210
Fig. 6.39. Localised deformation in the web was observed in the FE model.	210
Fig. 6.40. Representation of standard compartment fire and cavity fire interaction.	212
Fig. 6.41. Gas temperature variation at the bottom of the cavity under burner heat release rates varied according to the shape of the standard fire curve.	213
Fig. 6.42. True stress-strain curves for G 350 steel.	215
Fig. 6.43. The FDS model geometry used in the parametric analysis.	216
Fig. 6.44. Typical Abaqus model geometry, mesh and boundary conditions used in the parametric analysis.....	216
Fig. 6.45. Visual representation of the displacement-based failure criteria (Failure criteria 2).	217
Fig. 6.46. Fire resistance levels for a 100 × 100 mm column under 22.5 kW cavity fire intensity.....	222
Fig. 6.47. Failure probabilities under different parametric variations: (a) failure criteria 1 and (b) failure criteria 2.....	224
Fig. 6.48. ANN architecture of the ML model predicting failure time under failure criteria 2.	227
Fig. 6.49. Loss (Mean square error) curve for training and testing data sets.....	228
Fig. 6.50. Trained and test data distribution with predicted values.	228
Fig. 6.51. SHAP summary plot explaining the ML model prediction.	232
Fig. 6.52. Dependency plot for Cavity width.....	232

Fig. 6.53. Design charts for the FRL of a 100×100 SHS column (G350) under cavity fire exposure: (a) $100 \times 100 \times 2$ mm SHS section, (b) $100 \times 100 \times 5$ mm SHS section.	235
Fig. 6.54. Risk variation with cavity width under failure criteria: (a) Failure criteria 1, (b) Failure criteria 2.	237
Fig. 6.55. Average COV values for the selected critical temperature metrics.	239
Fig. 6.56. Parametric analysis data vs predicted data for train and test sets: (a) Failure criteria 1, (b) Failure criteria 2.	241
Fig. 6.57. SHAP summary plots for developed ML models to predict critical temperature: (a) Failure criteria 1, (b) Failure criteria 2.	243
Fig. 6.58. Mean predictions for critical temperature under criteria 1 grouped under load ratio and cavity width.	245
Fig. 6.59. Critical temperature VS load ratio relationship.	246
Fig. 6.60. Critical temperature (Section average temperature) variation for cavity widths under failure criterion 2.	247
Fig. 6.61. Maximum increment of restraint force against load ratio under different cavity fire intensities: (a) 2.5 kW, (b) 17.5 kW, (c) 22.5 kW and (d) 60 kW.	250
Fig. 6.62. The variation in capacity obtained from FEA and using existing provisions in AS4600.	255
Fig. 6.63. Identification of the effect of temperature distribution and Load ratio on the variation between FEA capacity and capacity from design calculation.	255
Fig. 6.64. Effect of modifying design capacity values: (a) Capacity from FEA vs modified design capacity value, (b) Variation with the FEA value with the modification factor. (c) Variation with the FEA value without the modification factor.	258
Fig. 7.1. Proposed fire protection solution for cavity fire exposure to structural elements.	263

Fig. 7.2. Experimental setup used to test column specimens under cavity fire conditions with plasterboard protection: (a) pictorial diagram, (b) schematic diagram.	266
Fig. 7.3. Flame height monitoring for test 1 over a 10-second duration.....	267
Fig. 7.4. Gas temperature (T_g) measured along the height of the cavity during protected column experiment: (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) and 1500 mm.	269
Fig. 7.5. The surface temperature of the hot flange ($T_{s, HF}$) measured during the protected column experiment, along the height of the cavity: (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.....	271
Fig. 7.6. Cold flange surface temperature ($T_{s, CF}$) measured along the height of the cavity: (a) 600 mm and (b) 1200 mm.....	272
Fig. 7.7. Deformation of the column during the test: (a) test 01, (b) test 02, (c) test 03.	274
Fig. 7.8. Lateral displacements measured during the experiments.	275
Fig. 7.9. Failure modes in the protected column test in comparison with the ambient tests: (a) global buckling failure, (b) local buckling failure at the cold flange, (c) local buckling at the web (side flange).	277
Fig. 7.10. The geometry of the FDS model is modified to account for fire protection from the plasterboard layer.	281
Fig. 7.11. Gas temperature (T_g) results comparison between the experiment and the numerical model (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.	284
Fig. 7.12. Comparison of numerical model results for hot ($T_{s, HF}$) temperature with experimental results: (a) 300 mm, (b) 600 mm, (c) 900 mm, (d) 1200 mm, (e) 1500 mm.	286
Fig. 7.13. Comparison of Cold flange surface temperature ($T_{s, CF}$) results of the numerical model with experimental results: (a) 600 mm and (b) 1200 mm.....	287

Fig. 7.14. Comparison of lateral displacement in the FE model with experimental results.	288
Fig. 7.15. Comparison of the final deformed shape from the FE model with experimental observations.....	289
Fig. 7.16. Time vs. support reaction (column load) obtained from the FE model. ..	289
Fig. 7.17. FE model visualisations for the cold flange local buckling failure.	290
Fig. 7.18. Fire resistance levels for 100 × 100 mm column (G350) protected with plasterboard under cavity fire within different cavity widths: (a) 10 mm cavity; (b) 25 mm; (c) 50 mm; (d) 75 mm and (d) 100 mm (NP = no protection, 10P = with 10 mm plasterboard protection).	296
Fig. 7.19. Improvement in fire resistance under plasterboard protection.	297
Fig. 7.20. Probabilities of FRL exceeding a given FRL under a specified plasterboard thickness.....	300
Fig. 7.21. Influence of cavity width and load ratio on probabilities of FRL exceeding a given FRL under a specified plasterboard thickness: (a) load ratio and (b) cavity width.	301
Fig. 7.22. ANN architecture of the ML model predicting time vs lateral displacement variation to calculate failure time under failure criteria 2.....	303
Fig. 7.23. Trained and test data distribution with predicted values.	304
Fig. 7.24. Loss (Mean square error) curve for training and testing data sets.....	304
Fig. 7.25. Comparison of time vs lateral displacement predicted by ML model with the FEA results.....	306
Fig. 7.26. Design charts for the FRL improvement of a 100×100×5 SHS column (G350) under different cavity fire intensities: (a) 2.5 kW, (b) 17.5 kW, (c) 22.5 kW and (d) 60 kW.....	311
Fig. 7.27. Average COV values for the selected critical temperature metrics of the protected column.....	312

Fig. 7.28. Typical hot flange temperature distribution for unprotected and protected columns under cavity fire exposure ($89 \times 89 \times 5$ mm column, 50 mm cavity width under 17.5 kW fire).	313
Fig. 7.29. Comparison of critical hot flange average temperatures for failure criterion 1 for protected and unprotected columns.	314
Fig. 7.30. Critical average section temperatures for failure criteria 2 for protected columns.	315
Fig. 7.31. Different options to improve FRL.	316

LIST OF TABLES

Table 2.1. Classification of cavity types and their characteristics.	12
Table 2.2. Influential parameters for fire behaviour within cavity spaces indicated in the reviewed articles.....	13
Table 2.3. Effects of cavity boundaries on flame extension.	16
Table 2.4. Involvement of cavity geometries in increasing heat flux.	19
Table 2.5. Involvement of cavity geometries in increasing cavity surface/gas temperature compared to an open-fire scenario.	22
Table 2.6. Involvement of cavity geometries in increasing fire spread compared to a non-cavity geometry.....	24
Table 2.7. Location of fire initiation	26
Table 2.8. Usage of parallel panel testing geometries in fire testing.	45
Table 2.9. Building classes in NCC.	47
Table 2.10. Structural adequacy FRL requirements for structural columns specified in the NCC.....	48
Table 2.11. Fire resistance levels for cold-formed steel columns.....	50
Table 3.1. Comparison of model results.	62
Table 3.2. Numerical simulation program summary.	65
Table 3.3. Surface temperature increment rates for height at 0.85 m.	76
Table 3.4. The influence of increasing fire size from 10 kW to 40 kW.....	80
Table 3.5. Calculation of overall severity variation with cavity width for 40 kW cavity fire.	84
Table 3.6. Calculation of overall severity variation with cavity width for a 10 kW cavity fire.	84
Table 4.1. Partially opened cavity fire numerical simulation program summary.....	90
Table 4.2. Average flame heights at steady state.	91

Table 4.3. Temperature increment from the 120 th second to the 180 th second.	105
Table 4.4. Surface temperature distribution along the vertical direction against ignition criteria.	108
Table 4.5. Surface temperature distribution along the horizontal direction against ignition criteria	108
Table 4.6. Potential fire spread rates (mm/s) calculated from hypothetical ignition temperatures of 200 °C and 300 °C.	109
Table 4.7. Average steady-state velocity at the top of the cavity.	112
Table 4.8. Calculation of overall severity variation with cavity width for 40 kW cavity fire.	116
Table 4.9. Calculation of overall severity variation with cavity width for a 10 kW cavity fire.	116
Table 5.1. Thermocouple details and locations used in the experiment.	123
Table 5.2. Comparison of global buckling capacity under fire.	133
Table 5.3. Simulated fire scenarios.	136
Table 5.4. Parametric variations were made to assess the structural response of the intermediate column under cavity fire exposure.	138
Table 5.5. Restraining forces and the capacity reduction results.	149
Table 5.6 . Failure time.	159
Table 6.1. Parametric variations conducted to identify fire resistance of CFS SHS column sections under cavity fire.	215
Table 6.2. Parameter distribution in the cases where failure criterion 1 has governed the fire resistance of the column.	219
Table 6.3. Parameter distribution in cases where failure criterion 2 has governed the fire resistance of the column.	219
Table 6.4. Summary of Fire Resistance Level (FRL) ranges from the parametric analysis.	220
Table 6.5. Hyperparameter tuning details.	226

Table 6.6. Accuracy metrics of the developed ML model.....	228
Table 6.7. Parametric variations are used to develop design charts.....	233
Table 6.8. Optimised hyperparameters used to train the ML models on the critical temperature.....	240
Table 6.9. Accuracy metrics of the developed ML models for critical temperature.	241
Table 7.1. Comparison of protected column test results with unprotected column test results.	278
Table 7.2. Parametric variations were conducted to identify the fire resistance of CFS SHS column sections protected with plasterboard sheathing under cavity fire.	291
Table 7.3. Overall quantification of fire resistance improvement with a single layer of plasterboard protection.....	298
Table 7.4. Hyperparameter tuning details.	302
Table 7.5. Accuracy metrics of the developed ML model.....	303
Table 7.6. Parametric variations used to develop design charts.	307
Table 7.7. The plasterboard thickness requirements to achieve this 120 min FRL requirement for a $100 \times 100 \times 5$ column under different cavity widths.	308
Table 7.8. Parametric variations used to identify the minimum plasterboard thickness required to increase FRL by 30, 60,90 and 120 minutes.	317
Table 7.9. Parametric variations used to identify cavity width variation required to increase FRL by 30, 60,90 and 120 minutes.....	317
Table 7.10. Requirements to increase FRL by 30 min under different FRL improvement options.....	317

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

Appendix	Description	Page
Appendix – A	Python script used to incorporate FDS results in Abaqus	346
Appendix – B	Material testing under elevated temperature	351
Appendix – C	Gas temperature within the parallel panel setup	354
Appendix – D	Suitability of column sizes for structures up to 10 stories	356
Appendix – E	Results from unprotected column parametric analysis	361
Appendix – F	FRL variation with cavity width for unprotected columns	377
Appendix – G	ANN-based machine learning model development	389
Appendix – H	FRL Design charts for unprotected columns	394
Appendix – I	Calculation of the load capacity of a $89 \times 89 \times 5$ mm SHS column under cavity fire exposure	398
Appendix – J	FRL results for protected column specimens	408
Appendix – K	Design charts for the FRL improvement	418
Appendix – L	Publications and achievements	438