

Contents

1	Introduction and research motivation	1
1.1.	Background	1
1.2.	Research objectives.....	18
1.3.	Methodology.....	19
1.4.	Dissertation structure	21
2	State of the art	23
2.1.	Abstract.....	23
2.2.	Introduction.....	24
2.3.	Methodology	25
2.4.	Results	28
2.4.1.	General overview.....	28
2.4.2.	Fire safety regulations	32
2.4.3.	Fire risk assessment.....	35
2.4.4.	Fire protection and mitigation measures	40
2.4.5.	Spread of both fire and smoke and evacuation	44
2.4.6.	Thermomechanical behaviour of historic structures or materials	48

2.4.7. Fire safety engineering design.....	53
2.5. Discussion.....	56
2.5.1. Discussion of the results.....	56
2.5.2. Statistical analysis.....	59
2.5.3. Future research areas.....	62
2.6. Conclusions.....	63
2.7. Acknowledgements	64
3 Deterministic analyses.....	65
3.1. Abstract	65
3.2. Introduction.....	66
3.3. Case study	69
3.4. Basic safety requirements to be fulfilled.....	69
3.5. Methodology	70
3.5.1. Fire models	71
3.5.2. Thermal analysis.....	76
3.5.3. Mechanical analysis.....	91
3.6. Results and discussion.....	96
3.7. Parametric study.....	103
3.8. Conclusions and future work.....	108
3.9. Acknowledgements	110
4 Sources of uncertainty.....	113
4.1. Density and mechanical properties of historic timber	113
4.1.1. Abstract	113
4.1.2. Introduction.....	114
4.1.3. Materials and methods	116
4.1.4. Data on density, MOR and MOE of contemporary and historic timber	118
4.1.5. Probability density functions of density, MOR and MOE of contemporary and historic timber	126

4.1.6. Discussion	143
4.1.7. Conclusions and future research	150
4.1.8. Acknowledgements.....	152
4.2. Reduction of timber strength at elevated temperatures	153
4.2.1. Abstract.....	153
4.2.2. Introduction.....	153
4.2.3. Materials and methods.....	156
4.2.4. Data on temperature-dependent material strength of timber.....	158
4.2.5. Probabilistic modelling of the temperature-dependent strength..	168
4.2.6. Discussion	181
4.2.7. Conclusions	182
4.2.8. Acknowledgements.....	184
5 Probabilistic analyses	185
5.1. Abstract.....	185
5.2. Introduction.....	186
5.3. Case studies.....	188
5.4. Methodology	190
5.5. Random variables.....	194
5.5.1. Fire development	194
5.5.2. Thermal and structural response	196
5.6. Probabilistic fire risk analyses.....	203
5.6.1. Standard ISO-834 fire exposure.....	203
5.6.2. Parametric fire curves	206
5.7. Conclusions	213
5.8. Acknowledgements.....	215
6 Discussion.....	217
6.1. Research question 1.....	217
6.2. Research question 2.....	219
6.3. Research question 3.....	222

6.4. Research question 4	224
6.5. Research question 5	226
7 Conclusions.....	231
7.1. Main findings	231
7.1.1. Vulnerability of heritage and historic buildings to fire	231
7.1.2. Probabilistic characterisation of the density and mechanical properties of historic timber at ambient temperature.....	232
7.1.3. Probabilistic characterisation of timber strength reduction at elevated temperatures.....	234
7.1.4. Fire resistance of historic timber jack arch flooring systems	235
7.2. Recommendations for future research.....	240
8 References	245