

## LIST OF CONTENTS

<b>Preface</b> .....	8
Burgess Ian, <i>United Kingdom</i>	
<b>Session 1: Steel Structures</b>	
Simplified method for temperature distribution in slim floor beams.....	11
Zaharia R., Duma D., Romania, Vassart O., Luxembourg, Gernay Th., Franssen J.M., <i>Belgium</i>	
Elastic buckling of steel columns under thermal gradient .....	17
Tsalikis C.T., Koltsakis E.K., Baniotopoulos C.C., <i>Greece</i>	
Adhesion at high temperature of FRP bars straight or bent at the end of concrete slabs.....	23
Nigro E., Cefarelli G., Bilotta A., Manfredi G., Cosenza E., <i>Italy</i>	
Mechanical properties of reinforcing bars heated up under steady stress conditions .....	31
Abramowicz M., Kisieliński R., Kowalski R., <i>Poland</i>	
Coupled structural-thermal calculations for restrained steel columns in fire.....	37
Kwaśniewski L., Balcerzak M., Poland, Ali F., <i>United Kingdom</i>	
Modelling creep in steel structures exposed to fire.....	43
Lee J., Gillie M., <i>United Kingdom</i>	
Fire modelling of axially-restrained tubular steel beams .....	49
Salem O., Hadjisophocleous G., Zalok E., <i>Canada</i>	
Material and creep behaviour of S460 in case of fire: Experimental investigation and analytical modelling.....	55
Schneider R., Lange J., <i>Germany</i>	
An approximation method for critical temperatures of steel members and horizontal displacements of columns .....	61
Hirashima T., Ikuta H., Hidani Y., <i>Japan</i>	
A simplified approach for predicting steel temperatures under design fires.....	67
Dwaikat M.M.S., Kodur V.K.R., <i>USA</i>	
Modelling of multiple localised fires and steel structural members response using the software Elefir-EN.....	73
Vila Real P., Couto C., Lopes N., <i>Portugal</i>	
Constitutive equations for structural steel subjected to fire: Some remarks .....	79
Korzen M., <i>Germany</i>	
<b>Session 2: Concrete Structures</b>	
Modelling of reinforced concrete frames in fire following an earthquake .....	87
Kadir Ab.M. A., Usmani A.S., Gillie M., <i>United Kingdom</i>	
Techniques for the evaluation of concrete structures after fire .....	92
Annerel E., Taerwe L., <i>Belgium</i>	
Thermal diffusivity of tensile cracked concrete .....	97
Ervine A., Gillie M., Stratford T.J., Pankaj P., <i>United Kingdom</i>	

Colour change of heated concrete: RGB colour histogram analysis as a method for fire damage assessment of concrete.....	103
Hager I., <i>Poland</i>	
Influence of transient strain on fire resistance of concrete elements.....	109
Lu L., Annerel E., Taerwe L., <i>Belgium</i> , Yuan Y., <i>China</i>	
A rational approach to fire resistance analysis of RC columns subjected to uniaxial/biaxial bending and axial restraint.....	115
Nguyen T.T., Tan K.H., <i>Singapore</i>	
Using opensees for an RC frame in fire.....	122
Zhang J., Usmani A., Jiang J., Jiang Y., Kotsovinos P. May I., <i>United Kingdom</i>	
Probabilistic analysis of concrete beams during fire .....	127
Van Coile R., Annerel E., Caspele R., Taerwe L., <i>Belgium</i>	
Shear strength of concrete at elevated temperature .....	133
Smith H.K.M., Reid E.R.E., Beatty A.A., Stratford T.J., Bisby L.A., <i>United Kingdom</i>	
Fire design of concrete and masonry structures: Software tools developed at the Czech Technical University in Prague .....	139
Štefan R., Procházka J., Beneš M., <i>Czech Republic</i>	
Study of slab fire resistance according to Eurocode using different computational methods.....	145
Čajka R., Matečková P., <i>Czech Republic</i>	
Axial restrain effects on fire resistance of statically indeterminate RC beams .....	149
Cvetkovska M., Todorov K., Lazarov L., <i>Macedonia</i>	
Numerical investigations of composite slab-beam floor systems exposed to ISO fire .....	155
Nguyen T.T., Tan K.H., <i>Singapore</i>	
<b>Session 3: Composite Structures and Connections</b>	
Analysis of steel–concrete composite beam with interlayer slip in fire conditions .....	165
Hozjan T., Kolšek J., Planinc I., Saje M., Srpčič S., <i>Slovenia</i>	
Fire safety engineering applied to composite steel-concrete buildings: Fire scenarios and structural behaviour .....	171
Nigro E., Ferraro A., Cefarelli G., <i>Italy</i>	
Munich fire test on membrane action of composite slabs in fire: Test results and recent findings .....	177
Stadler M., Mensinger M., Schaumann P., Sothmann J., <i>Germany</i>	
Influence of semi-rigid joint moment-rotation characteristics on the behaviour of composite steel-framed structures under fire conditions .....	183
Yuan Z., Tan K.H., <i>Singapore</i>	
Component-based element for endplate connections in fire.....	195
Dong G., Burgess I.W., Davison J.B., <i>United Kingdom</i>	
The fractural behaviour of steel welds at high temperature .....	201
Yu H., <i>China</i>	
Numerical analysis of HSS endplate connections at ambient and elevated temperatures.....	206
Qiang X., Bijlaard F., Kolstein H., Twilt L., <i>The Netherlands</i>	
Fracture simulation in a steel connection in fire: Simulation of a flush endplate connection at ambient and elevated temperatures including different methods for fracture simulation .....	213
Schaumann P., Kirsch T., <i>Germany</i>	

Thermomechanical nonlinear analysis: Finite element analysis of bolted steel connections using contact mechanics .....	219
Kalogeropoulos A., Drosopoulos G.A., Stavroulakis G.E., <i>Greece, Germany</i>	
A component-based model for fin-plate connections in fire .....	225
Taib M., Burgess I.W., <i>United Kingdom</i>	
Behaviour of heated composite joints: Preliminary numerical studies .....	231
Haremza C., Santiago A., Simões da Silva L., <i>Portugal</i>	
<b>Session 4: Case Studies</b>	
A macroscopic finite element based computer model for evaluating the fire response of FRP-Strengthened Reinforced Concrete Beams .....	239
Ahmed A., Pakistan, Kodur V.K.R., <i>USA</i>	
Fire protection of steel structures using automatic water extinguishing system .....	246
Outinen J., <i>Finland</i>	
Role of CFD in the quantitative assessment of structural performance in fire scenarios .....	251
Gentili F., Grossi L., Bontempi F., <i>Italy</i>	
Evaluation of the fire resistance of the steel structure of a waste treatment plant using structural fire safety engineering .....	257
Vila Real P., Lopes N., <i>Portugal</i>	
Fire resistance of steel trusses with openees .....	263
Kotsovinos P., Usmani A., <i>United Kingdom</i>	
Temperature of steel columns exposed to localised fire .....	269
Sokol Z., <i>Czech Republic</i>	
Behaviour of frame columns in localised fires .....	275
Sun R., Burgess I., Huang Z., <i>United Kingdom</i>	
The role of active fire protection measures in a national fire safety concept in Germany .....	281
Klinzmann C., <i>Germany</i>	
Computational modelling for performance based fire engineering (PBFE) .....	287
Petrini F., Gkoumas K., <i>Italy</i>	
Loading-bearing capacity method for structural fire safety design – A case study .....	293
Du Yong D., Gou-qiang L., <i>China</i>	
RC frame exposed to fire after earthquake .....	299
Lazarov L., Todorov K., Cvetkovska M., <i>Macedonia</i>	
<b>Session 5: Numerical Modelling</b>	
Adaptation of fea codes to simulate the heating and cooling process of timber structures exposed to fire: Mechanical behaviour .....	307
Hopkin D., El-Rimawi J., Silberschmidt V., Lennon T., <i>United Kingdom</i>	
Simulation of the structural behaviour of steel-framed buildings in fire .....	313
Gentili F., Giuliani L., <i>Italy</i>	
Numerical analysis of structures in fire using openees .....	319
Jiang J., Usmani A., Zhang J., Kotsovinos P., <i>United Kingdom</i>	
Development of heat transfer modelling capability in openees for structures in fire .....	324
Jiang Y., Usmani A., Welch S., <i>United Kingdom</i>	

A numerically derived modified conductivity model for softwood exposed to parametric design fires: Background, benchmarking and adaptation for cooling .....	331
Hopkin D., El-Rimawi J., Silberschmidt V., Lennon T., <i>United Kingdom</i>	
Travelling Fires in large compartments: Realistic fire dynamics for structural design.....	337
Rein G., Stern-Gottfried J., <i>United Kingdom</i>	
Application of a virtual resistance furnace: Fire resistance test simulation on a plasterboard membrane .....	343
Cayla F., Leborgne H., Joyeux D., <i>France</i>	
The impact of assumed fracture energy on the fire performance of timber beams: A numerical study.....	349
Hopkin D., El-Rimawi J., Silberschmidt V., Lennon T., <i>United Kingdom</i>	
Stochastic analysis of structures in fire by Monte Carlo simulation .....	355
Shi K., Guo Q., Jeffers A.E., <i>USA</i>	
Integrated numerical modelling in fire safety assessment: Current needs, challenges, potentiality and perspectives.....	361
Król P.A., <i>Poland</i>	
Numerical investigations of plasterboard separating elements subjected to fire.....	367
Tran H., Leborgne H., Zhao B., Millard A., <i>France</i>	
Fire simulation application in fire safety design for tunnel structures .....	373
Dudáček A., Bradáčová I., Kučera P., <i>Czech Republic</i>	
Fire analysis of RC precast segmental tunnels .....	379
Lilliu G., <i>The Netherlands</i> , Meda A., <i>Italy</i>	
<b>Session 6: Fire Testing</b>	
Prediction of temperature variation in an experimental building .....	387
Cheng X., <i>China</i> , Veljkovic M., Byström A., Iqbal N., Sandström J., Wickström U., <i>Sweden</i>	
Effective thermal conductivity of fire proof materials and the measuring method.....	393
Han J., Li G-Q., Lou G-B., <i>China</i>	
Fire load survey of commercial premises in Finland.....	400
Björkman J., Autio V., Ylihärsilä H., Grönberg P., Heinisuo M., <i>Finland</i>	
Systematisation of design fire loads in an integrated fire design system .....	405
Heinisuo M., Laasonen M., Outinen J., Hietaniemi J., <i>Finland</i>	
A structural fire engineering prediction for The Veselí fire test, 2011 .....	411
Huang S-S., Burgess I., Davison B., <i>United Kingdom</i>	
Structural fire engineering in building renovation: Application of natural fire and heat transfer models to guarantee fire safety .....	417
Molkens T., <i>Belgium</i>	
Failure probability assessment for fire situation with a certain type of the network diagram: Example of application .....	423
Maślak M., <i>Poland</i>	
Application of fire safety engineering for open car parks in Italy.....	429
Nigro E., Ferraro A., Cefarelli G., Manfredi G. , Cosenza E., <i>Italy</i>	
Case studies of a new simplified natural fire model and safety concept for structural fire safety design .....	437

Zehfuss J., <i>Germany</i>	
Fire resistance of cast iron columns in Vinohrady brevery.....	443
Wald F., Dagefa M., <i>Czech Republic</i>	
Software application for estimation of fire resistance of the buildings construction.....	449
Vargovsky K., <i>Slovakia</i>	
The impact of flame retarded timber on Greek industries .....	456
Tsatsoulas D., <i>Greece</i>	
<b>Author Index</b> .....	<b>463</b>
<b>Scientific and Organizing Committee</b> .....	<b>466</b>

## PREFACE

Structural fire engineering is a relatively new field for designers and building control authorities. However there is a growing acceptance that the fire-resistant design of buildings should be based on a logical analysis of their performance in the context of realistic fire scenarios, determined from an approach to safety which considers both the statistics of risk and the severity of possible outcomes. Research in this field has experienced very rapid growth since the mid-1990s, particularly in Europe, and there are now many examples of major structures for which structural fire engineering has been incorporated in the design process together with the more traditional fire safety concepts.

The papers published in this volume were presented at the second conference entitled *Applications of Structural Fire Engineering*, which was held at the Czech Technical University in Prague in April 2011. They cover topics across a wide range of research and advanced practice in structural fire engineering, and leading research groups in the field from Europe and world-wide are represented. A declared theme of the conference was the use of advanced modelling, and this is reflected in at least two thirds of the papers. The types of structural systems covered include steel, concrete, composite and timber framed buildings, as well as thermal modelling of fire scenarios. In order to gain acceptance with national and local fire regulation authorities, academic research findings must be used to develop both powerful computational tools and the simplified methods which are more accessible to non-specialists. The latter are particularly suitable for implementation in codes of practice; the structural Eurocodes have initiated this process by including simple, though performance-based, calculation procedures for fire resistance of structural elements which can be used either manually or in spreadsheets. These are necessarily restricted in scope, but mark a very significant psychological move away from the traditional prescriptive rules for fire protection which still dominate in design practice. Much of the work presented here is aimed at evaluating and enhancing these lower-level procedures. In the longer term it seems inevitable that fire-resistant design, particularly of large, complex buildings, will be based on thermo-structural “whole-structure” modelling in realistic fires. The development of components of these modelling tools is well represented in these articles. Although large-scale fire testing is extremely expensive, some testing at realistic scale continues, and these are providing invaluable evidence against which both the simplified and advanced computational approaches can be evaluated. The issue of robustness, or avoidance of disproportionate collapse as a result of discrete structural failures, is increasing in importance. The risks were amply illustrated by the progressive collapse of several buildings of the World Trade Center in New York in 2001 after multi-storey fires. It is clearly desirable that, in future, large buildings are designed so that failures due to unforeseen circumstances are arrested before a catastrophic sequence occurs.

This volume will be of interest both to active researchers and to those (such as regulatory authorities, fire safety engineers and structural designers) with an interest in the movement towards practical performance-based design of structures against fire.

*Ian Burgess*