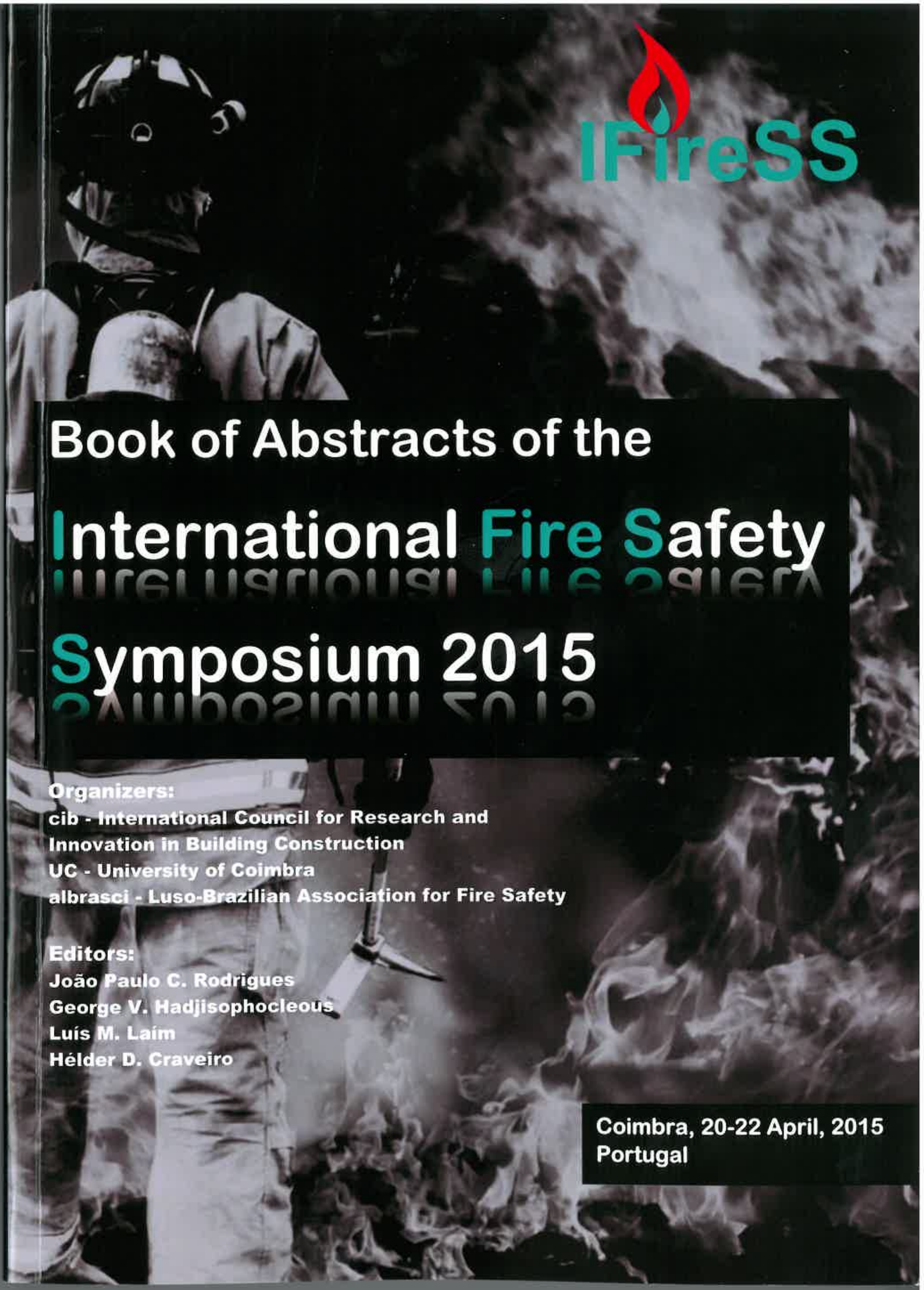

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FIRE REACTION OF CONCRETE WITH AND WITHOUT PP FIBRES: EXPERIMENTAL ANALYSIS AND NUMERICAL SIMULATION



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Keywords: Fire reaction; Concrete; PP fibres; Thermal performance; heat release rate.

1. INTRODUCTION

Structural elements of reinforced concrete, in general, present good performance in case of fire. However, more recent structures have adapted new types of concrete (high strength, self-compacting, etc.) presenting different thermo mechanical behaviour, acquiring special importance the study of spalling. One of the most common procedures to minimize this events is the addition of polypropylene fibres (PP) to natural components, reducing the internal void pressure of the material through the channels created by the fusion of the fibres.

The experimental study of concrete under fire conditions and the development of new numerical models has allowed the assessment of more or less complex phenomena to determine temperature evolution and other state variables, enabling different levels of approaches, using

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coupled or uncoupled field interaction (thermal, mechanical, hydrodynamic, chemical). This investigation studies the thermal performance of a two dimensional model, using nonlinear and transient finite element analysis.

2. MATERIAL AND METHODS

The experimental analysis is based on calorimetric test using small-scale samples of concrete, with dimensions 100x100x40 mm using the test method EN ISO 13927 [1]. In addition to the standard test, normally used to determine the mass loss rate and the heat release rate, four thermocouples type k were positioned in different coordinates of the samples and the infrared thermography camera (FLIR 365) was used to evaluate temperature field in one lateral surface of each sample. A numerical simulation model was defined to evaluate the thermal performance of samples when submitted to different heat fluxes 35 and 75 [kW/m^2] and different level of fibres contents, see table 1. In order to use the cone calorimeter experiments to validate the numerical model, small changes to standard test procedure were made.

Table 1: Tested samples.

Samples	**Materials**	**Heat flux[kW/m^2]**
01	AN	35
02	AN	35
03	AN	75
BF1_600	AN + PP [600 g/m3]	35
BF2_600	AN + PP [600 g/m3]	75
BF1_1200	AN + PP [1200 g/m3]	35
BF2_1200	AN + PP [1200 g/m3]	75

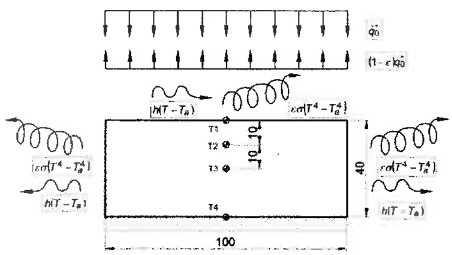
The thermal performance of the samples depends on the thermal balance in the boundaries. The Eq. 1 should be solved in the two dimensional domain of the sample (Ω), taking into account the exchange of heat with the surroundings $(\partial\Omega_i)$. On the top surface of the sample $(\partial\Omega_1)$, the heat flow balance (input and output) should verify Eq. 2. The net incident heat flux at the top surface of the sample is composed by the heat flux coming from the cone heater, radiation reflected from the surface, convective and radiative heat losses. On the lateral surfaces of the sample $(\partial\Omega_2)$ the convective and radiative heat losses should be considered by Eq. 3 and at the bottom surface of the domain $(\partial\Omega_3)$ the adiabatic condition may be assumed, Eq. 4. In these equations T represents the main state variable (temperature), the thermal properties of concrete are represented by the specific mass $\rho_{(T)}$, specific heat $C_{p(T)}$ and conductivity $\lambda_{(T)}$. The emissivity of concrete ε was considered equal to 0.7. The Stefan-Boltzmann coefficient is denoted by σ and h represents the convection coefficient that was approximated by an experimental correlation for a hot horizontal plate in air, with the hot surface uppermost [2]. T_a represents the ambient temperature. These equations should consider the nonlinear behaviour of material properties [3]. The balance model is represented in figure 1, as well as the setup used in experiments.

$$\nabla \cdot (\lambda_{(T)} \cdot \nabla T) = \rho_{(T)} \cdot C_{p(T)} \cdot \partial T / \partial t \qquad (\Omega) \tag{1}$$

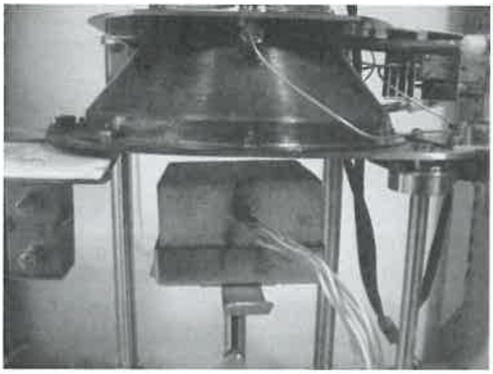
$$(\lambda_{(T)} \cdot \nabla T) \cdot \vec{n} = \dot{q}_0'' - h(T - T_a) - \varepsilon\sigma(T^4 - T_a^4) - (1-\varepsilon)\dot{q}_0'' \qquad (\partial\Omega_1) \tag{2}$$

$$(\lambda_{(T)} \cdot \nabla T) \cdot \vec{n} = -h(T - T_a) - \varepsilon\sigma(T^4 - T_a^4) \quad (\partial\Omega_2) \tag{3}$$

$$(\lambda_{(T)} \cdot \nabla T) \cdot \vec{n} = 0 \qquad (\partial\Omega_3) \tag{4}$$



a) Thermal model.



b) Cone heater and thermocouples.

Figure 1: Test model and instrumentation.

3. RESULTS

Figure 2 presents the thermocouple measurements during tests. These values are useful to validate the numerical thermal model. The heat release rate was also measured and there was no significant difference between samples with and without PP fibres for the heat flux level of 35 [kW/m^2].

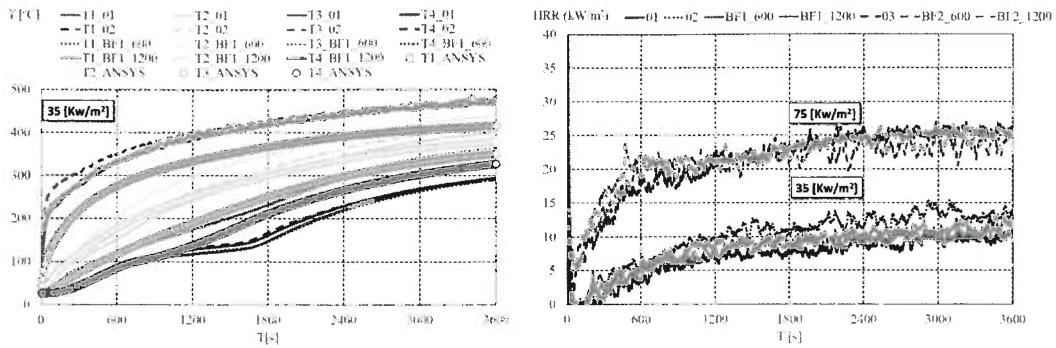


Figure 2: Thermal performance with simulation results and Heat Release Rate of same samples.

4. CONCLUSIONS

The thermal behaviour of concrete samples, with and without polypropylene fibres was presented, when submitted to a uniform heat flux of 35 and 75 [kW/m^2]. This study was performed experimentally with two methods and numerically, with the validation of the numerical model. The numerical model has the limitation of predicting the motion of the moisture in the samples.

It can also be concluded that addition of different amounts of polypropylene fibres has no significant effect on the heat release rate and on the thermal performance of the samples.

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