Modeling fires in structures with an atrium in the FDS field model

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Abstract. Modeling of dangerous fire factors is an important element in the system of modern fire safety assessment of buildings and structures. The paper presents a comparative analysis of the characteristics of the software system PyroSim. The verification of the fire model in the FDS program, which was performed on the basis of full-scale tests conducted by Professor Chau W.L., was analysed. The analysis of empirical and calculated data on modeling of fire in the atrium is made. The conclusion is made about the accuracy of simulation in the FDS program and the coincidence of the experimental data with the calculated ones.

1 Introduction

In order to study the FDS[1] field model in the PyroSim program (FDS graphical interface), the initial conditions of the full-scale test were set by prof. Chau [2]. The full-scale test was carried out on a constructed installation that had the following geometric parameters: length 35 m, width 9 m, height 28 m. The structure consisted of a metal frame and translucent panels as enclosing walls. Thermocouples are located in the left part of the installation at a level of 0 m in steps of 2 m to a height of 22 m. The temperature values were measured by 12 thermocouples, indicated in Fig. 1 points $T_1 - T_{12}$. The structure has 6 ventilation apertures: 4 horizontal at 0 m and 2 vertical at a height of 28 m (pre-ceiling ventilation holes). Ventilation openings have the form of a square. Ceiling ventilation openings are located at a distance of 13.5 m from the top left of the structure, the area of the ceilings is 9 m² (each). Ventilating apertures at a level of 0 m have an area of 3.61 m² (each) and are located at a distance of 4.7 and 20.7 m from the extreme left of the design from the front and back. In the full-scale test, methanol was used as the fire load, which is located in 6 steel pallets (pallet area $S = 0.51$ m², volume $V = 16$ liters, burning rate is given on the basis of PyroSim reference materials) located on the right side of the structure (Fig. 1).

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Fig. 1. The scheme of the design used in the natural experiment [1]

2 Methods

Geometric parameters of the structure are reproduced in the PyroSim program. The simulation area in PyroSim is divided into 144,768 computational cells in the form of a cube, the size of the edge of one cell was 0.5 m (Fig. 2). The decision on the size of the cell was based on the previous modeling experience in FDS, the simulation accuracy for a given cell size and the estimated FDS simulation time of 48 h (the central processor of the computer is IntelCorei5-7400, 3 GHz).

Fig. 2. Model used for testing in the PyroSim program, 1 - calculated area, 2 - design with atrium

3 Results

In Fig. 3 - 5 shows the graphs with the data of thermocouples (control points) in full-scale testing and modeling in FDS 5.3.0 and FDS 6.5.3. The style for the names is First Names, typed in italic 10-point Times, then Last Name, typed in 10-point Times, with a comma after all except the last author, which is separated by comma + “and”. Do not use academic titles.

Fig. 3. Thermocouple data (T1-T4)

Fig. 4. Thermocouple data (T5-T8)

Fig. 5. Thermocouple data (T9-T12)

4 Discussion

The deviation (difference) of the temperature of the full-scale test and the simulation data for the thermocouple T1 ($h = 22$ m) does not exceed 15°C . Such a deviation remains to the level $h = 14$ m and for thermocouples T2-T5. The temperature difference for thermocouples T6-T12 is 5°C .

The reference points (thermocouples) T6-T12 show the most accurate simulation data, the results of calculating the RPT for T6 are comparable with the full-scale test data.

5 Conclusion

The results of the fire hazard [3 – 7] modeling experiment in the PyroSim FDS graphical interface and the comparative analysis of the full-scale fire experiment in the atrium confirm the relevance of mathematical model of fire development. The parameters of the temperature curves deviate from the values of the actual experiment. The results of modeling the heat transfer process under given conditions have a certain degree of correspondence depending on the location of the control points. It can be assumed that the deviations of the simulation results from the full-scale test data for the T1-T5 reference points are due to the lack of heat exchange conditions for the walls with internal structural elements (in the PyroSim program, the structural elements of the model are specified as inert bodies), and also with the size of the calculated cell.

The accuracy of FDS modeling depends on the size of the calculated cell, the smaller the cell size, the more accurate the simulation result. As the size of the calculated cell decreases, the modeling time is significantly increased, since the total number of calculated cells in the given volume increases. At the control points T1-T5, the deviation (up to 15°C) of the simulation results from the full-scale test data is observed, the most accurate modeling data is FDS 5.3.0. (including FDS 6.5.3.) and the smallest difference in the temperature of the full-scale test and computer simulation are noted at the control points T6-T12. All results must be evaluated by a competent expert. Probably, it is necessary to consider in more detail the applicability of mathematical model of fire in the simulation of RPT at various sites, depending on the class of functional fire hazard. It is also necessary to limit legislatively the use of fire risk calculation results in support of deviations from regulatory requirements due to unsatisfactory results of comparison of experimental and calculated data on the distribution of fire hazard modeling.

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