

RECENT ADVANCES IN INTEGRITY-RELIABILITY-FAILURE

J.F. Silva Gomes, Shaker A. Meguid
Editors



*Proceedings of the 4th International Conference on Integrity, Reliability
and Failure, Funchal, Portugal, 23-27 June 2013*

Edições INEGI

About the Book

Innovative engineering in mechanics, materials and systems have witnessed the most significant progress in recent years. Important and dramatic improvements in component design will continue to be made by the use of the latest advances in mechanics, materials and manufacturing processes. Different tools are available to optimize any engineering solution, and we must continue our efforts to develop and use superior materials, apply reliable analytical and numerical techniques and validate these with sound experimental methods. During the last few decades the development of computer based techniques, as well as laser-optics methods, nanotechnologies and nanomaterials, among many other technological advances, added new dimension and perspectives to minimize or prevent catastrophic failures of engineering systems, structures and components.

This volume contains the extended Abstracts of the 380 papers accepted for presentation in the IRF2013-4th International Conference on Integrity, Reliability and failure held in Funchal/Portugal, 23-27 June 2013. The book is complemented by an accompanying CD-ROM containing the full length papers.

IRF2013 is part of a prestigious series of conferences that was initiated in 1999, in Porto (Portugal), coordinated by the International Scientific Committee on Mechanics and Materials in Design. The conference attracted over 300 participants with 380 accepted submissions from 45 different countries around the world. These papers were presented in June 23-27, 2013 in the magnificent city of Funchal, Madeira, and the conference themes focused on nanoengineering, computational and structural mechanics, micromechanics, experimental mechanics, advanced materials, thermo-fluid systems and case studies, among other engineering topics.



ISBN: 978-972-8826-27-7

799

EDITORS PREFACE

801

803 As the engineering community continues to cross the boundaries of known practices,
805 materials and manufacturing techniques into the frontiers of new functional materials,
807 environments and applications, the opportunities for catastrophic failures will inevitably
809 increase. If our knowledge of how to engineer systems, structures and components to
minimize or prevent catastrophic failure is to keep pace with modern manufacturing
technologies, the demanding applications, and the intolerance of a safety conscious society,
we must continue our efforts to develop and use superior materials, apply reliable analytical
techniques and validate these with sound experimental tools. It is with this in mind that this
series of conferences was organised.

811 The objectives of this gathering are to provide a forum for the discussion and dissemination of
813 recent advances in assessing the integrity, reliability and failure of engineering structures,
815 components, and assemblies, foster research in these areas, and promote international co-
817 operation among scientists and engineers in the field. The goal is to enable concerned
researchers and scientists from all over the world to exchange ideas on mechanics, materials
and design as they relate to system integrity and reliability.

819 This fourth international conference, which is sponsored by the University of Porto, the
University of Toronto and the University of Madeira, is part of a prestigious series of Integrity
Reliability and Failure conferences coordinated by the International Scientific Committee on
Mechanics and Materials in Design. The conference attracted over 300 participants with 380
accepted submissions from 45 different countries around the world. These papers were
821 presented in June 23-27, 2013 in the magnificent city of Funchal, Madeira. The conference
823 themes which address integrity, reliability and failure focused on Analytical and Numerical
825 tools, Testing and Diagnostics, Surface and Interface Engineering, Sensors and
Instrumentation, Tribology, Mechanical Design and Prototyping, Modes of Failure,
Composite Materials, Nanotechnologies and Nanomaterials, Biomechanics, Energy and
Thermo-Fluid Systems, Impact and Crashworthiness and Case Studies.

827 We are particularly indebted to the authors and special guests for their plenary lectures and
presentations. Each of the more than 380 contributions offered opportunities for thorough
829 discussions with the authors. We acknowledge all of the participants, who contributed with
innovations, new research approaches, novel modeling and simulation efforts, and invaluable
critical comments. We are also indebted to the outstanding plenary lecturers who highlighted
the conference themes with their contributions: Professor Xiong Zhang (Tsinghua University,
P. R. China), Professor E.A. Elsayed (Rutgers University, USA) and Professor Noritsugu
Umehra (Nagoya University, Japan). We also take this opportunity to thank the members of
the International Scientific Committee and reviewers for their time and effort.

Last but by no means least, we offer our sincere gratitude to the symposia organisers for their
contribution to the success of the event and the local organising committee for attending to
many aspects of the conference demands. For all of them, we are truly very grateful.

Shaker A. Meguid and J.F. Silva Gomes
Funchal / Madeira, June 2013

International Scientific Committee

Aben, H. (Estonia)	Dourado, N. (Portugal)	Masato, Y. (Japan)	Sainov, V. (Bulgaria)
Abreu, M.J. (Portugal)	Eberhardsteiner, J. (Austria)	Meda, A. (Italy)	Santos, J.M. (Portugal)
Adali, S. (S. Africa)	Esteves, J.L. (Portugal)	Meguid, S.A. (Canada)	Santos, Telmo (Portugal)
Afonso, C.F. (Portugal)	Fanguciro, R. (Portugal)	Melo, F.Q. (Portugal)	Semenski, D. (Croatia)
Alexopoulos, N. (Greece)	Fernandes, A.A. (Portugal)	Mileiko, S.T. (Russia)	Silva, A.J. (Portugal)
Alves, A. (Portugal)	Ferreira, D. (Portugal)	Miller, R.E. (Canada)	Silva, Lucas (Portugal)
António, C.C. (Portugal)	Ferreira, J.G. (Portugal)	Mines, R. (UK)	Silva Gomes, J.F. (Portugal)
Banks-Sills, L. (Israel)	Fiúza, A. (Portugal)	Miranda, R. (Portugal)	Sjödahl, M. (Sweden)
Baptista, J.S. (Portugal)	Fonseca E. (Portugal)	Morcia, F. (Portugal)	Soares, C.M. (Portugal)
Barros, R.C. (Portugal)	Gdoutos, E. (Greece)	Moreira, P. (Portugal)	Sousa, L.C. (Portugal)
Bathe, K.J. (USA)	Geraldes, M. (Portugal)	Morimoto, Y. (Japan)	Sousa, R. (Portugal)
Botsis, J. (Switzerland)	Guedes, R.M. (Portugal)	Moura, M.F. (Portugal)	Suleman, Afzal (Portugal)
Bremard, F. (France)	Hejum, Du (Singapore)	Muc, Aleksander (Poland)	Takagi, T. (Japan)
Caetano, E. (Portugal)	Igartua, A. (Spain)	Navarro, C. (Spain)	Talaia, M. (Portugal)
Camanho, P. (Portugal)	Ignaszak, Z. (Poland)	Navas, H. (Portugal)	Tamalsky, E. (Brazil)
Campos, J.R. (Portugal)	Iliescu, N. (Romania)	Pappalettere, C. (Italy)	Tamuzs, V. (Latvia)
Castro, C.F. (Portugal)	Jones, N. (UK)	Pieczyska, E. (Poland)	Tavares, J.M. (Portugal)
Castro, P.T. (Portugal)	Jorge, R.N. (Portugal)	Piloto, P. (Portugal)	Tavares, P. (Portugal)
Catarino, A. (Portugal)	Kahlen, F-J. (S. Africa)	Pindera, M.J. (USA)	Thomsen, O.T. (Denmark)
Cavalcante, M. (Brazil)	Klein, W. (Germany)	Prime, M. (USA)	Tooren, M.J. (Netherlands)
Chen, T. (Taiwan)	Kourkoulis, S. (Greece)	Quelhas, O. (Brazil)	Truman, C.E. (UK)
Chenot, J-L (France)	Laermann, K. (Germany)	Ramesh, K. (India)	VanHemelrijck, D. (Belgium)
Cirne, J. (Portugal)	Langseth, M. (Norway)	Reddy, J.N. (USA)	Varum, H. (Portugal)
Correia, A. (Portugal)	Lima, G. (Brazil)	Restivo, M.T. (Portugal)	Vasques, C. (Portugal)
Croccolo, D. (Italy)	Lino, J. (Portugal)	Ribeiro, J.E. (Portugal)	Vaz, Mário P. (Portugal)
Cunha, A. (Portugal)	Lopes, H. (Portugal)	Robinson, J. (Ireland)	Vilas-Boas, J. (Portugal)
Datta, S. (USA)	Lu, Jian (Hong Kong)	Rocha, A.B. (Portugal)	Wang, Wei-Chung (Taiwan)
Degrieck, J. (Belgium)	Madureira, L. (Portugal)	Rodrigues, H. (Portugal)	Weng, G. (USA)
Dias, G. (Portugal)	Maia, Lino (Portugal)	Rodrigues, J.D. (Portugal)	Yoneyama, Satoru (Japan)
Dietrich, L. (Poland)	Mal, A. (USA)	Ruiz, G. (Spain)	Yoon, Y.C. (Singapore)
Diogo, M.T. (Portugal)	Marques, A.T. (Portugal)	Ruzicka, M. (Czech R.)	Zhang, Z. (China)

Institutional Sponsors

FEUP

*University of Porto
Portugal*

MADL

*University of Toronto
Canada*

CCEE

*University of Madeira
Portugal*

Co-Chairs

J.F. Silva Gomes (*U. Porto*)

Shaker A. Meguid (*U. Toronto*)

Organizing Committee

Carlos C. António, Clíto F. Afonso, José M. Cirne

Lino Maia, Mário A.P. Vaz, Paulo G. Piloto, Pedro M.G.P. Moreira

Conference Secretariat

Nuno Pinto, Lurdes Catalino, Carla Gonçalves
M.F. Silva Gomes,

with the support of

ABREU-PCO, Professional Congress Organizer (<http://pco.abreu.pt>)

Mercatura Conference System (<http://www.mercatura.pt>)

ACKNOWLEDGMENTS

IRF2013 conference is sponsored by the following institutions, whose contributions are gratefully acknowledged:

FEUP-Faculdade de Engenharia, Universidade do Porto
MADL-Mechanics and Aerospace Design Lab, University of Toronto
CCEE-Centro de Ciências Exactas e de Engenharia, Universidade da Madeira
Governo Regional da Madeira
IVBAM-Instituto do Vinho, do Bordado e do Artesanato da Madeira, I.P.
APAET-Portuguese Association for Experimental Mechanics
EURASEM-European Society for Experimental Mechanics
SEM-American Society for Experimental Mechanics
BSSM-British Society for Strain Measurement
JSME-Japanese Society of Mechanical Engineering
IMEKO-International Measurement Confederation
AFM-Association Française de Mécanique
DYMAT-European Association for Dynamics of Materials
INEGI-Instituto de Engenharia Mecânica e Gestão Industrial
LABIOMEPLaboratório de Biomecânica do Porto
FCT-Fundação para a Ciência e a Tecnologia
ABREU-PCO, Professional Congress Organizer

U. PORTO

FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

madl
MECHANICS AND AEROSPACE DESIGN LAB

UNIVERSIDADE da MADEIRA



TRACKS / MAIN TOPICS:

- Topic_A: Analytical and Numerical tools
- Topic_B: Testing and Diagnostics
- Topic_C: Surface and Interface Engineering
- Topic_D: Civil Engineering Applications
- Topic_E: Sensors and Instrumentation
- Topic_F: Tribology, Gears and Transmissions
- Topic_G: Mechanical Design and Prototyping
- Topic_H: Modes of Failure
- Topic_I: Composite Materials
- Topic_J: Nanotechnologies and Nanomaterials
- Topic_K: Biomechanical Applications
- Topic_L: Energy and Thermo-Fluid Systems
- Topic_M: Impact and Crashworthiness
- Topic_N: Case Studies

SPECIAL SYMPOSIA:

- Symp_01: Smart Materials and Structures
Coordinator: M.J. Galdes (UBI)
- Symp_03: Imaging and Visualization
Coordinator: João Tavares (U.Porto)
- Symp_04: Optical Techniques of Experimental Mechanics in Design
Coordinators: Hernani Lopes (IPB), João Ribeiro (IPB)
- Symp_05: Blood Flow Mechanical Behaviour
Coordinators: Catarina Castro (U.Porto), Luisa Sousa (U.Porto)
- Symp_06: Integrity, Reliability and Failure in Dental Materials
Coordinators: J.C. Reis Campos (U.Porto), André Correia (U.Porto)
- Symp_07: Mechanical Characterization of Bone Behaviour
Coordinators: Marcelo Moura (U.Porto), Nuno Dourado (UTAD)
- Symp_10: Structural and Multidisciplinary Optimization
Coordinator: Carlos C. António (U.Porto)
- Symp_11: Innovative Joining Processes
Coordinators: Pedro Moreira (INEGI/U.Porto), Lucas Silva (U.Porto)
- Symp_12: Vibration and Structural Acoustic Analysis
Coordinator: César Vasques (INEGI)
- Symp_13: Dynamics, Stability and Control in Engineering Structures
Coordinator: Rui C. Barros (U. Porto)
- Symp_14: Assessment, Monitoring and Control of Civil Engineering Structures
Coordinators: Álvaro Cunha (U.Porto), Elsa Caetano (U.Porto)
- Symp_15: Behaviour Characterization of Constructions for Earthquake Demands
Coordinators: Humberto Varum (U.Aveiro), Hugo Rodrigues (U.Aveiro)
- Symp_17: Concrete Material Performance
Coordinators: Nuno Dourado (UTAD), Marcelo Moura (U.Porto)
- Symp_18: Safety of Wooden Structures
Coordinators: Elza Fonseca (IPB), Débora Ferreira (IPB)

- Symp_19: Occupational Safety and Health
Coordinators: J. Santos Baptista (U.Porto), M. Tato Diogo (U.Porto), Gilson Lima (LATEC), Osvaldo Quelhas (LATEC)
- Symp_20: Thermodynamics and Thermo-Fluid Systems
Coordinators: Clito F. Afonso (U.Porto), Carlos C. António (U.Porto)
- Symp_21: Lean and Green Manufacturing
Coordinators: Anabela Alves (U.Minho), Rui Sousa (U. Minho), Franz-Josef Kallen (U. Cape Town)
- Symp_26: Advances in Fibrous and Composite Materials for Civil Engineering
Coordinators: Raul Figueiro (U. Minho), Sohel Rana (U.Minho)
- Symp_27: Structural Health Monitoring of Advanced Structures
Coordinators: Júlio C. Viana (Critical Materials, SA), Gustavo Dias (Critical Materials, SA)
- Symp_28: Fire and Structural Engineering
Coordinators: Paulo G. Piloto (IPB), Alberto Meda (U. Roma)
- Symp_29: Metrology, Quality Control and Reliability
Coordinator: Helena V.G. Navas (FCT/UNL)
- Symp_30: Medical Devices and Healthcare Materials
Coordinators: Maria José Abreu (U.Minho), André Catarino (U.Minho)
- Symp_31: Micromechanics and Homogenization of Heterogeneous Media
Coordinators: Marek-Jerzy Pindera (U. Virginia), Marcio Cavalcante (U.Alagoas)
- Symp_32: Failure and Fatigue of Structural Elements
Coordinator: Aleksander Muc (Cracow U.T.)

RECENT ADVANCES IN INTEGRITY-RELIABILITY-FAILURE

J.F. Silva Gomes, Shaker A. Meguid (Ed)

Proceedings IRF2013

**4th International Conference on Integrity, Reliability and Failure
Funchal/Portugal, 23-27 June 2013**

SYMPOSIUM_18

Safety of Wooden Structures

Coordinators:

Elza M.M. Fonseca^(*)

Department of Applied Mechanics, Polytechnic Institute of Bragança, Portugal

Débora R.S.M. Ferreira^(*)

Department of Applied Mechanics, Polytechnic Institute of Bragança, Portugal

^(*)Associate Editors for the papers in this Symposium

PAPER REF: 4057

NUMERICAL MODEL TO EVALUATE THE FIRE RESISTANCE IN WOODEN SLABS WITH CAVITIES

D. Coelho^(*), E.M.M. Fonseca², P. Vila Real³, J.A. Faria¹, A. Arede¹¹Faculty of Engineering, University of Porto, Porto, Portugal²Polytechnic Institute of Bragança, Bragança, Portugal³University of Aveiro, Aveiro, Portugal^(*)Email: diana.coelho@gmail.com

ABSTRACT

The main objective of this paper is to develop a numerical model for thermal analysis of wooden slabs with cavities, when subjected to the fire action. The temperature profiles, the charring depth layer and the charring rate will be determined using the finite element method with ANSYS program. The numerical calculation of the temperature profiles will be obtained through a transient and a non-linear thermal analysis, where the material properties are temperature dependent. These properties were established in accordance with the referenced data and numerically calibrated. Two different models of wooden slabs with cavities were studied. One model characterizes a wood slab with void cavities and other with insulation material. To characterize the fire resistance in wooden slabs with insulated cavities or void cavities, different typical curves of charring depth layer will be obtained. A numerical procedure is proposed to identify the heating action into the slab cavities. All numerical results permit the verification of the fire safety in wooden slabs with cavities.

Keywords: wooden slab, fire, insulated cavities, void cavities.

INTRODUCTION

Wood is a friendly material, attracted by engineers and architects, due the attractive attributes such as architectural features, structural characteristics and also a renewable material. This material when exposed to accidental actions, such as fire action, presents a decomposition process, pyrolysis, and produces a surrounding charring depth layer. On the fire exposure side a charcoal layer, without effective resistance, causes the reduction of the element cross-section. However, this charring depth layer can delay the heating process, from the exposed side, to the wood core section and acting as a good insulating material. Several researchers have presented experimental models and analytical methods to calculate the physical degradation of wood due high temperatures (White, 1999), (Poon, 2003), (Janssens, 2004), (Frangi, 2008). The main objectives of this work are:

- Present a numerical model to obtain the same results from Frangi when uses experimental wooden slabs;
- Evaluate the thermal performance of wooden slabs with insulated cavities or void cavities, when subjected of a fire situation;
- Determine different stages of the charring rate through all wooden slabs;
- Present a numerical model who intends to be a replica of prefabricated wooden slabs common in Nordic countries, and used in residential and commercial buildings;

- Use two different insulated materials (glass fiber and rock wool) in order to evaluate the thermal effect into the wooden slab cavities.

RESULTS AND CONCLUSIONS

This study considers a replica of a prefabricated wooden slab with cavities exposed to fire, with two constructive solutions, figure 1. In the first solution, the slab cavities have an insulation material, and for the second solution the internal slab cavities have no insulation. These models were based on the constructive solution proposed by Frangi. The numerical model proved to be a great importance in the determination of the charring depth layer in wooden slabs with insulated cavities and void cavities. The temperature profiles obtained in transient analysis, as well as the charring rate in different phases in wooden slabs with cavities exposed to fire were calculated using the finite element method with ANSYS program. Two different insulation materials used into the wooden cavities were compared and the mineral wool exerts higher protection in relation to the fiber glass, figure 2a. The results obtained through the proposed numerical model have a good correlation between the values of Frangi and Eurocode 5. As regards with the study of the wooden slab with void cavities, it is possible to conclude that at the end of one hour of fire exposure, the structural resistance vanishes completely, as represented in figure 2b.

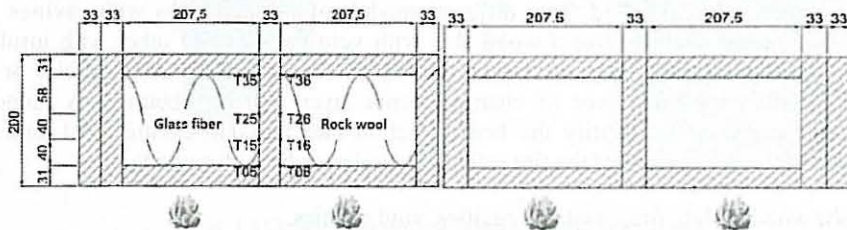


Fig. 1 - Prefabricated wooden slab with insulated and void cavities dimensions in mm.

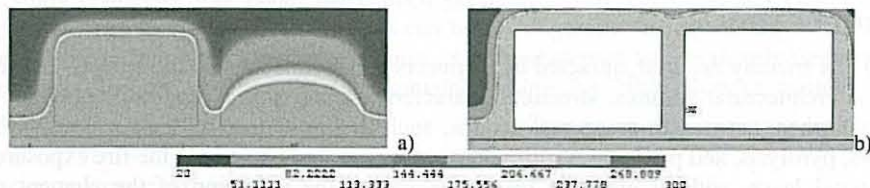


Fig. 2 - Temperatures in wooden slab with insulated and void cavities at the end of 3600s.

REFERENCES

- [1]-White RH, Dietsberger MA. Fire Safety, Chapter 17, Wood Handbook: Wood as an Engineering Material, Forest Products Laboratory, USDA Forest Service, 1999.
- [2]-Poon L, England JP. Literature Review on the Contribution of Fire Resistant Timber Construction to Heat Release Rate - Timber Development Association, Warrington Fire Research Aust. Pty. Ltd., Project No.20633, version 2b, pp.1-78, 2003.
- [3]-Janssens ML. Modeling of the thermal degradation of structural wood members exposed to fire. Fire and Materials, 28, pp.199-207, 2004.
- [4]-Frangi A, Knobloch M, Fontana M. Elsevier - Fire design of timber slabs made of hollow core elements. Elsevier - Engineering Structures, USA, 2008.