



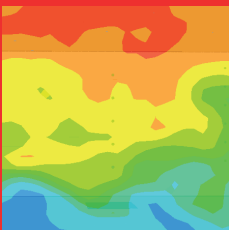
LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL



associação luso-brasileira
para a segurança contra incêndio

5.^{as} JORNINC

Jornadas de Segurança
aos **Incêndios Urbanos**



LISBOA • LNEC • 1 e 2 de junho de 2016

PROGRAMA

Programa geral

1 de junho de 2016

Hora	Auditório	Sala
8:00 às 8:30		
8:30 às 9:00	Sessão de abertura	
9:00 às 9:30	Sessão plenária I	
9:30 às 11:00	Comportamento das estruturas e dos materiais ao fogo I	
11:00 às 11:30		
11:30 às 12:00	Sessão plenária II	
12:00 às 13:30	Regulamentação, normalização e certificação em segurança contra incêndios	
13:30 às 14:30		
14:30 às 15:00	Sessão plenária III	
15:00 às 16:30	Comportamento das estruturas e dos materiais ao fogo II	Evacuação e comportamento humano em situação de incêndio
16:30 às 17:00		
17:00 às 17:30	Sessão plenária IV	
17:30 às 19:15	Controlo de fumo	Análise de risco de incêndio

2 de junho de 2016

9:00 às 9:30	Sessão plenária V
9:30 às 10:30	Comportamento das estruturas e dos materiais ao fogo III
10:30 às 11:00	
11:00 às 12:00	Organização e gestão da segurança contra incêndio
12:00 às 12:30	Sessão plenária VI
12:30 às 13:00	Sessão de encerramento

SESSÃO PLENÁRIA I

9:00 ÀS 9:30

Moderador da sessão: António Leça Coelho (Laboratório Nacional de Engenharia Civil)

O Regime Jurídico de SCIE - do D.L. nº 220/2008 ao D.L. nº 224/2015
Carlos Souto (Autoridade Nacional de Proteção Civil)

SESSÃO 1

9:30 ÀS 11:00

Comportamento das Estruturas e dos Materiais ao Fogo I

Moderador da sessão: Luis Laím (Universidade de Coimbra)

- 9:30 Contributo das geociências na investigação de incêndios em edifícios históricos: o caso da Sé de Lisboa
Amélia Dionísio, Maria Amália Sequeira Braga e João Carlos Waerenborgh
- 9:45 Modelação numérica de ensaios experimentais de vigas metálicas à temperatura normal e em situação de incêndio
André Reis, Nuno Lopes, Esther Real e Paulo Vila Real
- 10:00 Comportamento ao fogo de vigas de betão armado reforçadas com laminados de CFRP instalados em rasgos: ensaios de resistência ao fogo e simulação numérica
João Pedro Firmo, Mário Rui Arruda e João Ramôa Correia
- 10:15 Modelação numérica da resposta térmica de perfis pultrudidos tubulares de GFRP em situação de incêndio
Tiago Morgado, Nuno Silvestre, João R. Correia e Fernando Branco
- 10:30 Wooden cellular slabs with and without insulation submitted to fire conditions
Djaafer Haddad, Belkacem Lamri e Elza M. M. Fonseca
- 10:45 Exploratory tests on structures' resistance during forest fires
Luís Mário Ribeiro, Ricardo Oliveira, Jorge Raposo, David Caballero e Domingos Viegas

SESSÃO PLENÁRIA II

11:30 ÀS 12:00

Moderador da sessão: Carlos Souto (Autoridade Nacional de Proteção Civil)

Segurança contra incêndio em edifícios. Facilidades para a intervenção dos bombeiros

Carlos Ferreira de Castro (Action Modulers)

SESSÃO 2

12:00 ÀS 13:30

Regulamentação, Normalização e Certificação em Segurança Contra Incêndios

Moderador da sessão: Carlos Ferreira de Castro (Action Modulers)

- 12:00 Bocas-de-incêndio armadas: compatibilização do dimensionamento hidráulico
Armando Silva Afonso, Paulo Gomes e Carla Pimentel-Rodrigues
- 12:15 A legislação de segurança ao incêndio na reabilitação de edifícios: resultados de inquérito a entidades e profissionais do sector da construção
António Leça Coelho e João Branco Pedro
- 12:30 Análise dos critérios e fatores que determinam as "categorias de risco" previstas na atual legislação de segurança ao incêndio
António Leça Coelho
- 12:45 A legislação de segurança contra incêndio em diferentes países
António Leça Coelho
- 13:00 A segurança ao incêndio e a reabilitação sustentável de edifícios
José Manuel Silva, António Leça Coelho e Luís Bragança
- 13:15 Elevadores para evacuação - Caso de estudo
Paulo Ramos

SESSÃO PLENÁRIA III

14:30 ÀS 15:00

Moderador da sessão: Paulo Piloto (Instituto Politécnico de Bragança)

Verificação da resistência ao fogo de estruturas de aço e mistas aço-betão

Paulo Vila Real (Universidade de Aveiro)

SESSÃO 3

15:00 ÀS 16:30

Comportamento das Estruturas e dos Materiais ao Fogo II

Moderador da sessão: Paulo Vila Real (Universidade de Aveiro)

- 15:00 Behaviour of cellular beams protected with intumescent coatings
Brahim Lamri, Luís Mesquita, Abdelhak Kada e Paulo Piloto
- 15:15 Estudo numérico e experimental de ligações aparafusadas autoperfurantes de chapas finas a temperaturas elevadas
Armandino Parente, Rui Dias e Luís Mesquita
- 15:30 Estudio analítico de la inestabilidad por pandeo lateral de vigas parcialmente embebidas expuestas a fuego ISO834
Ana Belén Ramos-Gavilán, Paulo Piloto e Luís Mesquita
- 15:45 Modelação numérica de perfis enformados a frio a temperaturas elevadas
Flávio Arrais, Nuno Lopes e Paulo Vila Real
- 16:00 Load carrying capacity of partially encased columns for different fire ratings
Abdelkadir Fellouh, Nourredine Benlakehal, Paulo Piloto, Ana Ramos e Luís Mesquita
- 16:15 Comportamento ao fogo dos CFRP - sistemas passivos de proteção
Débora Ferreira, Luís Duarte, Luís Mesquita e Paulo Piloto

Evacuação e Comportamento Humano em Situação de Incêndio

Moderador da sessão: Pedro Lopes (Autoridade Nacional de Proteção Civil)

- 15:00 Comportamento humano em caso de incêndio
Elisabete Cordeiro, António Leça Coelho, Miguel C. S. Nepomuceno e João Craveiro
- 15:15 Fatores humanos e a segurança contra incêndios em túneis rodoviários
Dirceu Santos e Nelson Tico
- 15:30 Planeamento de emergência baseado em cenários de incêndio
António B. Leiras, João Paulo Rodrigues e Brian J. Meacham
- 15:45 MEECI: a Modelação da Evacuação de Edifícios em Caso de Incêndio
António Leça Coelho
- 16:00 Realidade virtual e jogos sérios: um novo paradigma de treino de pessoas em evacuação de edifícios
João Emílio Almeida, Rosaldo Rossetti e António Leça Coelho
- 16:15 Modelação de incêndios em edifícios de ensino superior - polo I da Universidade de Coimbra
Claude Almeida e António M. Correia

SESSÃO PLENÁRIA IV

17:00 ÀS 17:30

Moderador da sessão: João Viegas (Laboratório Nacional de Engenharia Civil)

Ventilação e controlo de fumo em túneis rodoviários
Jorge Saraiva (Dinâmica Aplicada)

SESSÃO 5

17:30 ÀS 19:15

Controlo de Fumo

Moderador da sessão: Jorge Saraiva (Dinâmica Aplicada)

- 17:30 Controlo de fumo em parques de estacionamento cobertos - Complexo Sky Center, Luanda
Pedro Cordeiro, Rui Vaz, Martin Eimermann e João Carlos Viegas
- 17:45 O sistema de ventilação e controlo de fumo do túnel do Marão; Então...(2007)
Jorge Saraiva, Dirceu Santos e Nelson Tico
- 18:00 Full-size experiments of air curtains for smoke control in case of fire: final results
João Carlos Viegas e Hildebrando Cruz
- 18:15 Controlo de fumo por meios passivos em túneis
João Carlos Viegas
- 18:30 Escoamento longitudinal em túneis longos
Dirceu Santos, Jorge Saraiva e João Paulo Rodrigues
- 18:45 CFD analysis for the evaluation of the thermal radiation on a pool fire in an offshore platform
Aleksandra Mielcarek, Aldina Santiago e Filippo Gentili
- 19:00 Extintor automático de incêndios
Sónia Bergano

Análise de Risco de Incêndio

Moderador da sessão: Carlos Pina dos Santos (Laboratório Nacional de Engenharia Civil)

- 17:30 Avaliação do risco de incêndio no Núcleo Urbano de Aljustrel
Lurdes Belgas, Tânia Valentim, Romeu Vicente e Tiago Ferreira
- 17:45 Incêndios em edifícios na cidade de Lisboa, análise e caracterização das ocorrências no período de 2010 a 2014
Paulo Manuel Pereira Nunes e Rui Manuel da Cruz Oliveira
- 18:00 Modelação do comportamento de uma estrutura sujeita a um incêndio de compartimento
Hugo Nunes e António Correia
- 18:15 Avaliação de risco de incêndio urbano - apresentação da aplicação numérica CHICHORRO 2.0
Miguel Chichorro Gonçalves, Ricardo Ferreira e André Correia
- 18:30 MARIE: Modelo de Análise de Risco de Incêndio em Edifícios Existentes
António Leça Coelho
- 18:45 Medidas para a eficiência no combate aos incêndios urbanos
José Pedro Lopes e João Paulo Rodrigues

2 DE JUNHO DE 2016

SESSÃO PLENÁRIA V

09:00 ÀS 09:30

Moderador da sessão: Nuno Lopes (Universidade de Aveiro)

A transmissão do calor e a dinâmica do fogo
João Ventura (IN+, Instituto Superior Técnico)

SESSÃO 7

09:30 ÀS 10:30

Comportamento das Estruturas e dos Materiais ao Fogo III

Moderador da sessão: Elza Fonseca (Instituto Politécnico de Bragança)

- 9:30 Comparação estatística dos resultados da aplicação de métodos diversos na verificação da resistência ao fogo de pilares em betão armado
Miguel Chichorro Gonçalves e Alzira Ramalho
- 9:45 Análise termomecânica de colunas tubulares de aço de secção quadrada e retangular preenchidas com betão em caso de incêndio
João Azevedo, Luís Laím e João Paulo Rodrigues
- 10:00 Aplicação computacional dos métodos simplificados de cálculo da EN 1994 - 1.2
Rui Costa, João Paulo Rodrigues e Luís Laím
- 10:15 O efeito das altas temperaturas na resistência à compressão de um betão com adição de fibras de aço e têxteis reciclados de pneu
Maria Eduarda Mendes Daniel, Cristina Calmeiro dos Santos e João Paulo Rodrigues

SESSÃO 8

11:00 ÀS 12:00

Organização e Gestão da Segurança Contra Incêndio

Moderador da sessão: Aldina Santiago (Universidade de Coimbra)

- 11:00 O papel da direção escolar na gestão da segurança contra incêndio nas escolas
Susana Almeida Monteiro e Rui Cruz Oliveira
- 11:15 Importância da Gestão da Segurança Contra Incêndio em Edifícios: casos de incêndios com falhas de gestão graves
Rui Cruz Oliveira, Lino Forte Marques e João Paulo Rodrigues
- 11:30 Caracterização da combustão de tendas de campismo
Jorge Raposo, Miguel Almeida, Domingos Viegas, Marta Martins e Joel Teixeira
- 11:45 Extinção automática em hottes de cozinha
Jorge Miguel Filipe e Sónia Bergano

SESSÃO PLENÁRIA VI

12:00 ÀS 12:30

Moderador da sessão: João Ventura (IN+, Instituto Superior Técnico)

Sustentabilidade, eficiência energética e os desafios para a segurança face ao incêndio

Carlos Pina dos Santos (Laboratório Nacional de Engenharia Civil)



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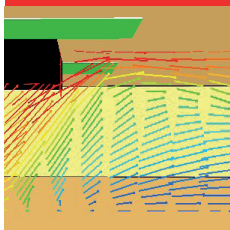
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PREFÁCIO

A segurança aos incêndios urbanos assume particular importância pelo risco normalmente associado a este tipo de acidentes, tendo como objetivo a redução do número de ocorrências, das vítimas mortais, dos feridos, dos prejuízos materiais, dos danos patrimoniais, ambientais e de natureza social. O conhecimento associado a esta situação accidental é o resultado da evolução do conhecimento empírico, desenvolvido ao longo dos anos com incêndios reais e exercícios, e o resultado do conhecimento científico, normalmente desenvolvido nas instituições do Sistema Científico e Tecnológico, tendo em consideração a complexidade dos fenómenos e a respetiva interdisciplinaridade. Com vista à redução do risco de incêndios urbanos, Portugal tem assistido ao crescimento e atualização desta legislação.

Tendo por objetivo criar um fórum de discussão científica e técnica deste tema, no ano de 2005 foi dado início ao ciclo de Jornadas de Segurança aos Incêndios Urbanos, com a realização das 1as Jornadas na Universidade de Coimbra.

Seguiram-se as 2as e as 3as Jornadas, realizadas nos anos de 2011 e 2013 também na Universidade de Coimbra, e as 4as Jornadas, realizadas em 2014 no Instituto Politécnico de Bragança com o apoio da ALBRASCI (Associação Luso-Brasileira para a Segurança Contra Incêndio). As 5as Jornadas pretendem dar continuidade à divulgação do desenvolvimento do conhecimento nos diversos domínios da segurança ao incêndio, de modo a constituir um fórum de debate alargado entre engenheiros, arquitetos, professores, investigadores, técnicos, licenciadores e demais entidades do sistema de proteção civil.



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WOODEN CELLULAR SLABS WITH AND WITHOUT INSULATION SUBMITTED TO FIRE CONDITIONS



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ABSTRACT

The wooden cellular slabs are lightweight structures, easy to assemble, and with excellent architectural features, as good thermal and acoustic conditions. The wooden cellular slabs with perforations are typical and very common engineering solutions, used in the ceiling or flooring to improve the acoustic absorption of compartments, and also have a good insulation and relevant architectonic characteristics. However, the high vulnerability of wooden elements submitted to fire conditions requires the evaluation of its structural behaviour with accuracy. The main objective of this work is to present a numerical model to assess the fire resistance of wooden cellular slabs with different perforations. Also the thermal behaviour of the wooden slabs will be compared considering material insulation inside the cavities. The time-temperature history and the residual cross-section of wooden slabs were numerically measured and analysed.

KEY WORDS: Cellular slab; perforation; wood; fire; insulation.

1. INTRODUCTION

The problem of fire resistance of wooden elements is analysed from the behaviour that the material presents when is in fire exposure. Fire resistance relates to the period for which an element will resist to a flame passage, remains free from collapse and insulate against an excessive temperature rise of the unexposed face. Different fundamental phenomena need to

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be evaluated: combustion, heat transfer and evolution of the wood properties with temperature dependence.

In this work wooden cellular slabs are considered for study with typical applications in auditoriums, offices, restaurants, concert halls, schools, hotels, gymnasiums, etc. They are typical panels applied in building structures with a rustic and decorative look. The combination between the wood materials and other acoustic material layers offers aesthetics and sound absorption effect. Also, perforations in these slabs are common and available in different patterns and sizes. Fire experimental tests in different wooden surfaces were performed by Frangi *et al.* [1], enlarging the experimental background of these elements in fire and predicting simplified calculation models.

Wood is a thermally degradable and combustible material. Wood when subjected to fire produces a surrounding charring depth layer, with no mechanical resistance, resulting a reduced cross-section. Several researchers have presented experimental models and analytical methods to calculate the physical degradation of wood due high temperatures, [2, 3, 4]. The charring rate is strongly affected by the material density and it has been studied by different researchers [5 to 14], using empirical models or performing different fire tests.

In perforated cellular wooden slabs, the size of perforations facilitates and increases the heat flow and flames penetration over the slab. An insulation material in combination with other building materials allows to reduce the heat transfer inside and out. There are many kinds of insulating materials, each of which has its own set of advantages and disadvantages, and none of which are the perfect solution. The best insulation materials should have the lowest thermal conductivity, in order to reduce the total coefficient of heat transmission. The insulation material should be rated as non-flammable and non-explosive. In the event that the insulation material burns, the products of combustion should not introduce toxic hazards. The main question is to choose the correct thermal insulation material which help to satisfy building requirements as a mostly energy and cost efficient.

Our proposal is use an advanced calculation method for determining the charring depth, the profiles and the temperature distribution through the construction elements during a fire scenario. This work describes the basic idea of the 2D numerical model, to predict the time-temperature history and the residual cross-section identification in wooden cellular slabs with and without perforations. Different constructive solutions will be numerically analysed. Insulation material will be added inside the cellular cavities to determine the influence on time-temperature history. The main results of the numerical analysis are presented. The results enlarge the knowledge of the fire behaviour of different insulation materials applied in wooden slabs, and complete others investigations developed by the authors of this work [15 to 18].

2. PRESENTATION OF THE WORK

2.1 Material properties and standard fire curve

The thermal properties of the used materials in this work were based on a literature review.

Wood material when exposed to fire presents a thermal physical degradation. The interface between charred and noncharred wood is the transition phase between black and brown material and is characterized by a threshold value of 300°C, according Eurocode 5 [19]. Also the thermal properties of wood vary with temperature and should be defined according Annex B of Eurocode 5 [19]. This standard code provides the design values for density, thermal conductivity and specific heat of wood. The non-linearity due to the thermal properties dependence will be taken into account in the numerical simulation. The wood specie (Spruce) considered in this study presents a value of density equal to 450kg/m³.

The wooden cellular slabs in study have three different cavities. In the wooden slab with insulation material, the internal cavities will be filled with air and the thermal properties were considered in the numerical study [20].

To analyse the effect of the insulation, two different materials (Medium Density Fiberboard MDF or Mineral wool RW) will be used inside the cavities.

MDF is a wood-based panel composed by fibres that are mixed with resin and pressed into flat panels under high temperature and pressure. MDF material is combustible and the level of fire resistance depends of their density. The MDF considered in the present study has properties according ISO 10456 [21] and EN316 [22]. The considered values are: thermal conductivity equal to 0.14W/mK, specific heat equal to 1700J/kgK and density equal to 600kg/m³.

Mineral wool (RW) is a general name for fibre insulation materials that are formed by spinning or synthetic minerals. The RW is non-combustible with a melting point approximately equal to 1177°C, [23, 24]. The thermal properties considered for RW are: thermal conductivity equal to 0.04W/mK; specific heat equal to 840J/kgK and density equal to 100kg/m³.

For fire situation, a standard curve refers to the time-temperature used in tests for defining the fire resistance rating of elements in general. The International Standards Organization's standard (ISO 834) time-temperature curve is given by equation 1 [25], where the fire evolution is (θ in °C) over time (t in min):

$$\theta_{\infty} = 20 + 345 \log_{10}(8t + 1) \quad (1)$$

2.2 2D models and geometry

The model of wooden cellular slab is based on the dimensions of a constructive solution tested in laboratory [17, 18]. In this work only the two-dimensional (2D) slab cross-section with perforations was considered for analysis. The cross-section includes three different cellular zones (two with perforations and one without perforations).

The wooden cellular slab in study has different types of perforations (rectangular R or circular D) at the bottom, as represented in Figure 1.

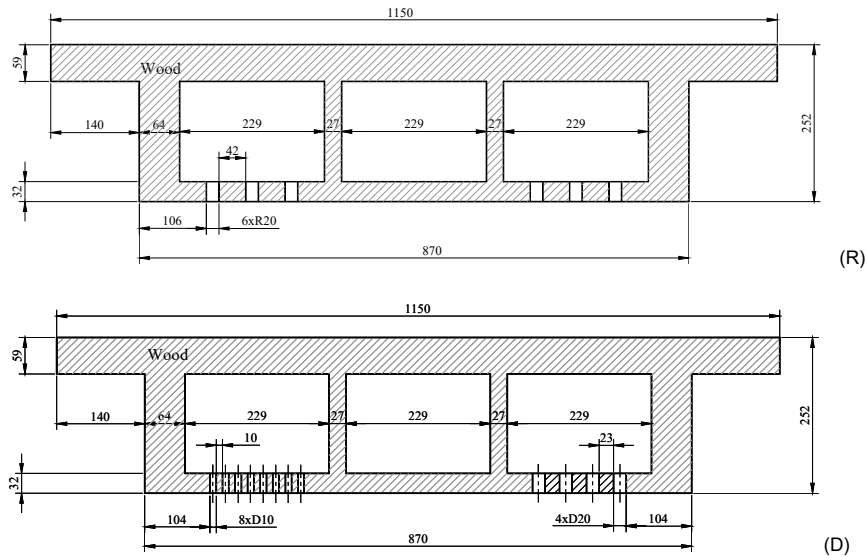


Figure 1: Wooden cellular slab: rectangular (R) and circular (D) perforations.

Additional 2D models will be considered with internal insulation material (MDF and RW). The MDF and RW were added inside the perforated cavities and considered with different sizes (18mm or 36mm), as shown in Figure 2. Due the combination between materials and slab geometries, ten numerical models were solved. For each model, one side was considered to fire scenario and the time-temperature history was obtained during one half hour of fire exposure.

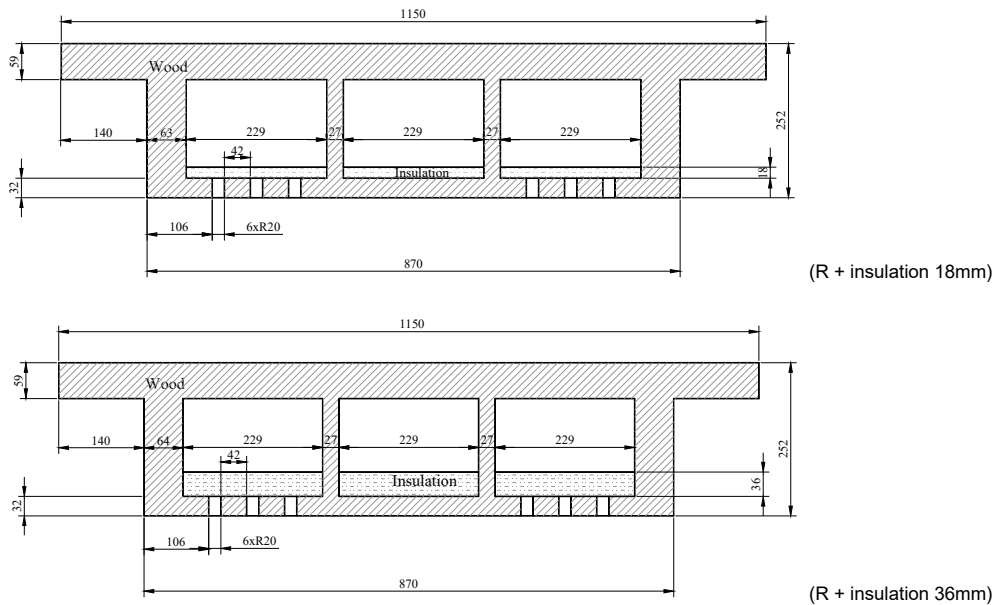


Figure 2: Wooden cellular slab: rectangular (R) and circular (D) perforations and insulation.

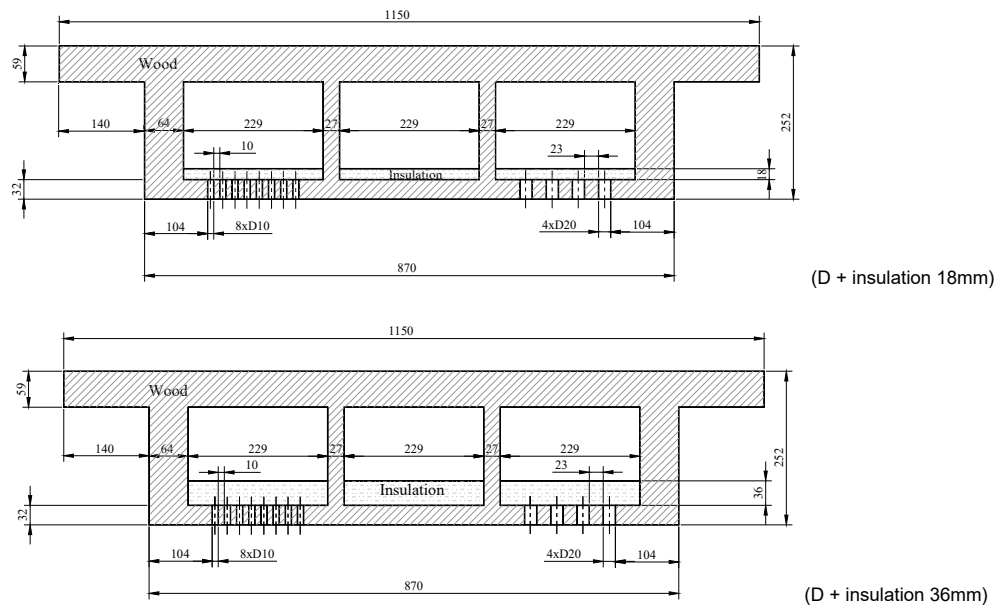


Figure 2: Wooden cellular slab: rectangular (R) and circular (D) perforations and insulation (cont).

2.3 2D Models and Finite Element Thermal Analysis

For the calculation of the temperature development in wooden cellular slabs subjected to an ISO fire a finite element thermal analysis was conducted using Ansys program. 2D finite element (Plane77) with 8 nodes was used for thermal and nonlinear material in transient analysis.

The heat balance equations set out non-linear boundary conditions and material properties which vary with temperature. In order to fully satisfy the nonlinear conditions of the numerical problem, an iterative procedure in each time step it is necessary to employ, as an implicit single step method. In Ansys a modified Newton-Raphson method was adopted to solve the nonlinear problem, and the time interval considered for each step was equal to 10s. The bottom surface of the wooden slab was exposed to standard fire curve [25] during 1800s. The boundary conditions consist of an exchange of energy with the surroundings and the energy flow at the boundary comprises radiation and convection. The temperature in the wooden cellular slabs on the internal cavities without insulation material follows real heating curves obtained previous during experimental tests [17, 18].

For the boundary conditions, the convection coefficient is taken equal to $25\text{W/m}^2\text{K}$ [25] inside cavities and in the exposed surface. At the unexposed surface the room temperature (20°C) is applied and the value of convection coefficient is equal to $4\text{W/m}^2\text{K}$. The emissivity of the flames is taken equal to 1.0 for exposed side and internal cavities [25]. When insulation material is considered the adjacent cellular zones were filled with air.

3. RESULTS AND DISCUSSION

3.1 Temperature and residual cross-section of 2D wooden cellular slabs

In this study ten different calculation cases are presented. The numerical results are given in figure 3 in which the influence of different insulation materials and perforations were considered.

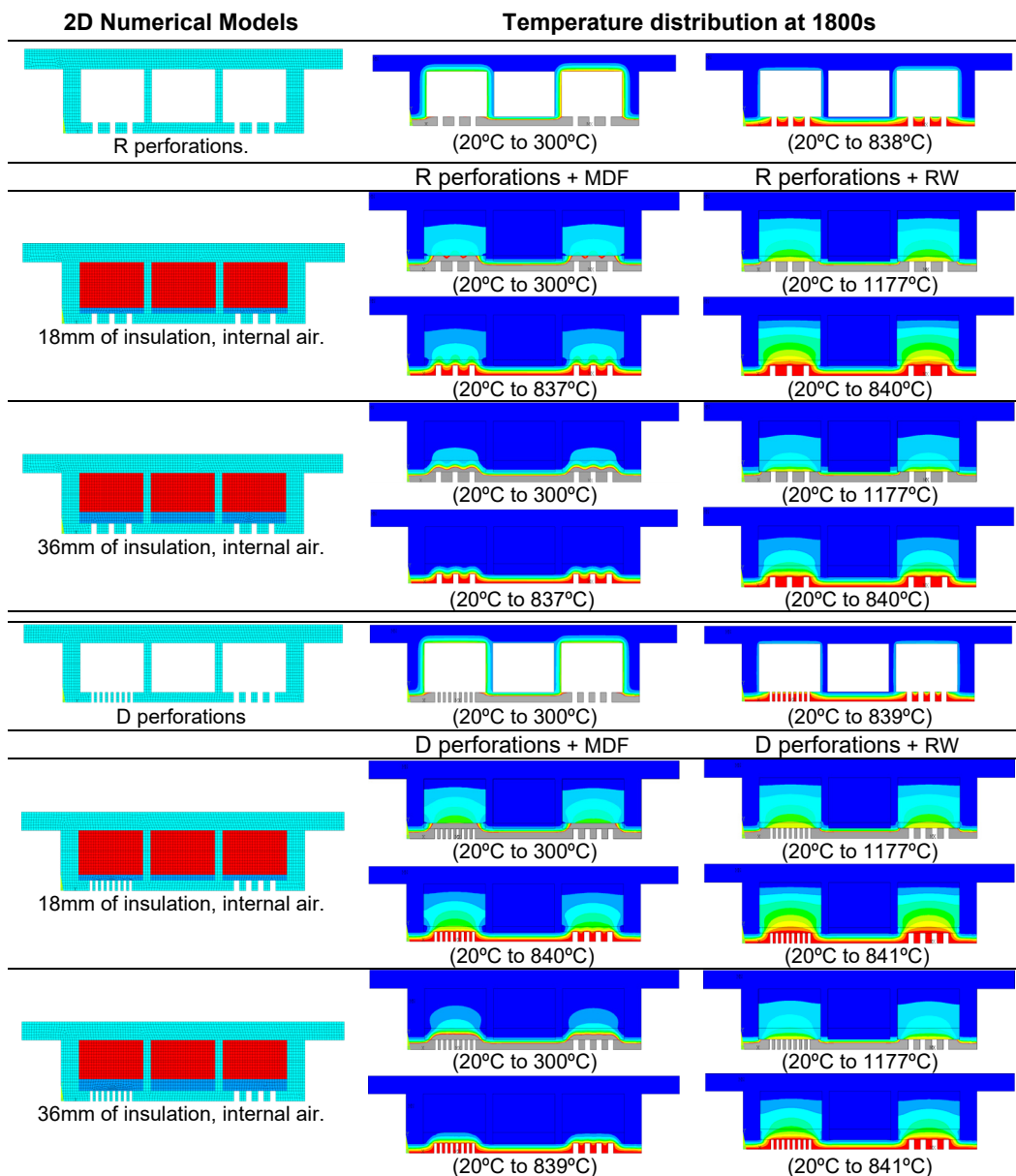


Figure 3: Temperature evolution and residual cross-section of wooden slab with perforations.

Figure 3 represents the temperature at one side fire exposure (bottom surface) of the wooden slab with and without insulation at the end of 1800s, and the correspondent mesh. The physical behaviour of the wooden slab is conditioned by the char layer formation. This phenomenon only was considered in the post processor of the results, according the criterion of char layer applied by the isothermal of 300°C Eurocode 5 [19]. The results shown represent the residual cross-section on the wood material, in grey colour. The numerical results of the residual cross-section of cellular zone without perforations have similar behaviour in all wooden slabs. At the end of fire exposure and inside these cells, temperatures are below than 100°C. The behaviour of cells with perforations are different, all cross sections suffers high level of char due fire. At the last time instant of exposure fire the cells with perforations don't have any residual cross section. In cell with small D perforations the physical degradation starts first when compared with R and higher D perforations. In the border of the R and D perforations the values of temperatures are higher and following the ISO fire. Inside the wood material the temperature remains lower.

The use of insulation material increases the fire resistance and the safety of the wooden slab, with no heat flow propagation for inside the cavities. Nevertheless, RW material offers high values of temperatures, the heat inside cavity increases due the value of thermal diffusivity of the material, but the physical degradation only starts when temperature reaches 1177°C. MDF only resists until 300°C, nevertheless the heat inside cavity is lower due the thermal diffusivity of this material. Two different thickness of insulation material were used. During the fire exposure RW material resists without any degradation and more durability. MDF only resists when a board thickness is equal to 36mm in the model with R perforations.

3.2 Time-temperature history in 2D wooden cellular slabs

The time-temperature history for each wooden slab was compared between the results when the insulation was changed in material and thickness. Figure 4 to Figure 7 show some graphs with the time-temperature history, in the perforated cells considering for comparison the same nodal positions (node 1 and node 2) in air mesh location (A). Figures 4 and 5 show the evolution of temperature inside the cellular zones in the wooden slab with D perforations.

The comparison between the use of different insulation materials (RW and MDF) and different thicknesses, show that the use of MDF produces lower temperatures than the use of RW insulation. When the thickness of the insulation increases the temperature evolution inside the cellular zones has a reduction on temperature approximately equal to 100°C at the time end. Also, the number and the dimensions of the D perforations influence the temperature evolution between node 1 and node 2. In the cellular zone where exist more perforations (even with lesser size) the heat flow is higher when compared with the cellular zone with lesser D perforations. The graphics represented in Figures 6 and 7 show the time-temperature history inside the cellular zones in the wooden slab with R perforations, dependent of the insulation and size thickness material. The use of RW insulation material inside the cavities produces higher temperature evolution when compared with the MDF material. Also, the increase of the insulation thickness produces a decrease in time-temperature history inside the cavities, approximately equal to 100°C at the time end of the fire exposure. In this wooden slab, the cavities 1 and 2 have the same type of R perforations and the temperature evolution has the same behaviour.

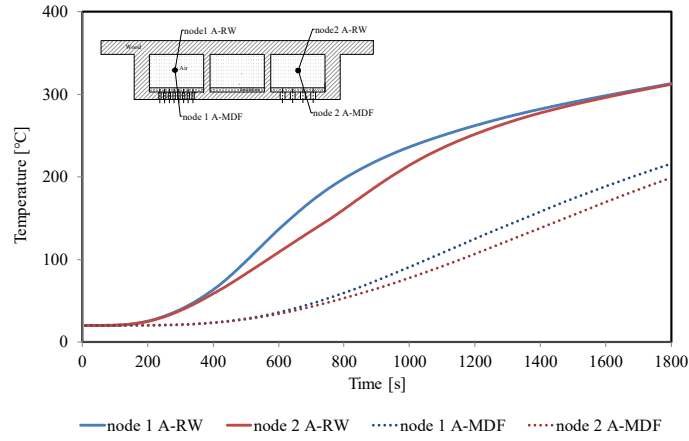


Figure 4: Time-temperature history in wooden cellular slab, D perforations, 18mm of insulation.

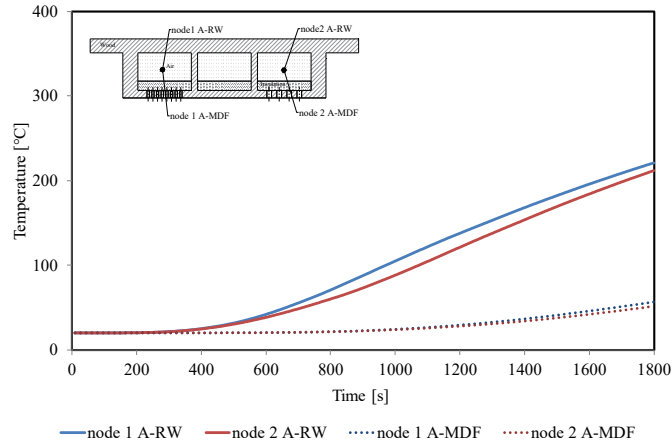


Figure 5: Time-temperature history in wooden cellular slab, D perforations, 36mm of insulation.

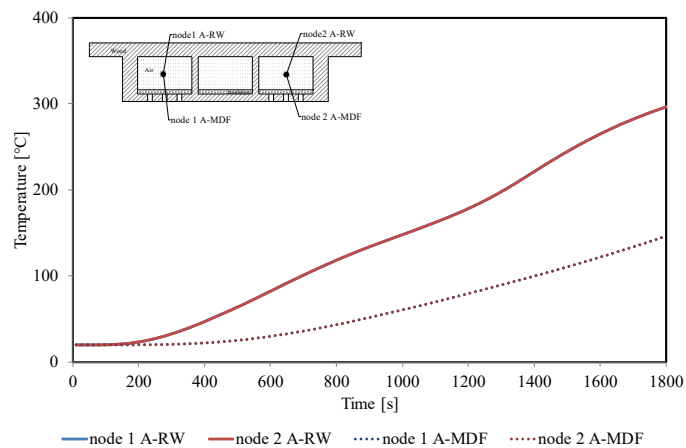


Figure 6: Time-temperature history in wooden cellular slab, R perforations, 18mm of insulation.

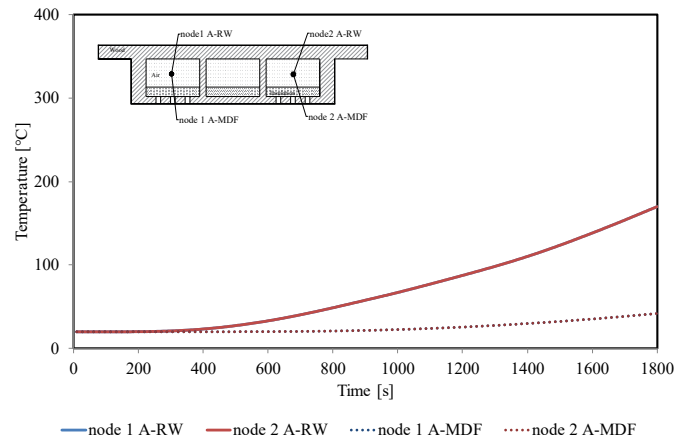


Figure 7: Time-temperature history in wooden cellular slab, R perforations, 36mm of insulation.

4. CONCLUSIONS

Fire reduces the dimensions of the wooden slab cross-section as well the strength and stiffness. The residual cross-section after charring is used to determine the reserve of capacity during and after exposure to extreme temperatures, it serves as a guidance in estimating the wood member capacity during fire exposure. Theoretically, a linear relationship is used between the charring depth and the time of fire exposure, referred to the char front assumed uniform over the entire wood section. This happens in wooden slab without perforations, but with different perforations the wooden slab has a residual cross-section and consequently a charring depth strongly affected by the perforated open space. Proper selection of the insulating materials is based on the thermal properties which include the density, low thermal conductivity and high specific heat. Also a lower thermal diffusivity leads to a good thermal insulation. This parameter determines the temperature distribution in non-steady or transient conditions and measures the ability of a material to transmit a thermal disturbance, indicating how quickly a material's temperature will change. Also all thermal properties are function of temperature, porosity, density and particle sizes. Different material insulation could be used in addition to guarantee more durability in wooden cellular slabs with perforations. This study allows verifying the evolution of the temperature and the residual cross-section throughout a wooden slab. It was possible to characterize the thermal behaviour of the various elements and characterizing the temperature evolution inside the cellular zones with the insulation effect.

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