PROGRESS IN
MECHANICS AND MATERIALS IN DESIGN

J.F. Silva Gomes
Shaker A. Meguid
Editors

Proceedings of the 7th International Conference on Mechanics and Materials in Design, Albufeira/Portugal, 11-15 June 2017

FEUP-INEGI
(2017)

M2D2017

PROGRESS IN MECHANICS AND MATERIALS IN DESIGN

Editors

J.F. Silva Gomes and Shaker A. Meguid

FEUP-INEGI
(2017)

Published by

INEGI-Instituto de Ciência e Inovação em Engenharia Mecânica e Gestão Industrial
Rua Dr Roberto Frias, 4200-465 Porto - Portugal
Telefone: +351 22 9578710; Email: inegi@inegi.up.pt
http://www.inegi.up.pt/

June, 2017

ISBN: 978-989-98832-6-0
N. DL: 423739/17

Printed by:

LusoImpress S.A.
Rua Venceslau Ramos, 28 - 4430-929 Avintes, Portugal
Tel: +351 22 787 73 20; Fax: +351 22 787 73 29
www.lusoimpress.com

TABLE OF CONTENTS

SYMPOSIUM-12: SUSTAINABLE ENERGY SYSTEMS **637**

SYMPOSIUM-13: FIRE AND STRUCTURAL ENGINEERING **653**

EDITORS' PREFACE

M2D2017 is the seventh international gathering of a prestigious series of conferences coordinated by the International Scientific Committee of Mechanics and Materials in Design. This series of conferences is wholy devoted to advances in mechanics, materials, structural integrity and design. M2D2017 is sponsored by the University of Porto, the University of Toronto and the University of Algarve. The conference attracted over 230 participants with 360 accepted submissions from 40 countries out of 416 submissions. These papers were presented in June 11-15, 2017 in the magnificent city of Albufeira/Algarve, Portugal. The conference themes which address novel and advanced topics in Mechanics and Materials in Design focused on computational mechanics, experimental mechanics, fatigue and fracture mechanics, composite and advanced materials, nanotechnologies and nanomaterials, tribology and surface engineering, mechanical design and prototyping, biomechanical applications, civil engineering applications, impact ant crashworthiness, energy and thermo-fluid systems, and industrial engineering and management.

The conference also included an Open Forum on *The Challenges Facing Engineering Education*, where an expert panel with over 100 years of collective and active researchers and educators addressed the roles of professors that they meet, the obligations of their stakeholders and current challenges facing engineering education.

We believe that the meeting offered our delegates a forum for the dissemination of their recent work in mechanics and materials and their applications in engineering design, fostered research that integrates mechanics and materials in the design process, and promoted exchange of ideas and international co-operation among scientists and engineers in this important field of engineering.

We are particularly indebted to the authors and special guests for their presentations. Each of the more than 360 contributions offered opportunities for thorough discussions with the authors. Particularly, we acknowledge the excellent contributions of the participants, their innovative ideas and research directions, the novel modeling and simulation techniques, and the invaluable critical discussions. We are also indebted to the outstanding keynote speakers who highlighted the conference themes with their contributions. We also take this opportunity to thank the members of the International Scientific Committee, the members of the Advisory Committee and the reviewers for their time, effort and helpful suggestions.

We offer our sincere gratitude to the symposia organisers for their efforts and valuable contributions to the success of the event, and the local organising committee for attending to the conference demands and delegates needs.

All in all, M2D2017 was a great success and the credit must go to all the participants for their significant contributions and lively discussions, the keynote speakers for bridging the gap between the different disciplines and the organizing committee for an absolutely superb organization of the meeting in this magnificent city. To all of you, we offer our gratitude.

Given the rapidity with which science is advancing in all areas of mechanics and materials, the next conference in this series (Integrity, Reliability and Failure - IRF2018) will take place in Lisbon, the capital city of Portugal, in July 2018. Undoubtedly, we expect IRF2018 to be as stimulating and interesting as M2D2017, as evidenced by the excellent contributions offered in this current event. We look forward to seeing all of you in Lisbon in 2018.

Shaker A. Meguid and J.F. Silva Gomes
Albufeira / Portugal, June 2017

International Scientific Committee

Aben. H. (Estonia)
António, C.C. (Portugal)
Banks-Sills, L. (Israel)
Barros, R.C. (Portugal)
Bremand, F. (France)
Croccolo, D. (Italy)
Goldak, J. (Canada)
Guagliano, M. (Italy)
Hess, Peter (Germany)
Kaleta, Jerzy (Poland)
Kuhn, Erik (Germany)
Meguid, S.A. (Canada)
Mileiko, S.T. (Russia)
Mines, R. (UK)
Morimoto, Y. (Japan)
Ng, T.Y.(Singapore)
Nowell, David (UK)
Owen, D.R.J. (UK)
Pieczyska, E. (Poland)
Reddy, J.N. (USA)
Ruiz, Gonzalo (Spain)
Semenski, D. (Croatia)
Silva Gomes, J.F. (Portugal)
Slocum, Alexander (USA)
Sousa, Nelson (Portugal)
Tröster, T. (Germany)
Umehara, N. (Japan)
Van Hemelrijck, D. (Belgium)
Van Tooren, M. (USA)
Weng, G.(USA)
Xu, H. (China)
Yoshino, Masahiko (Japan)
Zhang, X. (China)

Advisory Committee

Alexopoulos, N. (Greece)
Azevedo, Alvaro (Portugal)
Baptista, João S. (Portugal)
Bravi, Laura (Italy)
Braz Cesar, M. (Portugal)
Campos, Vicente (Portugal)
Carvalho, Hélder (Portugal)
Correia, André (Portugal)
Cunha, Alvaro (Portugal)
Dinis, Lúcia (Portugal)
Fonseca Elza. (Portugal)
Gerasimov, A. (Russia)
Gonçalves, Gil (Portugal)
Kruszka, L. (Poland)
Lino, Jorge (Portugal)
Liu, Yan (China)
Lino, Jorge (Portugal)
Machado, Carla (Portugal)
Meda, Alberto (Italy)
Mocko, W. (Poland)
Morgado, Teresa (Portugal)
Murmura, Federica (Italy)
Pappalettere, C. (Italy)
Santos, Gilberto (Portugal)
Santos, Telmo (Portugal)
Seabra, Eurico (Portugal)
Seabra, Jorge (Portugal)
Silva, Luis (Portugal)
Silva, Maria J. (Portugal)
Sousa, Hipólito (Portugal)
Sousa, Luisa (Portugal)
Teixeira, Pamies (Portugal)
Turmanidze, Raul (Georgia)
Varum, Humberto (Portugal)
Wang, Changguo (China)
Zelepugin, S. (Russia)

Institutional Sponsors

FEUP	MADL	UAlg/ISE
University of Porto	*University of Toronto*	*University of Algarve*
Portugal	*Canada*	*Portugal*

Co-Chairs

J.F. Silva Gomes (*U. Porto)*
Shaker A. Meguid (*U. Toronto*)

Organizing Committee

Carlos C. António, Catarina F. Castro, Clito F. Afonso, José M. Cirne
J. Reis Campos, M. Carlos Nunes, Mário A.P. Vaz, Paulo G. Piloto

Conference Secretariat

Eduarda Jesus, Lurdes Catalino

With the support of

ABREU-PCO, Professional Congress Organizer (http://pco.abreu.pt)
Mercatura Conference System (http://www.mercatura.pt)

11. CARDIOVASCULAR AND ORTHOPAEDIC COMPUTATIONAL DESIGN, promoted by Luisa C. Sousa (U.Porto, Portugal) and Catarina F. Castro (U.Porto, Portugal). (Pages: 625-636)

12. SUSTAINABLE ENERGY SYSTEMS, promoted by Clito F. Afonso (U.Porto, Portugal). (Pages: 637-652)

13. FIRE AND STRUCTURAL ENGINEERING, promoted by Alberto Meda (U. Rome "Tor Vergata, Italy) and Paulo A.G. Piloto (IPB, Portugal). (Pages: 653-670)

14. QUALITY MANAGEMENT: THEORY, APPLICATIONS AND CASE STUDIES, promoted by Laura Bravi(Politics University of Urbino Carlo Bo, Italy), Federica Murmura (Politics University of Urbino Carlo Bo, Italy) and Gilberto Santos (College of Design Polytechnic Institute Cávado Ave, Portugal). (Pages: 671-690)

15. A PROBABILISTIC APPROACH IN THE NUMERICAL SIMULATION OF DEFORMATION, FRACTURE AND FRAGMENTATION OF SOLIDS, promoted by Alexander V. Gerasimov (Tomsk State University, Russia) and Sergey A. Zelepugin (Tomsk State University, Russia). (Pages: 691-712)

16. MECHANICS AND MATERIALS IN THE REHABILITATION OF ORAL AND MAXILOFACIAL STRUCTURES, promoted by J.C. Reis Campos (FMDUP/U.Porto, Portugal), Mário A.P. Vaz (FEUP/U.Porto, Portugal) and André Correia (HSIV/U. Católica, Portugal). (Pages: 713-726)

17. MECHATRONICS DESIGN: APPLICATIONS AND CASE STUDIES, promoted by Luís F. Silva (U.Minho, Portugal), Eurico Seabra (U.Minho, Portugal), Hélder Carvalho (U.Minho, Portugal) and Gilberto Santos (College of Design Polytechnic Institute Cávado Ave, Portugal). (Pages: 727-758)

18. DURABILITY, DAMAGE AND MANUFACTURING PROCESSES, promoted by Teresa Morgado (FCT/UNL, Portugal), Carla Machado (FCT/UNL, Portugal), Pamies Teixeira (FCT/UNL, Portugal) and Telmo Santos (FCT/UNL, Portugal). (Pages: 759-778)

19. STRUCTURAL DYNAMICS AND CONTROL SYSTEMS: THEORY, EXPERIMENTS AND APPLICATIONS, promoted by Rui C. Barros (U. Porto, Portugal) and Manuel Braz Cesar (IPB, Portugal). (Pages: 779-792)

PAPER REF: 6529

FIRE PERFORMANCE OF NON-LOADBEARING LIGHT STEEL FRAMING WALLS - NUMERICAL SIMULATION

Paulo A.G. Piloto[1(*)], Mohamed S. Khetata[2], Ana B.R. Gavilán[3]

[1]LAETA-INEGI, Department of Applied Mechanics, Polytechnic Institute of Bragança (IPB), Portugal
[2] Science and Technology Park - Brigantia-EcoPark, Portugal
[3]Department of Mechanical Engineering, University of Salamanca (USAL), Spain
[(*)]*Email:* ppiloto@ipb.pt

ABSTRACT

Light steel frame and prefabricated panels are widely used in non-load-bearing walls, with direct application to steel framed buildings. The fire resistance is usually provided by one or more layers of fire protection materials and the assembly is able to achieve a fire resistance in accordance to technical regulations. Many different types of board materials can be used, including gypsum-based boards. This investigation evaluates the behaviour of the cavity, with and without insulation material. The finite volume method is applied to perform the thermal analysis of the wall taking into account the fluid effect in the cavity. The finite element method is applied to perform the thermal analysis of the wall with insulation material in the cavity. The fire resistance is compared for both models (with and without insulation) and a new simple formula is proposed for the temperature evolution in the cavity zone. Some insulant materials can reduce the fire resistance of the wall, taking into to consideration the insulation criterion.

Keywords: LSF walls, fire resistance, ANSYS FLUENT, ANSYS MULTIPHYSICS.

INTRODUCTION

Light Steel Frame (LSF) walls must provide the required fire resistance specified by regulations and usually this is a result of the assembly effect of certain materials and members. The steel frame must be covered with panels to prevent it from fire. In case of a non-loadbearing member (partition walls), some incombustible insulation material can improve the fire resistance of the LSF wall, specially helping to keep the integrity of the wall (Arcelor, 2005). Each component of a LSF wall determines the fire rating of the whole assembly. The spacing of the panels, the thickness and the number of coating panels, the thermal properties of the materials as well as the width of the insulation material are decisive for fire rating. The fire performance of the building products is regulated by the European standard EN13501-2 (CEN, 2009), using data from fire resistance tests. The performance characteristics must include the integrity capacity (E) (not evaluated in this investigation) and the insulation capacity (I). The assessment of the insulation (I) shall be made by the calculation of the average temperature rise on the unexposed face limited to 140 °C above the initial average temperature, or, with the maximum temperature rise at any point limited to 180 °C above the initial average temperature.

MATERIALS AND METHODS

A total of 12 simulations were performed (6 with fluid activity in the cavity and 6 with solid insulation of the cavity). The maximum dimension of the LSF is 975 mm wide and 93 mm depth. The thickness of each gypsum panel is 12.5 mm. The number of panels varies and the LSF also changes (spacing of studs, shape of studs), according to Fig.1. The Steel Frame is made of C90x43x15x1.5 studs and U93x43x1.5 tracks. Cavity changes from air fluid to rock fibre solid insulation (specific mass of 120 kg/m^3), being all thermal properties temperature dependent. The thermal analysis is transient and nonlinear with fire load ISO834 in one side and the convection conditions on the unexposed side (CEN, 2002). The flow analysis is laminar and based on density variation. The fluid motion is induced by heat transfer. ANSYS FLUENT Density-based solver solves the governing equations of continuity, momentum and energy simultaneously. Pressure is obtained through the equation of state. Governing equations, for additional scalars, will be solved afterward and sequentially (radiation). The integration time for each time step was 60 s, with the possibility to be reduced to 5 s. The convergence criterion is based on the residuals for each equation. ANSYS MULTIPHYSICS solves transient and nonlinear thermal analysis, using full option solution method. The same integration time step was used with similar convergence criterion for the heat flux.

RESULTS AND CONCLUSIONS

The insulation of the cavity with rock fibre, in most of the cases, decreases the fire resistance. This conclusion is in accordance to the experimental evidence (Gunalan *et al.*, 2014). The increase of the number of the studs is responsible for the reduction of the fire resistance. The fire rating of the solid analysis (ANSYS MULTIPHYSICS) is defined by the maximum temperature criterion, while the fire rating of the solid/fluid analysis (ANSYS FLUENT) is defined by the average temperature criterion. Doubling the number of panels (GYPSUM), LSF wall increases the fire resistance to more than the double. The fire resistance is also presented in the Fig.1, assuming that the non-loadbearing wall maintains the integrity.

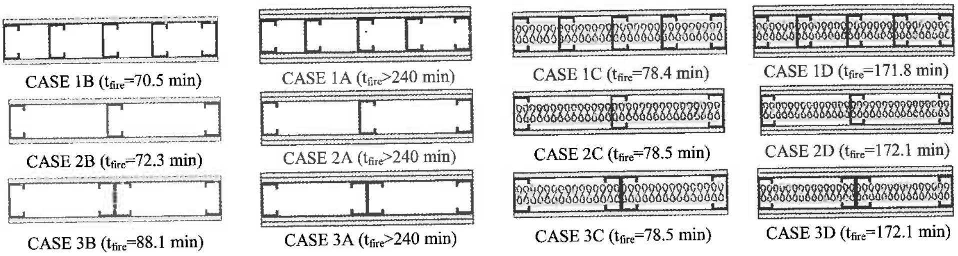

Fig. 1 - Fire resistance of the LSF walls.

REFERENCES

[1]-Arcelor, E. L. S. C. A. European Lightweight Steel Framed Construction - technical guide, Luxemburg, 2005, p: 88.

[2]-CEN- European Committee for Standardization, "EN 13501-2:2007 - Fire Classification of Construction Products and Building Elements - Part 2: Classification Using Data from Fire Resistance Tests, Excluding Ventilation Services". Brussels, 2009, p: 79.

[3]-CEN- European Committee for Standardization, "EN 1991-1-2 - Eurocode 1: Actions on Structures - Part 1-2: General Actions - Actions on Structures Exposed to Fire." Brussels: CEN, 2002, p: 59.

[4]-Gunalan, S. and M. Mahendran. Fire Performance of Cold-Formed Steel Wall Panels and Prediction of Their Fire Resistance Rating. Fire Safety Journal 64, 2014: p: 61-80.

About the Book:

Mechanics and Materials Science and Engineering have witnessed the most significant progress in recent years, and important and dramatic improvements in components design will continue to be made by the use of the latest advances in this field. During the last few decades the development of computer based techniques, as well as new experimental methods, nanotechnologies and nanomaterials, among many other material technological advances, added new dimension and perspectives to mechanical design and manufacturing of engineering systems, structures and components.

This volume contains the Extended Abstracts of papers accepted for presentation in the *M2D2017 - 7th International Conference on Mechanics and Materials in Design* held in Albufeira/Portugal, 11-15 June 2017. The book is complemented by an accompanying USB-card containing the full length papers.

M2D2017 is the seventh international gathering of a prestigious series of conferences coordinated by the International Scientific Committee of Mechanics and Materials in Design. This series of conferences is wholly devoted to advances in mechanics, materials, structural integrity and design. M2D2017 is sponsored by the University of Porto, the University of Toronto and the University of Algarve.

The conference attracted over 230 participants with 360 accepted submissions from 40 different countries. The conference themes which address novel and advanced topics in Mechanics and Materials in Design focused on computational mechanics, experimental mechanics, fatigue and fracture mechanics, composite and advanced materials, nanotechnologies and nanomaterials, tribology and surface engineering, mechanical design and prototyping, biomechanical applications, civil engineering applications, impact ant crashworthiness, energy and thermo-fluid systems, and industrial engineering and management, among other topics

ISBN: 978-989-98832-6-0