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Diffusion of combustion products in a five-storeyed educational building

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Diffusion of Combustion Products in a Five-Storeyed School Building: *Occurrence and development of fire in a five storey school building of the Technical University – Sofia are simulated by the means of mathematical modeling. The results of the simulation show the fire development and the diffusion of combustion products – smoke, temperature and other harmful emissions. The results give a different innovative approach in solving the main problem of firefighting and adequate evacuation of people. Recommendations are given of how to improve evacuation and to control smoke direction. Through the simulation we get the idea of the values, distribution and the velocity gradient of basic and critical parameters which should be taken into consideration in fire safety design of buildings and installations and as well in firefighting and evacuation of people and property.*

Key words: *Fire, Evacuation, Numerical Simulation, PyroSim, Smoke, Combustion Products.*

FIELDS OF APPLICATION & FUNDAMENTAL PURPOSE

Fire prevention, optimization of firefighting, minimizing the risks, including psychological effects of the combustion products. Provides clarity in the investigation of fire causes and if proven necessary – updates in the legislation [1].

Determination of the dynamics of fire dangerous (hazardous) factors is based on solving 3-D unstable differential equations for heat conduction through a multilayer wall (Composite Solids) [2, 3]. For solid surfaces in a premise the boundary conditions in these equations are defined by a 3-D regional model for calculation of fire heat and mass transfer (connected to theoretical heat and mass transfer problem [4, 5, 6]

Fire in premises develops in complex thermo-gas dynamic conditions under a simultaneous impact of a number of factors:

- ✓ Non isometric flow (unlike the temperature of solid surfaces, side walls and gas flows);
- ✓ compression (gas density is not a constant value);
- ✓ pressure gradients;
- ✓ blowing through;
- ✓ radiation;
- ✓ chemical reactions;
- ✓ biphasic processes (simultaneous running of several phases);
- ✓ irregularities of the surface;
- ✓ curvature of the surrounding surface;
- ✓ turbulence;
- ✓ type of the insulators;
- ✓ transition from laminar to turbulent flow.

The impact of the above listed factors leads to a substantial difference in the fire heat and mass transfer compared to the heat transfer modeling when well-researched “standard” conditions are used. Therefore, the calculating methods for heat and mass transfer in a fire should take into consideration the fire thermo-gas dynamic conditions.

The main specific features of heat and mass transfer processes in a fire are as follows:

- ✓ The highest difference between the values of the pressure in the different zones of the premise does not exceed one tenth percent of the value of the average pressure in the premise in the absence of explosion with shock wave.

- ✓ The speed of the gas flow is less than the speed of sound (in the absence of combustion and shock wave.

The extents of gas transfer are large enough, i.e. the processes of thermal diffusion and turbulent diffusion should be taken into account.

The model for calculating heat and mass transfer during fire consists of a system of basic differential equations and the mass, momentum and energy conservation laws, as well as additional equations necessary for the calculation.

The main purpose is to demonstrate the air transfer in the premises through following analyses in which the locations of the window gaps, the door and the fire source are predefined the air transfer is simulated and the zones with crucial parameters of emissions, smoke and fire are shown.

After the geometric volume is designed – the scene where the current develops, it is necessary to design the pillars, the windows and the entrance and exit doors. It is taken for granted that smoke, harmful substances and heat come from the burning bookcase and the piles of books in the premise and the vacuum – towards the windows on the west, southern wall and mainly the door.

RESULTS

The simulation of the investigated case is done through the computer program PyroSim. The use of this program is motivated by the facility delivered by the interface and the results cultivation. Fig.1 shows the educational building which is the object of combustion products diffusion (the object on fire is shown in red color).

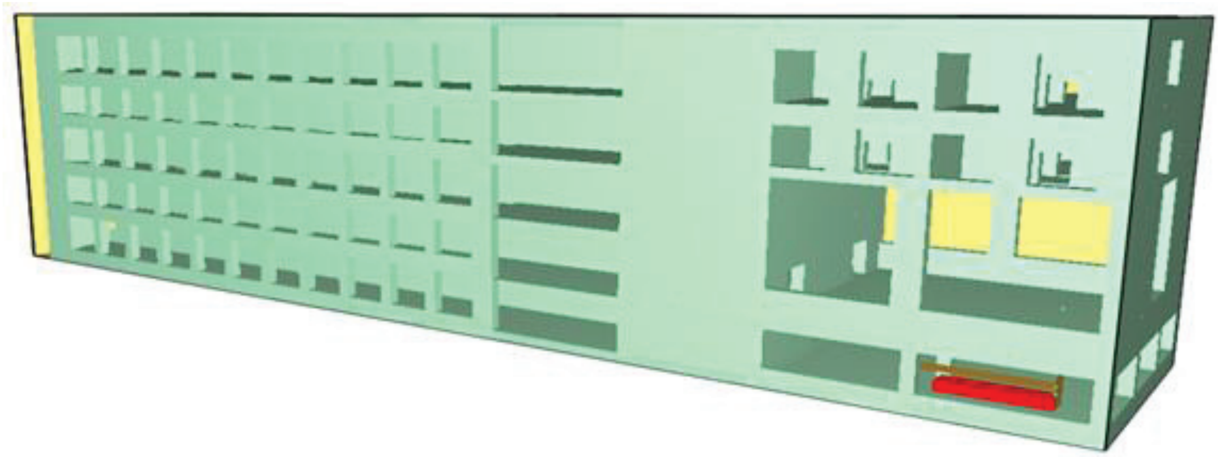

Fig.1The building

Fig.2 – Fig.7 shows the diffusion of combustion products for a defined period of time, since the moment of combustion till the moment when the smoke reaches the adjacent building.

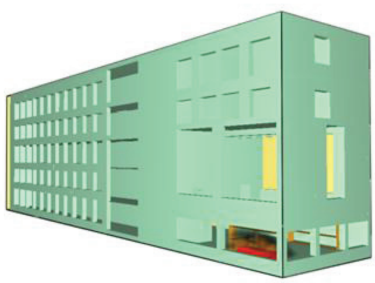

Fig.2 The building with no smoke

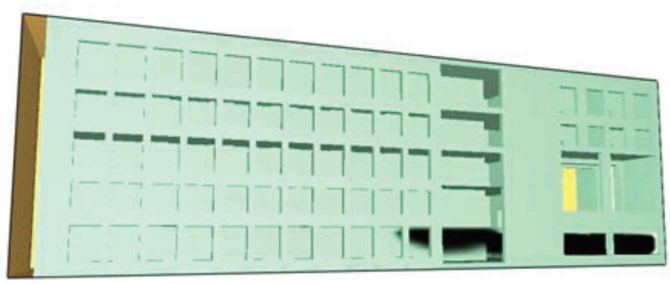

Fig.3 Smoke diffusion at 50 sec.

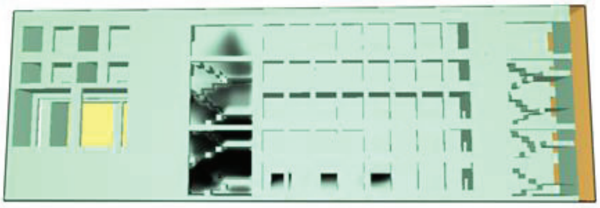

Fig.4 Smoke diffusion at 60 sec.

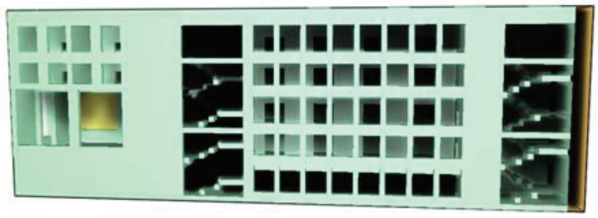

Fig.5 Smoke diffusion at 440 sec.

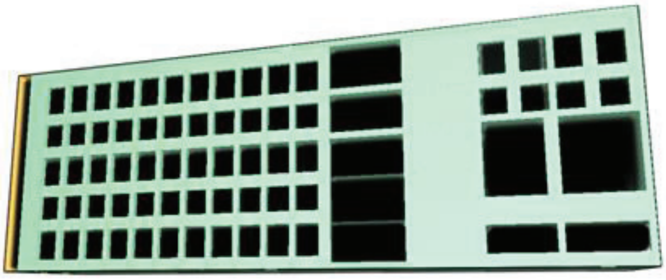

Fig.6 Smoke diffusion at 1080 sec.

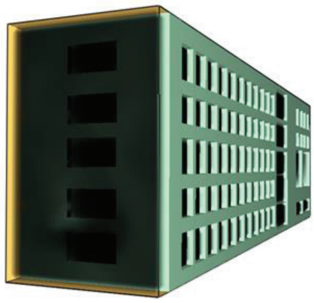

Fig.7 Smoke diffusion at 1200 sec.

In figures 8 to 13 the distribution of pressure for a defined period of time is shown, since the moment of combustion (Fig. 8)

The simulation model shows clearly that at the beginning of the fire reverse pressure occurs in a section of the premise. Among firefighters it is known as “back draft” when sudden flow of oxygen causes explosion!

Fig.8 Distribution of pressure with no smoke

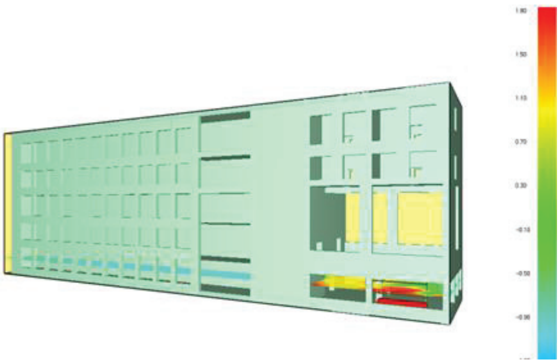

Fig.9 Distribution of pressure at 50 sec.

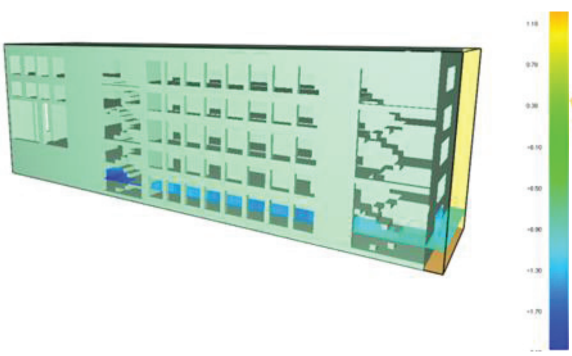

Fig.10 Distribution of pressure at 60 sec.

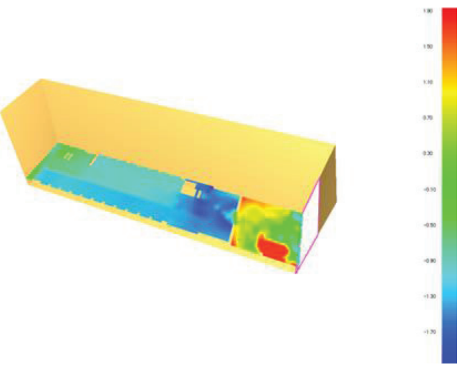

Fig.11 Distribution of pressure at 440 sec.

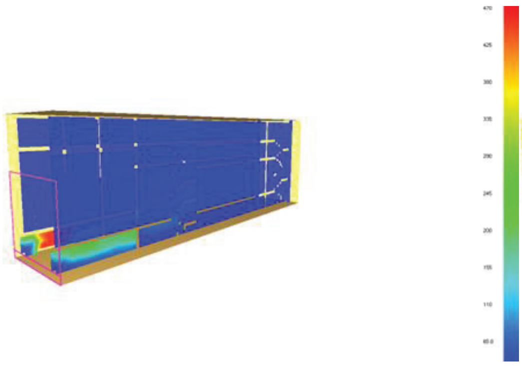

Fig.12 Distribution of pressure at 1080 sec.

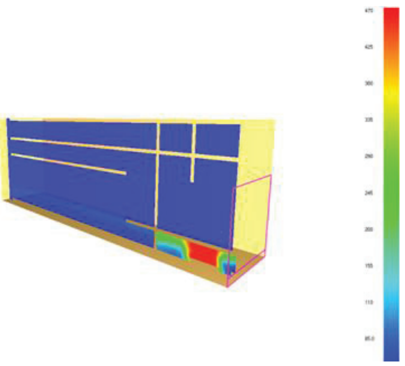

Fig.13 Distribution of pressure at 1200 sec.

On Fig.14 is shown the speed of fluid flows in the building. The speed is higher on the premises with the flame.

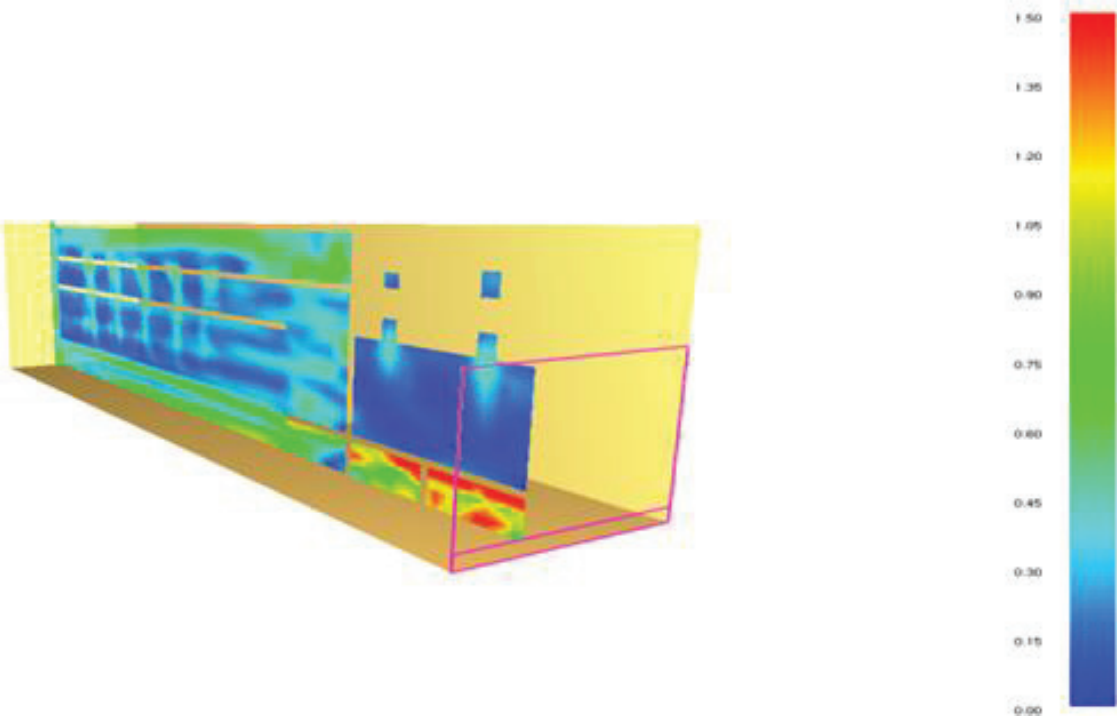

Fig.14 Speed of fluid flows in the building

In this way we get the idea of the values, distribution and the velocity gradient of basic and critical parameters which should be taken into consideration in fire safety design of buildings and installations and as well in firefighting and evacuation of people and property.

CONCLUSIONS

The visualization of speed and direction of smoke and diffusion of harmful substances shows that they hinder the ways for evacuation and proves the necessity of smoke extracting and ventilation systems especially in premises where many people gather.

From the fire safety point of view the variety of architectural styles and projects as well as building materials hampers good decision making.

The above said leads to the conclusion that constructional decisions connected with smoke protection, respectively smoke extraction which help effective evacuation of people and property and reduces the risks for the firefighters are among the most important decisions in designing and constructing of buildings and installations.

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This paper has been reviewed.