Contents

1 Introduction 1
1.1 Background to the Project 1
1.2 Objective and Originality 2
1.3 Outline of Chapters 3
References 4

2 Fire Modeling 7
2.1 Introduction 7
2.2 One-Zone Compartment Fire Model 8
2.2.1 Heat Balance Equation 8
2.2.2 Heat Release Rate (*HRR*) 8
2.2.3 Heat Loss Due to Convective Flow ($\dot{q}_{o,c}$) 10
2.2.4 Heat Loss by Radiation Through the Openings ($\dot{q}_{o,r}$) 11
2.2.5 Heat Loss Through Wall ($\dot{q}_w$) 11
2.2.6 Heat Storage in Gas Volume ($\dot{q}_g$) 12
2.3 Temperature-Time Curves for Post-Flashover Fires 12
2.3.1 Standard Fire 12
2.3.2 Swedish Curves 13
2.3.3 Lie Correlations 13
2.3.4 EC1 Parameter Fire Curve 14
2.4 The Concept of Time Equivalent 15
2.4.1 Overview 15
2.4.2 EC1 Correlation 16
2.5 Finite Element Simulation 17
2.5.1 Numerical Tool 17
2.5.2 Basic Elements 17
2.5.3 FE Model 18
2.5.4 Verification of the FE Model 19
2.6 Conclusion 20
References 20

3 Steel Temperature in Natural Fires 21
3.1 Introduction 21
3.2 One-Dimensional Heat Transfer Model 21
3.3 Current Calculation Formulae 23
3.3.1 CECS200 Formula 23
3.3.2 Pettersson et al.'s Formula 24
3.3.3 EC3 Formula 24
3.3.4 ECCS Formula 24
3.3.5 Silva's Formula 25
3.4 Shortcomings of the Current Formulae 25
3.5 Proposed Simple Approach 26
3.5.1 Methodology 26
3.5.2 Compare with OZone V2 27
3.5.3 Compare with FEM 31
3.5.4 Compare with Test Data 32
3.5.5 Profession Factor 32
3.6 Conclusions 35
References 36

4 Thermal Properties of Intumescent Coatings in Fire 37
4.1 Introduction 37
4.2 Theoretical Models for Intumescent Coatings 39
4.2.1 Intumescing Process 39
4.2.2 Thermal Conductivity of the Char 39
4.3 Equivalent Thermal Resistance of Intumescent Coatings 40
4.3.1 Equivalent Thermal Resistance 40
4.3.2 Equivalent Constant Thermal Resistance 41
4.4 Experimental Investigation 41
4.4.1 Test on Small-Scale Samples 41
4.4.2 Test on Steel Members 45
4.4.3 T_s Calculated by Using R_{const} 48
4.5 Conclusions 49
References 49

5 Behavior of Steel Columns in Fire 51
5.1 Introduction 51
5.2 Fundamental Principles 52
5.3 Design Method 54
5.3.1 Failure Criterion 54
5.3.2 Free Steel Column in Fire 55
5.3.3 Restrained Steel Column in Fire 56
5.3.4 FEM Model 57

5.4 Test Data . . . 58
5.4.1 Buckling Temperature of Free Column . . . 58
5.4.2 Buckling Temperature of Restrained Column . . . 66
5.4.3 Limit Temperature of Restrained Column . . . 66
5.5 Compare Among Predicted and Measured Results . . . 66
5.5.1 Buckling Temperature for Free Column . . . 66
5.5.2 Buckling Temperature for Restrained Column . . . 72
5.5.3 Limit Temperature for Restrained Column . . . 72
5.5.4 Discussion . . . 72
5.6 Professional Factor for Limit Temperature . . . 76
5.7 Conclusions . . . 79
References . . . 80

6 Reliability Analysis . . . 81
6.1 Introduction . . . 81
6.2 Deterministic Approaches . . . 81
6.3 Probabilistic Approach . . . 81
6.3.1 Parameter Uncertainties . . . 81
6.3.2 Professional Factors . . . 83
6.4 Reliability Theory . . . 83
6.5 Reliability Analysis . . . 85
6.5.1 Performance Function . . . 85
6.5.2 Investigated Cases . . . 85
6.5.3 Monte Carlo Simulations . . . 86
6.5.4 Results . . . 86
6.6 Conclusion . . . 102
References . . . 102

7 Service Life of Intumescent Coatings . . . 103
7.1 Introduction . . . 103
7.2 Probability of Fire Ignition . . . 103
7.3 Probability of Flashover Occurrence . . . 104
7.4 Probability of Structural Failure by Fire . . . 104
7.5 Service Life of Intumescent Coating . . . 105
7.6 An Example . . . 105
References . . . 106

8 Conclusions and Further Work . . . 107
8.1 Introduction . . . 107
8.2 Summary and Conclusions . . . 108
8.3 Further Work . . . 110
8.3.1 Testings . . . 110
8.3.2 Reliability Analysis . . . 111

Appendix A: Fundamentals of Heat Transfer 113

Appendix B: High Temperature Material Properties of Structural Steel 125

Appendix C: Commonds for Modified One Zone Model 131

Appendix D: Commonds for Monte Carlo Simulations 137

http://www.springer.com/978-3-662-46378-9

Reliability of Steel Columns Protected by Intumescent Coatings Subjected to Natural Fires

Zhang, C.

2015, XXIV, 140 p. 74 illus., Hardcover
ISBN: 978-3-662-46378-9