

---

**TABLE OF CONTENTS**

CHAPTER 1. INTRODUCTION..... 1

    1.1. Background .....2

        1.1.1. Advantages of CFT columns .....5

        1.1.2. Practical applications.....7

    1.2. Fire behaviour of CFT columns .....10

        1.2.1. Fire dynamics analysis.....15

        1.2.2. Heat transfer analysis.....18

        1.2.3. Structural analysis .....23

CHAPTER 2. STATE OF THE ART.....25

    2.1. General .....26

    2.2. Analytical models .....27

    2.3. Numerical models .....29

    2.4. Experimental investigations.....33

    2.5. Simple calculation models (design guidelines) .....37

    2.6. Elliptical hollow section columns .....40

CHAPTER 3. AIM AND SCOPE OF THIS THESIS.....43

    3.1. Aim of this thesis .....44

        3.1.1. Specific objectives.....44

    3.2. Scope and limitations of this thesis .....45

CHAPTER 4. DEVELOPMENT OF THE NUMERICAL MODEL .....47

    4.1. Characteristics of the numerical model.....48

        4.1.1. Geometry and finite element mesh of the model .....48

        4.1.2. Material properties at elevated temperatures .....50

            4.1.2.1. Thermal properties at elevated temperatures.....50

            4.1.2.2. Concrete material model at elevated temperatures .....51

            4.1.2.3. Steel material model at elevated temperatures .....57

*Numerical analysis of the fire resistance of circular and elliptical slender CFT columns*

---

4.1.3. Initial geometric imperfection of the column .....	59
4.1.4. Analysis procedure.....	60
4.1.5. Thermal analysis .....	62
4.1.6. Structural analysis.....	65
4.1.7. Nonlinear solution method.....	65
4.1.8. Thermal and mechanical contact at the steel-concrete interface .....	66
4.1.8.1. Thermal contact.....	66
4.1.8.2. Mechanical contact.....	68
4.2. Validation of the model.....	70
4.2.1. Validation against tests from the literature.....	70
4.2.1.1. Thermal response.....	72
4.2.1.2. Mechanical response.....	74
4.2.2. Validation against own experiments .....	80
4.3. Sensitivity analysis.....	93
4.3.1. Steel-concrete interface friction model .....	93
4.3.2. Gap thermal conductance.....	95
4.3.3. Initial geometric imperfection.....	99
4.3.4. Material mechanical models at elevated temperatures .....	99
4.3.5. Thermal expansion coefficient.....	102
4.3.6. Concrete moisture .....	106
4.3.7. Concrete density.....	109
4.3.8. Rebar finite element type.....	109
CHAPTER 5. CONCRETE FILLED ELLIPTICAL STEEL COLUMNS.....	111
5.1. Concrete filled elliptical hollow section columns at room temperature.....	112
5.1.1. Description of the finite element model.....	112
5.1.2. Material models at room temperature .....	115
5.1.3. Comparison between numerical and experimental results .....	116

---

5.1.4. Findings from the finite element modelling.....	118
5.2. Concrete filled elliptical hollow section columns exposed to fire.....	119
5.2.1. Description of the finite element model.....	119
5.2.2. Material models at elevated temperatures.....	121
5.2.3. Analysis procedure .....	122
5.2.3.1. Thermal analysis .....	122
5.2.3.2. Structural analysis .....	122
5.2.4. Validation of the model for CFEHS columns at elevated temperatures .....	123
5.3. Parametric studies .....	125
5.3.1. Analysis cases.....	125
5.3.2. Effect of column slenderness.....	130
5.3.3. Effect of load level .....	131
5.3.4. Effect of cross-section slenderness .....	131
5.3.5. Effect of section size .....	133
5.4. Comparison between elliptical and circular CFT columns in fire.....	134
CHAPTER 6. DEVELOPMENT OF A SIMPLE CALCULATION MODEL .....	139
6.1. Review of existing design guidance.....	140
6.1.1. Simple calculation model in Annex H of EN 1994-1-2.....	140
6.1.2. General method for composite columns in Clause 4.3.5.1 of EN 1994-1-2.....	142
6.1.3. French National Annex to EN 1994-1-2.....	144
6.1.4. Simplified design equation proposed by Kodur.....	145
6.1.5. Strength index formulation proposed by Han et al. ....	146
6.1.6. Fire resistance design formula used in Japan.....	147
6.2. Evaluation of the current calculation methods in Eurocode 4.....	148
6.3. Development of a new simple calculation model for axially loaded CFT columns ...	152
6.3.1. Parametric studies.....	152
6.3.1.1. Analysis of results .....	155

*Numerical analysis of the fire resistance of circular and elliptical slender CFT columns*

---

6.3.2. Study and discussion of Eurocode 4 Part 1.2 .....	157
6.3.3. Simplified cross-sectional temperature field .....	160
6.3.4. Flexural stiffness reduction coefficients.....	167
6.3.5. Comparison of the proposed method with experiments .....	178
6.3.6. Design example.....	180
6.4. Extension of the method to reinforced columns .....	183
6.4.1. Parametric studies .....	183
6.4.1.1. Analysis of results .....	184
6.4.2. Study and discussion of Eurocode 4 Part 1.2 .....	185
6.4.3. Simplified cross-sectional temperature field.....	188
6.4.4. Flexural stiffness reduction coefficients.....	191
6.4.5. Comparison of the proposed method with experiments .....	194
6.5. Application of the proposed method to CFEHS columns.....	196
6.5.1. Simplified cross-sectional temperature field.....	197
6.5.2. Flexural stiffness reduction coefficients.....	206
6.5.3. Comparison of the proposed method with experiments .....	211
6.6. Overview of the proposed calculation method .....	214
CHAPTER 7. CONCLUSIONS .....	219
7.1. General conclusions .....	220
7.2. Specific conclusions.....	220
7.3. Future work .....	224
REFERENCES.....	227
ANNEX I. COMPENDIUM OF PUBLICATIONS	
ANNEX II. MATERIAL CONSTITUTIVE MODELLING	