
Contents

Preface..... ix

Authors..... xi

Contributor..... xiii

Chapter 1 Fire and Explosion..... 1

 Summary 1

 1.1 Category and Classification..... 1

 1.2 Pool Fire 2

 1.3 Jet Fire 7

 1.4 Fireball.....10

 1.5 Flash Fire11

 1.6 Explosion11

 1.7 Explosion Classifications..... 14

 1.7.1 Vapor Cloud Explosion (VCE) 14

 1.7.2 Pressure Vessel Explosion (PVE).....15

 1.7.3 Boiling Liquid Expanding Vapor
 Explosion (BLEVE) 16

 1.7.4 Condensed-Phase Explosion (CPE)..... 23

 1.7.5 Dust Explosion 24

 1.8 Fire and Explosion Characteristics..... 25

 1.8.1 Combustion..... 25

 1.8.2 Ignition 25

 1.8.3 Autoignition Temperature (AIT)..... 25

 1.8.4 Spontaneous Combustion 25

 1.8.5 Flash Point..... 26

 1.8.6 Fire Point..... 26

 1.8.7 Flammability Limits 27

 1.8.8 Limiting Oxygen Concentration..... 27

 1.9 Flammability Diagram 30

 1.9.1 Constructing Flammability Diagram..... 30

 1.10 Damage Consequences of Fire and Explosion32

Chapter 2 Material Properties.....35

 Summary 35

 2.1 Introduction35

 2.2 Properties of Steel37

 2.2.1 Carbon Steel and Alloying Elements39

 2.3 Properties at High Temperature39

 2.4 Reinforcing Steel45

 2.4.1 Mechanical Properties.....45

 2.5 Concrete..... 49

2.5.1	Mechanical Properties.....	49
2.5.2	Thermal Properties.....	52
2.6	Functionally Graded Materials.....	56
2.6.1	FGM for High Temperature	58

Chapter 3	Fire Design	63
	Summary	63
3.1	Fire as a Hazard.....	63
3.2	Development of a Fire	66
3.3	Fire Safety	71
3.3.1	Objectives of Fire Safety	71
3.3.1.1	Life Safety	71
3.3.1.2	Property Protection.....	71
3.3.1.3	Environment Protection.....	71
3.3.2	Scenario Analysis.....	71
3.3.3	Fire Safety Measures.....	74
3.3.4	Structural Fire Safety	75
3.4	Codes and Standards	76
3.5	Fire Behavior	78
3.5.1	Fuels	79
3.5.2	Calorific Value.....	79
3.5.3	Heat Release Rate.....	80
3.6	Fire Load	81
3.7	Fire Initiation and Flame Spread.....	82
3.7.1	Phase Change and Decomposition	82
3.7.2	Fire Initiation.....	82
3.7.3	Flame Spread.....	83
3.8	Compartment Fires.....	83
3.8.1	Pre-Flashover Fires	84
3.8.2	t^2 Fire Model	85
3.9	Energy and Burning Time	85
3.9.1	Pre-Flashover Fire Calculations.....	87
3.10	Flashover.....	88
3.11	Post-Flashover Fires	89
3.12	Ventilation-Controlled Fire	89
3.12.1	Burning Rate	90
3.12.2	Ventilation Factor	91
3.12.3	Effects of Multiple Openings	91
3.13	Fuel-Controlled Fire	92
3.14	Time-Temperature Curves.....	93
3.14.1	Standard Fire	93
3.15	Design Fires.....	94
3.15.1	Constant Peak Temperature	95
3.15.1.1	Published Curves	96
3.16	Parametric Curves	96

3.17 Burning Period 97
3.17.1 Decay Rate 98
3.18 Time-Temperature Curves 98
3.19 Fire Resistance 100
3.20 Equivalent Fire Severity 101
3.20.1 Area Equivalence 101
3.20.2 Maximum Temperature Equivalence 102
3.20.3 Minimum Load Capacity Equivalence 102
3.21 Thermodynamic Properties 103
3.21.1 Conduction 103
3.21.2 Convection 107
3.21.3 Radiation 108
3.22 Transient Heat Transfer 115
3.23 Boundary Conditions 116
3.24 Lumped Capacity Idealization for Steel 118
3.25 Semi-Infinite Idealization for Concrete and Masonry 121
3.26 Structural Temperatures Under Standard Fire 125
3.26.1 Temperature Calculation for Steel
Structural Members 125
3.26.2 Temperature Calculation for Concrete
Structural Members 130
3.27 Design Theory – Limit States of Design 137
3.28 Tension Members 139
3.29 Design for Flexure – Beams 144
3.29.1 Steel Beams 144
3.29.2 Reinforced Concrete Beams 151
3.30 Compression Members – Columns 161
3.30.1 Steel Columns 161
3.30.2 Reinforced Concrete Columns 167
3.31 Slabs 173

Chapter 4 Fire Protection 177
Summary 177
4.1 Fire Protection 177
4.2 Active Fire Protection Systems 177
4.3 Passive Fire Protection Systems 178
4.4 Case Studies 179
4.5 Station Nightclub, USA 179
4.6 Grenfell Tower, London, UK 179
4.7 Plasco Building, Tehran, Iran 180
4.7.1 Fire Development and Growth 180
4.7.2 Structural Collapse 181
4.7.3 Important Observations 181
4.8 Chennai Silks Building, Chennai, India 181
4.8.1 Building Description and Use 182

4.8.2	Fire Protection.....	182
4.8.3	Fire Development and Growth.....	182
4.8.4	Structural Failure	182
4.8.5	Important Observations.....	183
4.9	Takshashila Complex, Surat, India.....	183
4.9.1	Building Description and Use	183
4.9.2	Egress Arrangements	183
4.9.3	Firefighting Access and Fire Protection Systems.....	184
4.9.4	Fire Growth and Development.....	184
4.9.5	Effects on Occupants.....	185
4.9.6	Important Observations.....	185
References		187
Index.....		193