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SMALL SCALE COMPARTMENT FIRE – GEOMETRY OF SPACE

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ABSTRACT

Knowledge of the burning processes and factors that affect them is necessary to successfully determine the causes of a fire. The various and complex phenomena accompanying combustion, in particular the features of combustion that come into play during fires, are in many cases the subject of research and discussion. Conflicts most often arise between an investigator and a technical expert during the evaluation of the versions of a fire outbreak and the possible causes of a fire. Expert opinions affect the final result of the investigation. The expert is the one who must take into account the peculiarities of the combustion which serves as the basis for the formulation of the expertise during the investigation. Deep knowledge of the conditions for the occurrence of fire, of the fire's basic properties, of fire-related technical characteristics of materials as well as of factors influencing the character of the fire are essential in the process of determining the causes of fires. Investigators, experts and fire fighters face these facts.

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burning processes, causes of a fire, combustion, compartment fire, fire-related characteristics of materials

INTRODUCTION

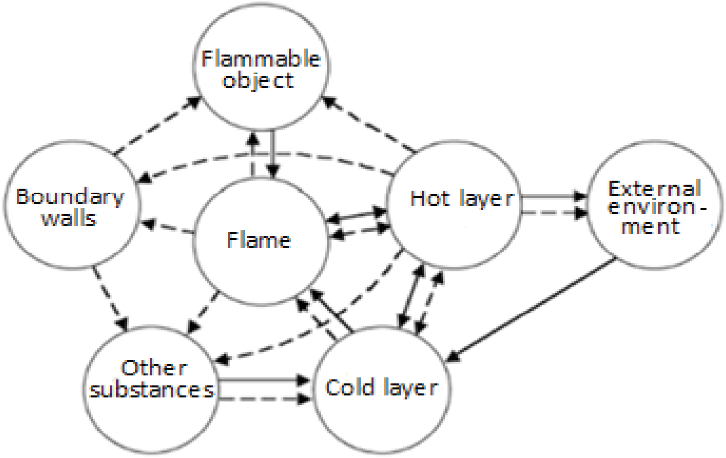
The course of a fire is influenced by various factors and just as the course of a fire in an enclosed space differs from the course of a fire in an open space, so do the factors that influence the course, rise or fall of temperature. Fire development is a term by which the gradual growth and the development of fire is meant. As part of the overall development of the fire, the temperature during the fire is also affected. One can therefore assume that the parameters that affect the development of internal fire also have a direct effect on the development of temperatures. The authors will therefore base on the factors that influence the development of a fire. Five basic factors affect the development of internal fire and, consequently, temperature. These are:

- initiation source,
- fuel,
- ventilation openings,
- space determining material,
- geometry of space.

The development of a fire is thus influenced primarily by the amount of combustible material and its arrangement in the room affected by the fire. The mutual interactions of these factors are schematically shown in Figure 1.[1] Oxygen supply is another decisive factor: if the space where combustion begins is closed, the intensity of combustion will gradually decrease, which means that the temperature of the smoke layer in this space decreases.

[1] B. Karlsson, J.G. Quintiere, *Enclosure fire Dynamics*, London 1999, p. 45.

Figure 1. Scheme of interactions between individual factors of fire development



Source: B. Karlsson, J.G. Quintiere, *Enclosure fire Dynamics*, London 1999.

Fire is a physic-chemical phenomenon which has an interactive nature. The fire does not only depend on the fire load but also on the dimensions and geometry of the building, and on the degree of insulation and ventilation conditions. This paper takes a closer look at one of the abovementioned factors related to the geometry of space.

GEOMETRY OF SPACE

The hot layer of smoke and the upper boundary surfaces of the enclosure radiate towards the burning fuel and thus increase the rate of increase of the fire. Other flammable objects in the room are also heated. The temperature and thickness of the hot layer and the temperature of the upper boundary surface have a significant effect on the growth of the fire. Burning fuel in a small room will cause relatively high temperatures and a rapid increase in fire. In large spaces, identical burning fuel will cause lower gas temperatures and less smoke, less fuel feedback, and slower fire growth. The fire entrains cold air as the mixture of flue gases and air moves up to the ceiling. The amount of cold air entrained depends on the distance between the fuel source and the interface of the hot layer. In an enclosed space with a high ceiling, it causes relatively low gas temperatures. The smaller area the faster process of filling space with smoke. With a low ceiling, the heat transfer to the fuel is greater and the flames can reach the ceiling and spread horizontally, which can result in a significant increase in feedback to the fuel and other combustibles, with a consequent rapid increase in fire. In areas with a high ceiling and a large area, the flames can reach the ceiling and the feedback to the fuel is low. Rather, the growth of fire occurs by direct radiation from the flame to nearby objects. In areas with a large area but low ceiling height, the return flow from the hot layer and the flame can be very intense near the fire.

As one observes either real or experimental fires in an enclosed space, one can divide their course into four characteristic time periods, which are often discussed in terms of temperatures within the space. If there is no attempt to control the fire, t the temperature tends to fluctuate over time. Characteristic time periods are:

- initiation,
- combustion,
- fully developed fire,
- decay.

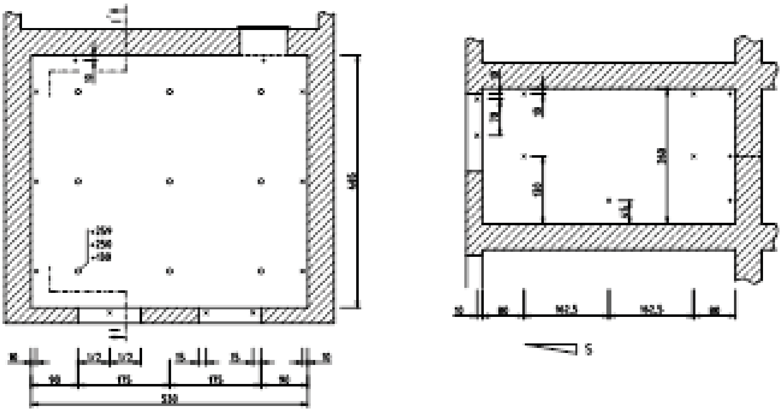
It is important to detect the interdependence between particular periods and time differences of selected observable fire indicators in the form of correlations depending on different fire loads and fuel type.

APPLICATION OF THE REDUCTION METHOD TO THE GEOMETRY OF SPACE

The method of reduction was applied to the object (prototype) presented by the Research Institute of Civil Engineering in Prague in 1981 within the research program Fire Spread Outside the Section. In the authors' research[2], it is a building built at the seat of the Research Institute of Civil Engineering in Veselí nad Lužnicí. The building is made of brick masonry with a ceiling of steel beams and special bricks. The wall thickness is 0.45 meters, while the internal dimensions are 5.3 meters (width), 4.85 meters (length) and 2.6 meters (height). Also, two openings are symmetrically placed on the front wall to replace the windows with adjustable dimensions. Figure 2 shows the dimensions of the experimental object as well as the location of the thermocouples that were used to measure the internal temperatures. They are shown in blueprint view (left) and side section (right).

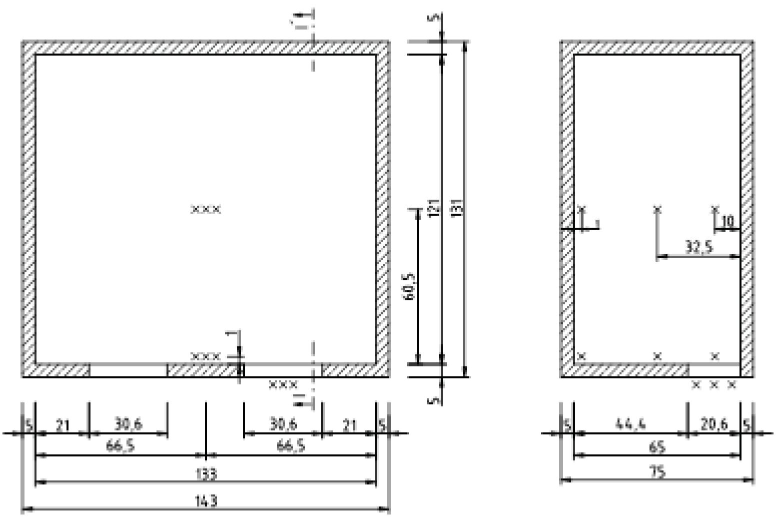
[2] V. Reichel, *Stanovení požadavků na stavební konstrukce z hlediska požární bezpečnosti*, [in:] *Svaz požární ochrany ČSSR*, Praha 1981, p. 27.

Figure 2. Floor plan and section of the selected object (prototype)



Source: own elaboration.

Figure 3. Floor plan and section of a scale model



Source: own elaboration.

The dimensions of the selected object (prototype) were reduced geometrically to ¼ from the full range of Figure 3. The material design of the walls included the selection of suitable insulation materials with properties that would be identical to full-scale brick walls. A detailed quantification of the individual characteristics is given in Table 1.[3]

The prototype (full-scale) brick walls should be replaced by an equivalent on a reduced scale ¼, which corresponds to 5 cm thick mineral wool with plasterboard 1.25 cm. The theory of modelling in small-scale for the fire test purposes is explained by Perricone, [4] Holborn[5] and Heskestad[6], in detail.

Table 1. Thermal and technical characteristics of materials in prototype and model

Reduction parameter	Material	κ $(W/m\,°C)$	ρ (kg/m^3)	c $(kJ/kg°C)$	δ (m)
s^1	Bricks	0,83	1700	0,92	0, 45
$s^{1/4}$	Mineral wool	0,064	60	0,88	0, 43

Source: P.S. Veloo, *Scale modeling of the transient behavior of heat flux in enclosure fires*, College Park, MD 2006.

The integrity of the model is ensured by a metal structure with dimensions of 143 × 131 × 75 cm, which is shown in Figure 4. The construction is relatively simple and therefore will not significantly affect the thermal insulation properties of the model. The construction is made of steel L-profile 30 × 30 × 2 mm.

[3] P.S. Veloo, *Scale modeling of the transient behavior of heat flux in enclosure fires*, College Park, MD 2006, p. 127.

[4] J.A. Perricone, *Scale Modeling of the Transient Behavior of Wood Crib Fires in Enclosures*, Maryland 2005, p. 87.

[5] P.G. Holborn, S.R. Bishop, *Experimental and theoretical models of flashover*, "Fire Safety Journal" 1993, vol. 21, no. 3, p. 262.

[6] G. Heskestad, *Modelling of enclosure fires*, "Combustion Institute Symposium on Combustion" 1973, no. 14, http://libgen.org/scimag/?s=Modeling+of+enclosure+fires.+&journalid=&v=&i=&p=&redirect=1 (accessed: 10.11.2019), p. 1025.

Figure 4. Steel construction of the supporting frame of the scale model

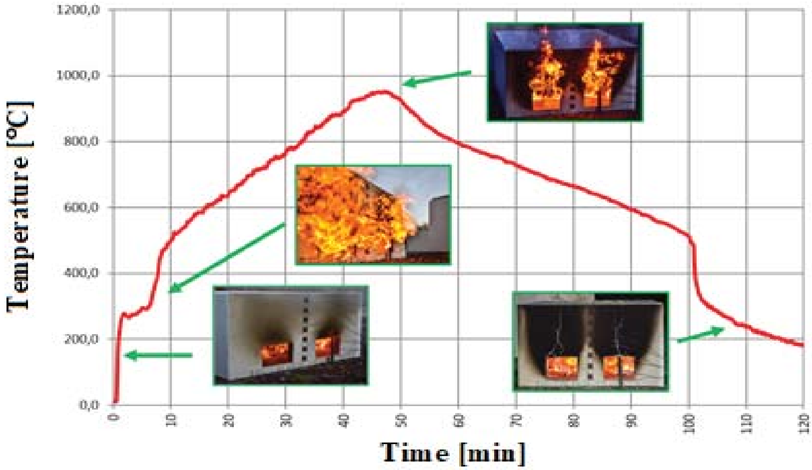
Source: authors.

EXPERIMENT RESULTS

The construction of the small-scale model with the plasterboard walls simulates the room or office within the building built by bricks. After that the wood cribs are placed inside with wooden wool and a number of temperature sensors. There are two openings to simulate the door and windows. The measurement started at the moment of the fire initiation. The temperatures were measured, the pictures on the figure (Figure 5) indicate the fire flow.[7] Figure 5 shows the fire curve of a scale model, which was aimed at burning a material consisting mainly of wood with a fire load of 30 kg/m^2. These conditions are characteristic of office space. This test can be understood as a simulation of an office fire.

[7] J. Mullerova, M. Krajcir, *Effect of fuel source on enclosure fire parameters. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 2018 (18)*, Albena 2018, p. 327.

Figure 5. Fire temperature curve with a fire load 30 kg/m²



Source: own elaboration.

Each office can have a different geometry of space and a different arrangement of equipment, for which reason the course of fire may be diverse. As mentioned, the properties of an interior are influenced by many factors such as the amount of material, the geometry of the space, the number and size of openings, the properties of the structure and the like. It is possible to state that the temperature curve of one fire will not be equivalent to another fire, but they will both fit a similar trend.

CONCLUSION

The material by which the surface of the enclosure is covered can significantly affect the temperature of the hot gases and thus also the heat flow into the burning fuel and other flammable objects. Energy-saving materials such as mineral wool limit the amount of heat flow on the surface so that hot gases retain most of their energy. At the same time, it is necessary to take into account the very interaction of fire with the structure, the materials from which it is made, as well as the materials located in the given environment. The results of examining the regularities of fires on a reduced scale may increase the knowledge of researchers, investigators and professional fire protection engineers. Models on a reduced scale have a great but insufficiently used potential for obtaining input data in modern computer programs that simulate fires in full.

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