HEAT RELEASE RATE PREDICTION BASED ON CONE CALORIMETER EXPERIMENTS

THIRY A.[1], ZHANG J.[2], HASSANALY J.[3] and BAZIN H[1].

[1]: Laboratoire Central de la Préfecture de Police, 39 bis rue de Dantzig, 75015 PARIS, France - www.lcpp.fr
[2]: Université de Technologie de Troyes, 12 rue Marie Curie, 10000 TROYES
[3]: RATP - Direction Générale - Contrôle Général de Sécurité - Sécurité Incendie, 54 quai de la Rapée, 75012 PARIS

Introduction

The French Central Laboratory of Police Prefecture (LCPP) is a technical and scientific institute in charge of risk assessment, expertise and prevention, as well as environmental health and safety. The LCPP deals with many kinds of investigation (e.g.: technological, malevolence, domestic, environmental) and has jurisdiction in the territory of Paris and immediate suburbs.

Managing fire hazard is a major issue for RATP, the parisian railway company. Studying the fire mechanisms is necessary to understand how a fire occurs, develops and interacts with infrastructures, trains and passengers. The LCPP and RATP have many cooperative research activities in fire modelling, smoke management and fire testing.

Prediction of the heat release rate is crucial for fire safety engineering and, more generally, for fire modelling. This work aims at determining mathematical functions to predict full-scale heat release rate by using cone calorimeter results.

This work took place as requirement for the degree of Master degree in Mechanical Engineering in LCPP's Fire Engineering division.

Theory

Convolution model[1]

$$\dot{Q}(t) = \int_0^t \dot{q}''(t-\tau)\,.\,\dot{A}(\tau)\,d\tau$$

with :

- $\dot{Q}(t)$: full-scale heat release (kW)
- $\dot{q}''(t)$: heat release rate per unit area measured at the cone calorimeter (kW/m²)
- $\dot{A}(\tau)$: flame spread rate (m²/s)

Flame spread models[2]

• **Wickstrom & Goransson model**

$$A(t) = A_0\left[1 + \alpha\,\frac{(t - t_x)^2}{t_{ign}}\right]$$

with :

- A_0 : initial area exposed to flames (m²)
- A_{max} : maximum area involved in flames (m²)
- α : empirical constant representative of fire spread (s⁻¹)
- t_{ign} : ignition time measured in the cone calorimeter (s)
- t_x : constant that stands for an ignition delay (s)

• **Hansen model**

$$A(t) = A_{max}\left[1 - \left(1 + \frac{t - \frac{t_0}{2}}{t_0}\right)\exp\left(-\frac{t - \frac{t_0}{2}}{t_0}\right)\right]$$

Calorimeter Cone Experiments

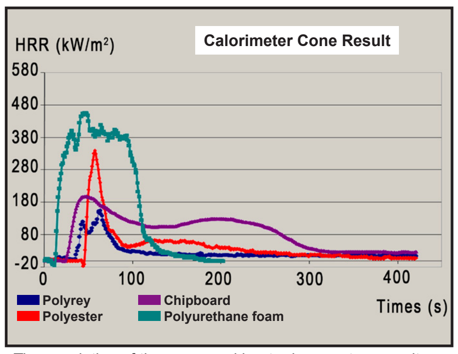
Small scale fire tests have been performed at the LCPP and at the RATP Testing and Measurement Laboratory. The ISO 5660-1 standard[3] have been followed, with the aim of measuring the heat release rate per unit area required to use the convolution model.

Results are summarized in the following graph.

A heat flux of 50 kW.m⁻² and a spark generator were used for all the tests.

The following materials have been tested:

- Chipboard (vertical)
- Polyester reinforced with glassfibers (vertical, from RATP)
- Polyrey (vertical, from RATP)
- Polyurethane foam (horizontal), **5 cm-thick for cone tests, and 10 cm-thick for full-scale**

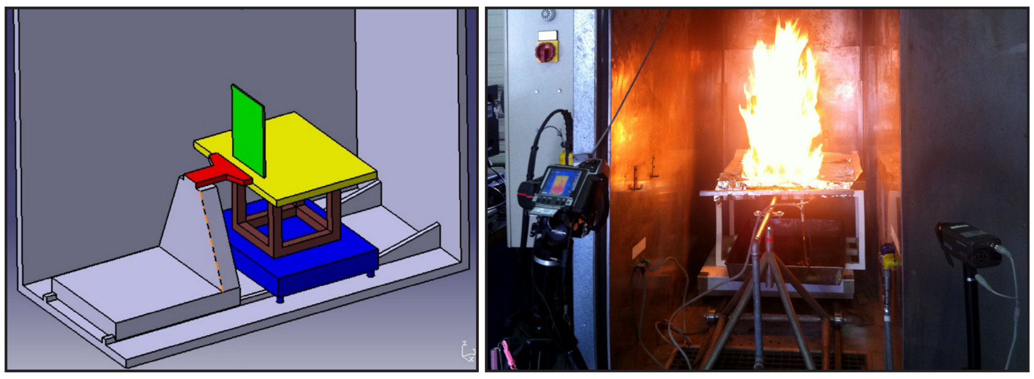


Time evolution of the measured heat release rate per unit area

Note : RATP train materials comply with the NF101-102-103 French standards on fire resistance. The tested materials (Polyrey and reinforced polyester) have a non-propagative behaviour.

Full-scale tests

Full-scale tests were scheduled at the RATP Testing and Measurement Laboratory. Ignition and test chamber were compliant with the NF EN 50266-1 French standard[4]. The objective of these tests was to measure the full-scale heat release rate for model-based prediction assessment.



Testing device : CATIAV5 & experimental set-up

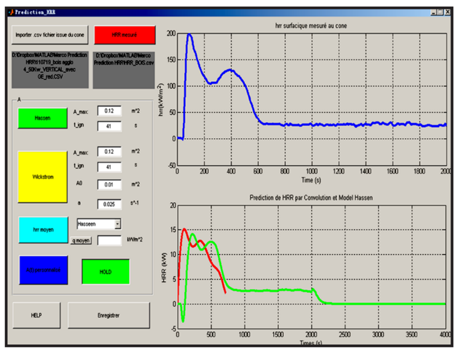
Bibliography

1. Prediction of Heat Release in the Single Burning Item Test. Fire and Materials, 26(2), 2002
2. Full-scale/Bench-scale correlations of wall and ceiling linings. Fire and Materials. 16(1) 1990
3. ISO 5660-1 : «Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part 1 : Heat release rate (cone calorimeter method)».
4. NF EN 50266-1 : Common test methods for cables under fire conditions - Test for vertical flame spread of vertically-mounted bunched wires or cables standards.

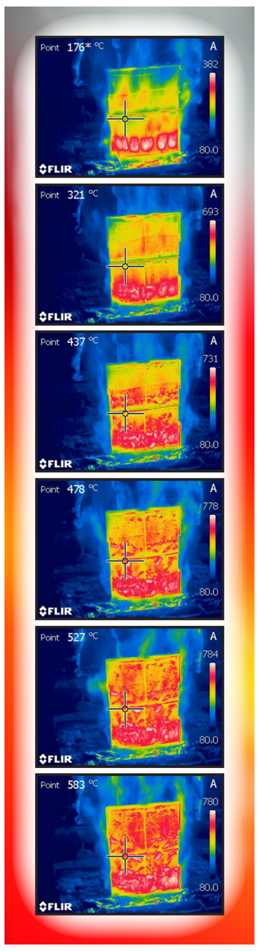
Graphical User Interface coded with MATLAB®

To ease either convolution model computation or comparison between models predictions, a GUI (Graphical User Interface) has been developed.

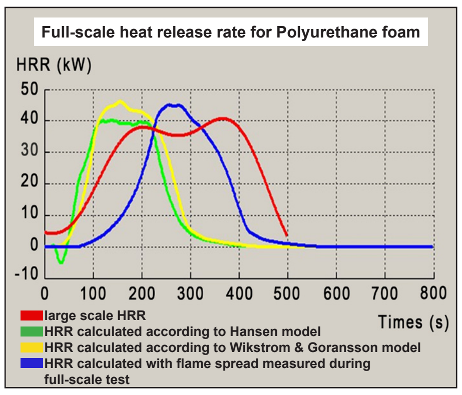
MATLAB® has been used because it offers a technical computing language and an interactive environment for algorithm development, data visualisation, data analysis, and numerical computation.

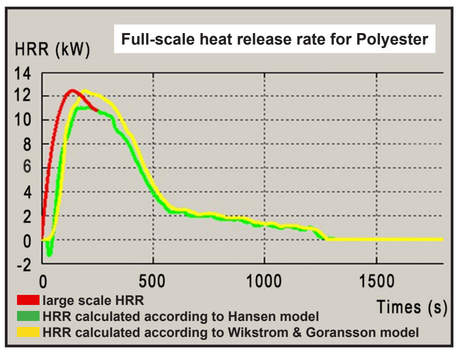


GUI developed with Matlab®

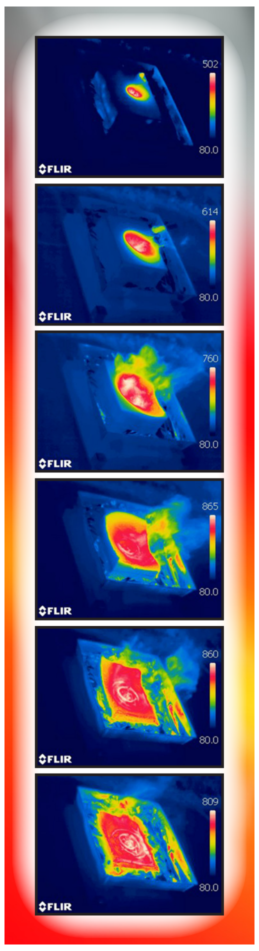


Polyurethane foam





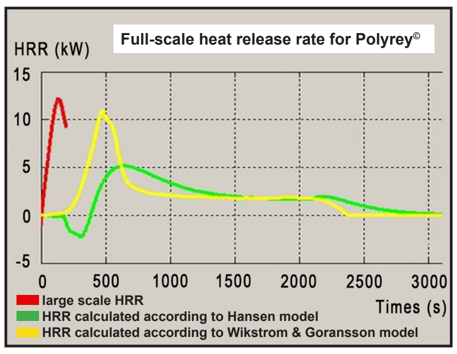
Polyester

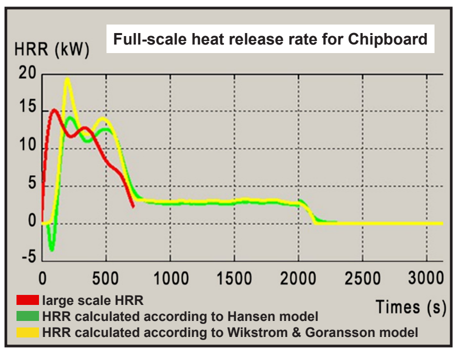


Results

The following figures show heat release rate comparison between real tests and results from models presented previously.

Figures show good agreement concerning growing phase and peak. However, there is a delay between model and reality for all materials and especially for Polyrey©. Such a difference may be explained by the ignition source used for the tests. In addition, the delay is enhanced for Polyrey because of the fire retardant properties of the product (t_{ign} = 178 s for cone tests...).





Conclusions and perspectives

Comparisons between full-scale tests and models show good agreement in terms of prediction of heat release rate (mainly peak HRR and growing phase).

The main difficulty still lies on a reliable methodology in order to assess flame area. In this study, only empirical models have been tested. Physics-based models could be investigated to predict A(t) for different kind of materials.

Improvements concerning ignition source have to be investigated in order to assess the calculation made.

Work is still going on in order to validate the method and allow fire engineering calculations for real configurations.

Test campaign involving 140x100 cm² mattresses took place in 2012 at FIRESERT fire lab in Belfast and will lead to further improvements in the developed method.

Contact : aurelien.thiry@interieur.gouv.fr