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3D SMALL-SCALE FIRE MODELLING EXPERIMENTS AND TESTING PREPARATION

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ABSTRACT

The paper deals with the problematic of small-scale fire tests, its preparation phase and fire experiments connected to Flashover phenomena. Real 3D experiments in small-scale need to be prepared in sense of exactness by exact calculations including mathematic π-non-dimensional groups in order to make a functional small-scale model representing the full scale modelling in the effective way. The interior represented by the cribs made mostly of wood, polymer and other materials common in rooms or offices need to be prepared in sense of their amount, position and porosity. After that the construction of the small-scale model can be started with respect to all the dimensions, amount and proportion of material calculations.

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1. INTRODUCTION

In past decades, scale models have been utilized in numerous fields. From civil to aerospace engineering, scale models demonstrate how a final product may perform. Models have been used to visualize interactions between various parts of a design, to experiment with different design ideas, and to improve the overall product.

Scale modelling can allow fire investigators to replicate specific fire dynamics at a dramatically reduced cost. A wood cribs are used to represent the wide range of fuels that investigators encounter. Modelling requires an in depth understanding of fire physics. Scaling a particular fire begins with assessing the governing conservation equations and selecting the appropriate dimensionless groups and scaling principles[1].

Full scale Experimental modelling of real fire accident situation is the most probably the oldest form of experimental fire engineering. Although, this way is very costly, the results in form of measured data of fire-relevant physical quantities such as temperatures, heat release rate, mass loss and their development during the experiment are very valuable (Table 1.)[2]. On the other hand the disadvantages are connected to time-consuming preparation, human resources required, funding. The repeating of full scale experiment is also very rare[3].

Table 1. Comparing of fire modelling systems[4]

Criteria	Full-scale modelling	Small-scale modelling
Accuracy	High	High
Relative costs [€]	Ten thousand	Hundreds
Professional competence	Upper intermediate	Upper intermediate
Preparation time	Months	Weeks
Number of iterations	Very limited	Limited

Many data and many realistic measurements are needed. But full scale modelling is very slow. A full-scale model takes too much time for. Especially models of entire buildings are very rare. And this is the place for

[1] B. Karlsson, J. G. Quintiere, *Enclosure fire Dynamics*, CRC Press LLC., London 2000, p. 123.

[2] J. Müllerová, R. Michalovič, *The effect of different fuel types on the flashover phenomena in 3D model fire experiment*, [in:] *SGEM 2016: ecology, economics, education and legislation. Albena, Bulgaria*, vol. II, STEF92 Technology, Sofia 2016, p. 815.

[3] J. G. Quintiere, *Fundamentals of fire phenomena*, University of Maryland, 2006, p. 235.

[4] J. Müllerová, R. Michalovič, *The effect…*, p. 816.

small-scale modelling. It enables much more iterations at the same time comparing to full-scale experiments. Its accuracy is comparable to full-scale modelling. The biggest advantage is the price for experiment reflecting much shorter preparation time. It enables more iterations in various conditions. The output data might be used in the PC modelling[5].

2. Flashover

The flashover is a near-simultaneous ignition of most of the directly exposed combustible material in an enclosed area. The prediction of flashover appearance is the key to prevent severe accidents affecting fire fighters. Early warning of Flashover prevents fatalities of Fire & Rescue Corps[6]. The extended knowledge on Flashover conditions, material sources, temperatures, statistics and probabilities of its appearance will help to increase the fire safety of buildings in cooperation to material and construction engineers[7]. The vision is to construct the buildings with such interiors having 0% probability to start the fire leading to flashover state[8].

Flashover is near-simultaneous ignition of most of the directly exposed combustible material in an enclosed area. The criteria for flashover usually require[9]:

– To achieve a temperature among 500–600 °C,
– Min. heat flux on the floor 15 to 20 kW. m^{-2},
– Min. mass burnt per second: 40–80 g/s,
– Critic temp. under ceiling 600,
– Flame tongues from the vents,
– Heat instability (among HRR and Heat losts).

[5] M. Orinčák, R. Švach, *Využitie simulačných programov a geoinformačných systémov v podmienkach HaZZ*, [in:] *Geoúdaje pre podporu záchranárskych jednotiek*, Technická univerzita vo Zvolene, 2011, p. 161.

[6] G. Heskestad, *Modelling of enclosure fires*, "Combustion Institute Symposium on Combustion", 1973, No 14, p. 1027.

[7] M. Orinčák, J. Dvorský, *Analysis and comparation of general fire indicators in Czech Republic and Slovak Republic*, [in:] *Advances in fire & safety engineering 2015*, Technická univerzita, 2015, p. 212.

[8] P. A. Croce, Y. Xin, *Scale modelling of quasi – steady wood crib*, "Fire Safety Journal", 2005, No 40, p. 135.

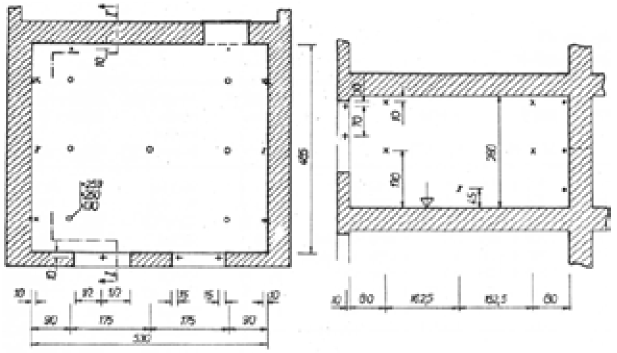
[9] P. G. Holdon, S. R. Bishop, *Experimental and teoretical models of flashover*, "Fire Safety Journal", 1993, No 21, http://www.sciencedirect.com.sci-hub.org/science/article/pii/037971129390030T, p. 259.

There are various software simulations trying to reflect the variability of interior material, construction shape, anti-fire elements and systems within the constructions like sprinklers, fire barrier, chemical fire retardants, sensors and alarms of early warning etc. The highest accuracy still belongs to full-scale models. Full-scale modelling is very often used to get the input data for PC modelling. The realistic accuracy is the biggest advantage[10].

3. Small scale modelling application

The prototype is a building room with 5300mm×4850mm floor and 2600mm height (inner dimensions) (Figure 1). The wall material of the prototype is assumed to be bricks and the ceiling is made of steel beams. The thickness of the compartment walls in the prototype is 450 mm.

Figure 1 Geometry of the prototype compartment[11]



Model at scale are designed. The model with 1400mm×1300mm floor and 750 mm height (inside dimensions)[12]. The inner walls of the model were covered with mineral wool 5 cm thick (Figure 2). The material was found out thanks to fundamental relations of scaling. Mineral wool was

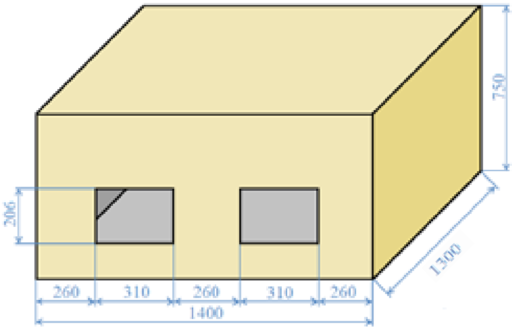
[10] M. Wang, *Scale modelling of structural behavior in fire*, Doctoral Thesis, Maryland: University of Maryland, 2006, p. 79; Ľ. Vrábľová, *Modelovanie rizikových situácií v trenažéri na nelineárne formy požiarov*, Dizertačná práca, FBI, Žilinská univerzita 2015, p. 38.

[11] V. Reichel, *Stanovení požadavků na stavební konstrukce z hlediska požární bezpečnosti*, [in*:] Svaz požární ochrany* ČSSR, 1 ed. Praha 1981, p. 313.

[12] M. Orinčák, I. Coneva, Účinnosť *plynových stabilných hasiacich zariadení a sprinklerových stabilných hasiacich zariadení*, [in:] *Riešenie krízových situácií v* špecifickom *prostredí*, Žilinská univerzita, Žilina 2016.

fixed to 1.25 cm thick plasterboard embedded in the metal frame (3mm thick and 30mm wide).

Figure 2 Geometry of the model compartment



With the help of glue for thermal insulation systems was sealed mineral wool to drywall. Closing of outer walls was carried out by screws placed in 15 cm intervals (Figure 3). During the tests, the material was exposed directly to the hot gases.

Figure 3 1/4-scale compartments

4. Fuel source

The source of fuel for the fire test were 60% of a wood and 40% of a polyamide placed inside the closed space (Figure 4). The wood used for lumber represented spruce wood with 15% humidity. The total weight of wood was 12.5 kg and polyamide was 4.3 kg. It is representing at full dimension fire load of 30 kg.m-2 of floor space. Packages were distributed into 6 boundaries, creating the streets, where the wood wool was added 0.3 kg (weight ratio of cotton and wood chips in a ratio of 1:70). Initiation of Fire was performed by electrically ignited 0.03 liters of alcohol. With emphasis on safety, fire initiation was carried out with the assistance of a firefighter.

Figure 4 Configuration of wood cribs

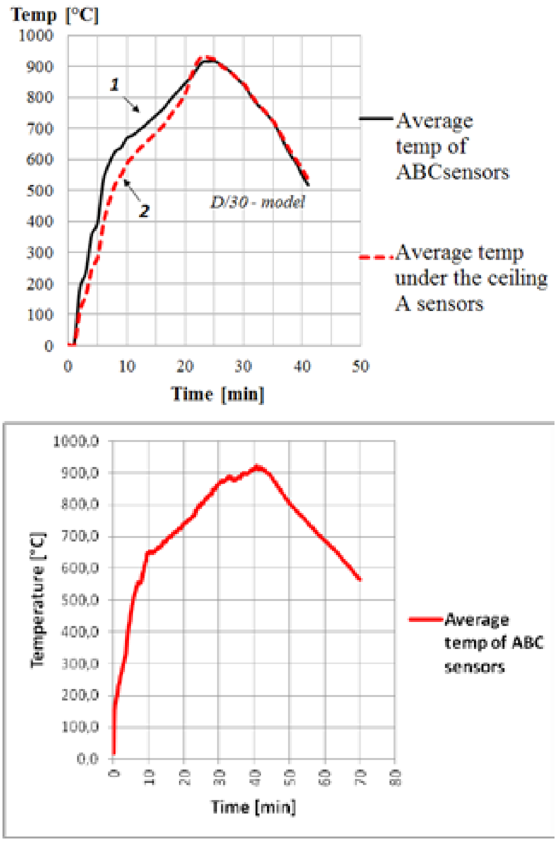
Into the interior we placed six cages (Figure 5.). In the experiments, the most commonly used gas burner, a container of combustibles or fuel bundle of wood. The choice of fuel depends on the required maximum temperature compared with respect to a real fire (the prototype). Then it reaches relatively the same temperature, heat flux and other characteristics of the model at full scale. Wooden crates are minimized by dimensionless groups. The rate of heat flow is controlled by the number and dimensions of the prisms and the spaces between them.

Figure 5 Configuration of fuel source

5. Temperature measurement

The results of measurement are as follows (Figure 6.). Maximum temperatures under the ceiling were 816,3 °C were measured at the time of 1195s. Flashover time was 362s. Of course the recorded temperature selected thermocouples can be observed differences especially when the floor temperature.

Figure 6 Compararison of prototype (up) and model (down)



Values of monitored parameters were recorded by measuring panel type Almemo 5690–1 with K-type thermocouple. Inside the space is located 15 thermocouples. Thermocouple and compensating cable were connected to the control panel ALMEMO 5690–1. Registration of temperatures was carried out in 2-second intervals.

Conclusion

In case of fire modelling in a small scale, the entry test was necessary to find out the accuracy of the application of the laws of reducing on selected object. Modelling on a reduced scale using dimensionless groups for compliance with the criteria of decreasing provides very similar results as a model in full scale. Modelling on a reduced scale can also make use of the forensic detection of fires or causes fire engineering. Fire test shows that the proposed method of reducing a confined space is useful for continuous fire tests. During the experiment it was very similar, including the prototype of the phenomenon of flashover. The results of both experiments confirm the high conformity with the model in full scale. We can say that models in reduced scale represent a large, yet underused potential for obtaining input data in modern computer programs that simulate fires or evacuating the accuracy of the model at full scale.

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