

INTEGRITY-RELIABILITY-FAILURE IN ENGINEERING, MATERIALS, MANUFACTURING AND BIOMECHANICS

Proceedings IRF2025

**8th International Conference on on Integrity-Reliability-Failure
Porto 15-18 July 2025**

Editors

**J.F. Silva Gomes
Shaker A. Meguid**

FEUP-2025

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(2025)

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PREFACE

IRF2025 is the eighth international gathering of a prestigious series of Integrity-Reliability-Failure conferences coordinated by the International Scientific Committee on Mechanics and Materials in Design. This series of conferences started in 1999 and they are wholly devoted to advances in assessing the integrity, reliability and failure of engineering systems, materials, manufacturing and biomechanics. IRF2025 is jointly sponsored by the University of Porto, the University of Toronto and the Portuguese Society of Experimental Mechanics. The conference attracted over 160 contributions, with 148 accepted submissions involving 454 authors from 27 different countries.

The conference themes, which address novel and advanced topics on Integrity, Reliability and Failure, focused on Theory, Experiments and Applications in Engineering, including Composite and Advanced Materials, Fatigue and Fracture Mechanics, Structural Dynamics, Mechanical Design and Prototyping, Civil Engineering Applications, Biomechanical Applications, Energy and Thermo-Fluid Systems, and Industrial Engineering, among other topics.

We believe that the meeting and these proceedings offered our delegates an excellent opportunity for the discussion and dissemination of their recent work in assessing the integrity, reliability and failure of engineering structures, components and systems. They 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 contributions. Each of the 138 approved papers offers an opportunity for thorough discussions with the authors and the scientific community. Particularly, we acknowledge the excellent contributions of the participants, their innovative ideas and research directions, the novel modelling and simulation techniques, and the invaluable critical comments. We also take this opportunity to thank the members of the International Scientific Committee and the reviewers for their time and helpful suggestions, the symposia organizers for their efforts and valuable contributions to the success of conference and this publication, and the local organizing committee for an absolutely superb organization of this “*virtual*” meeting. To all of them, we offer our deepest gratitude.

Porto/Portugal, July 2025

*J.F. Silva Gomes and Shaker A. Meguid
(Conference Co-Chairs and Editors)*

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NUMERICAL SIMULATION OF THE FIRE PROTECTION EFFECT AND LOAD LEVEL ON GLT TIMBER COLUMNS

Paulo A.G. Piloto^{1(*)}, Manuel D. Lorenzo ², Ana B. Ramos Gavilán ², Javier Sánchez-Haro ³

¹GICoS, Instituto Politécnico de Bragança, Bragança, Portugal

²Departamento de Ingeniería Mecánica, Universidad de Salamanca, Zamora, España

³Departamento de Ingeniería Mecánica y Estructural, Universidad de Cantabria, Santander, España

(*)Email: ppiloto@ipb.pt

ABSTRACT

The next generation of the Eurocode EN 1995-1-2 modifies the Effective Cross-Section Method (ECSM), where an adequate char depth reduces the initial timber cross-section. This char depth is based on the notional char layer (European Charring Model-ECM) and a zero-strength layer to compensate for the loss of strength and stiffness of heated but uncharred wood. The remaining effective cross-section has wood's strength and stiffness properties at room temperature and may be used to determine the load-bearing capacity. This investigation deals with gypsum-protected Glue Laminated Timber (GLT) columns under fire. The finite element method is also used to determine the fire resistance time based on a geometrical and material nonlinear analysis (GMNIA). Doubling the number of protection layers, from 12.5 mm thick to 25 mm thick, the fire resistance increases by an amount of 72% to 100% when the load level changes from 6% to 36%, with respect to load bearing at room temperature.

Keywords: Fire, Glue Laminated Timber, Gypsum protection, columns, load level.

INTRODUCTION

This research explores the principles and efficacy of gypsum-based fire protection for GLT columns. The thermal insulation is provided by gypsum and naturally by the char layer. As a sustainable and renewable building material, timber has seen a resurgence in modern architecture due to its aesthetic appeal, low environmental footprint, and structural versatility. The Glued-laminated timber (GLT) is prevalent for its strength and ability to span significant distances, making it suitable for columns and beams in mid- to high-rise buildings. However, timber's combustibility raises concerns about fire safety, especially for load-bearing structural elements.

ANALYSES, MATERIALS AND METHODS

This investigation used a simply supported timber column, with 1.2 m between supports and a cross-section of 100x80 mm². The material grade is spruce GL24h with a density of 365 kg/m³ (wet). The EN14080 [1] specifies the characteristic strength under compression and bending. The material is considered orthotropic, assuming the modulus of elasticity parallel to the grain of 11.5 GPa. The design of compressive strength along the grain is 24 MPa. Based on these basic values, the orthogonal direction effect of the material [2], and the temperature reduction effect on strength and stiffness [3], one can define the orthotropic mechanical behaviour of this wood species, neglecting the effect of bond integrity between lamellas. The mechanical effect of the gypsum layer was neglected, considering only its thermal effect. The thermal properties

of the protection material are based on gypsum plasterboard with a density of 832 [kg/m³] and multiple layers of 12.5 [mm] thickness according to prEN1995-1-2 [3]. The simulations, Figure 1, included an elastic buckling analysis to determine the first mode of instability and the buckling load, a second analysis using GMNIA to determine the buckling resistance at room temperature, a third analysis using the incremental non-linear thermal solution to determine the temperature in materials over time, and finally an incremental GMNIA analysis to determine the fire resistance time.

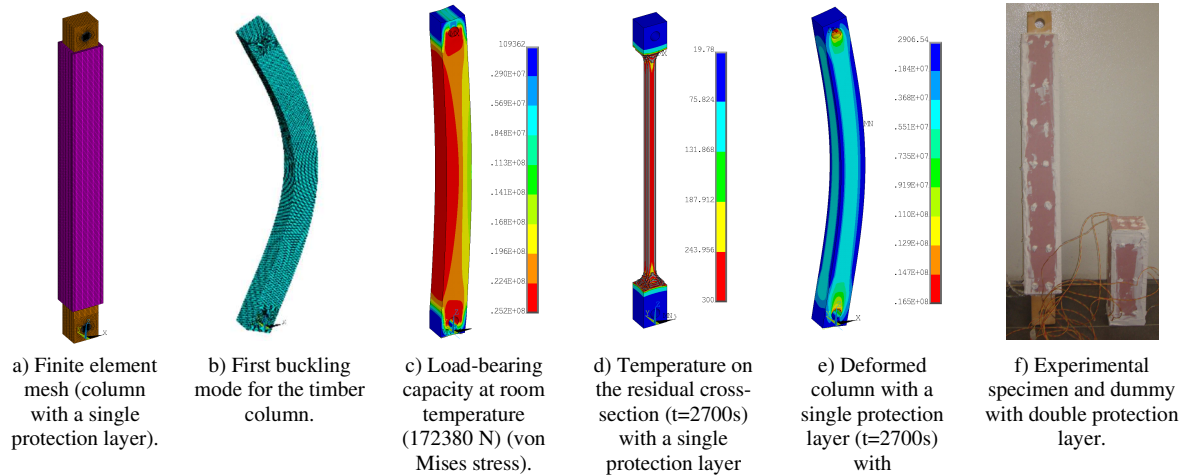


Fig. 1 - Validated finite element model.

RESULTS AND CONCLUSIONS

The fire resistance is determined by the last time step of the incremental solution where it is possible to maintain the equilibrium. The fire resistance of the timber column when using a single gypsum layer was found to be 21, 27, 31 and 37 min. These limits were modified to 43, 52, 58 and 65 min when using a double gypsum layer. These results were determined with 6%, 12%, 21% and 36 % of the load-bearing capacity at room temperature. The fire resistance increases with the number of protection layers and decreases with the load level, see the contraction axial displacement “C” over time in Figure 2.

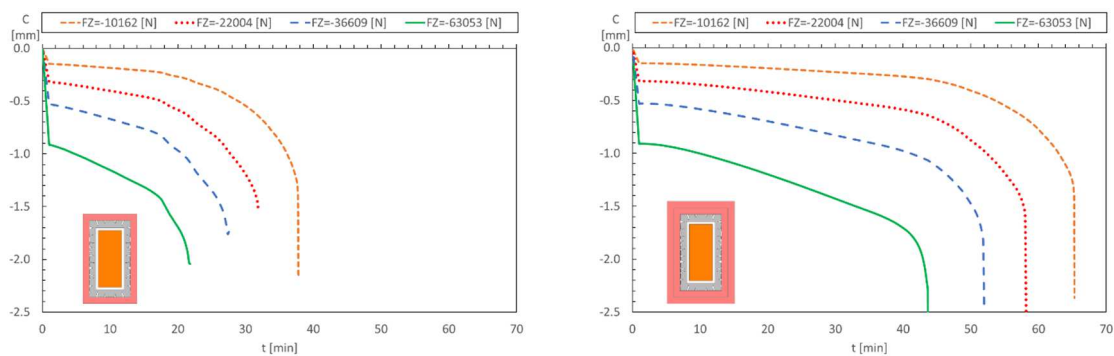


Fig. 2 - Influence of load and protection levels on the compression behaviour of GLT under fire.

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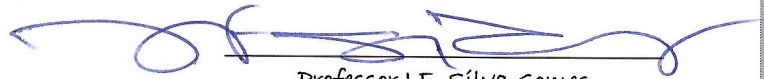
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CERTIFICATE

This is to certify that **Paulo Piloto**, from IPB (Portugal), has attended and contributed to the **8th International Conference on Integrity-Reliability-Failure (IRF2025)**, which took place in Porto/ Portugal, from 15 to 18 July 2025.

Porto, 18th July 2025



Professor J.F. Silva Gomes
(IRF2025 conference Co-Chair)