LVIV STATE UNIVERSITY OF LIFE SAFETY

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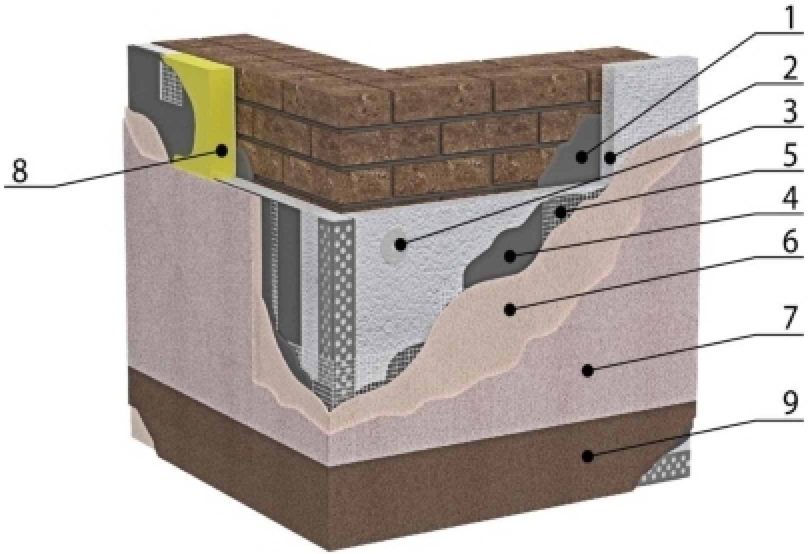
Numerical simulation of fire spread on façade heat insulating system using FDS

Exterior wall construction with facade thermal insulation is a system that includes a load-bearing part of the wall and a set of thermal insulation, designed to provide normative values of thermal performance of wall structures, protect buildings and structures from environmental influences, ensure the normative microclimate of buildings and structures and provide facades and structures of attractive aesthetic appearance. The facade thermal insulation system works as a single complex in which each layer fulfills its specific functions.

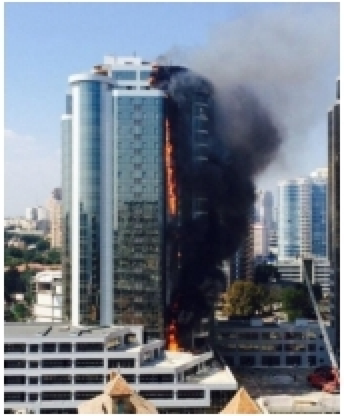


1 - glue mixture for gluing expanded polystyrene;
2 - expanded polystyrene plate;
3 - front dowel;
4 - adhesive reinforcing mixture for thermal insulation;
5 - alkali-resistant fiberglass mesh;
6 - pigmented adhesive primer;
7 - decorative mineral plaster with a finishing layer of dispersion silicate facade paint;
8 - mineral wool plate;
9 - basement system.

Examples of fires with the spread of fire on the facade systems of buildings indicate their particular danger

Astana, 2006
(Kazakhstan)

Vladivostok, 2007
(Russia)



Odessa, 2015
(Ukraine)

Grozny, 2013
(Chechnya)

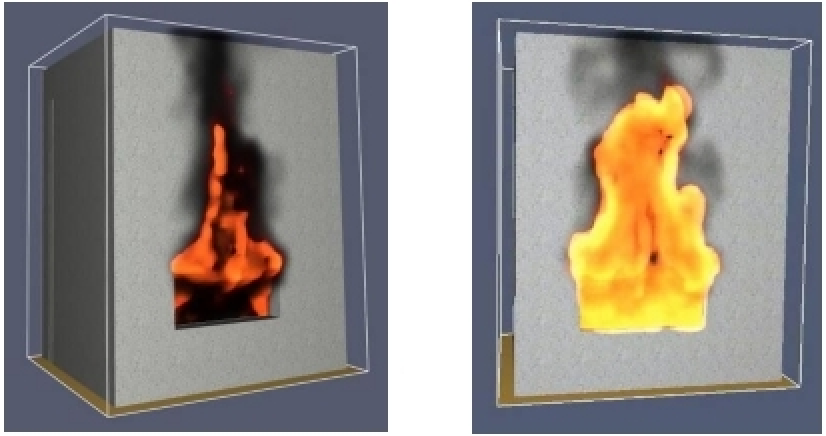
London, 2017
(Great Britain)

Full-scale tests for fire spread were conducted on an external wall construction fit with façade heat insulation and finished with rendering using slabs fabricated from expanded polystyrene as heat insulating material.
Essence of the test method lied in the determination of the sizes of the damaged section of the façade heat insulating system and temperature rise inside the heat insulating and finishing system having been applied to a fragment of two-floor building of 5.6 m total height at ground floor of which (fire chamber) temperature-time curve was being created close to standard temperature/time curve standardized.

a b

Appearance of the building fragment at the time of testing at the following moments from the commencement: a – 5 min.; b – 30 min.

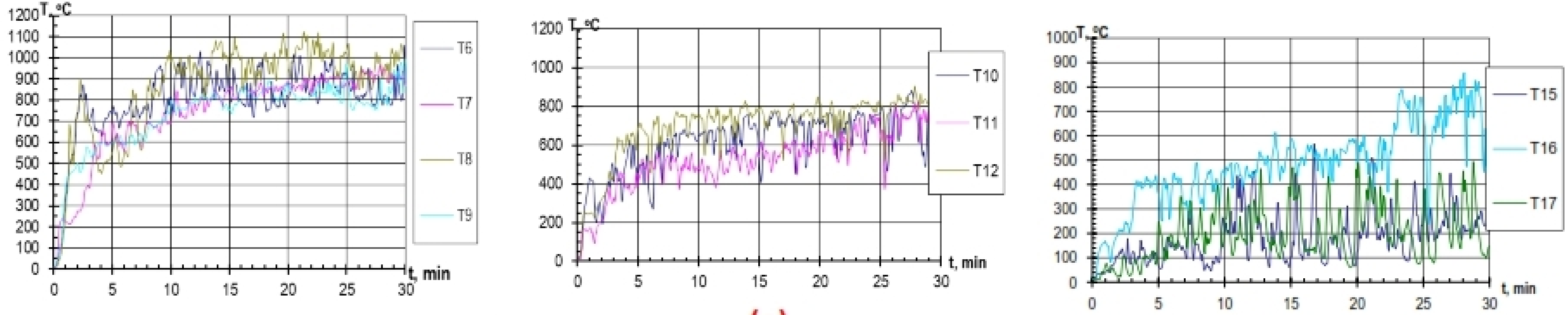
The simulation was performed in FDS using the PyroSim graphical interface. FDS implements a computational hydrodynamic model (CFD) of heat and mass transfer during combustion. The FDS numerically solves the Navier-Stokes equations for low-speed temperature-dependent flows, paying particular attention to smoke propagation and heat transfer in a fire. The model is a system of partial derivatives, including the equation of conservation of mass, moment and energy, and is solved on a three-dimensional regular grid. Thermal radiation is calculated by the finite volume method on the same grid.



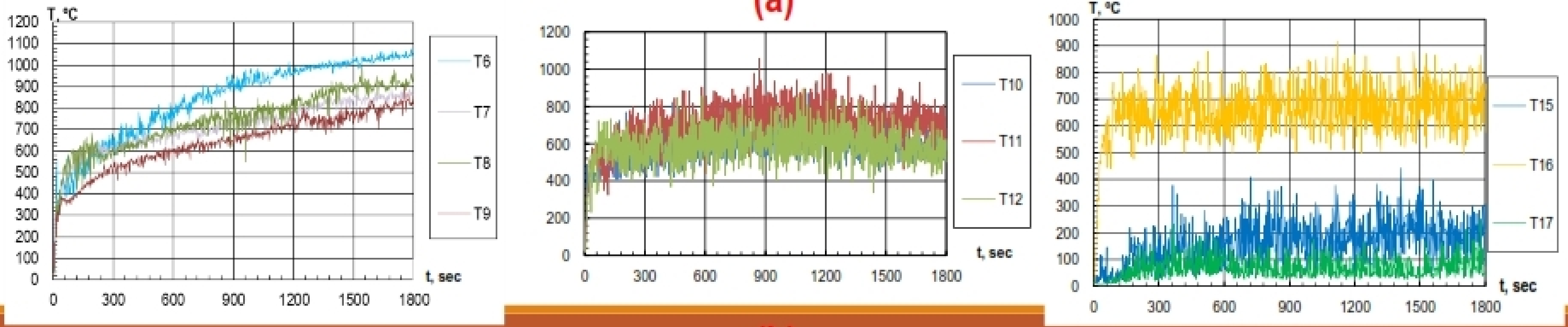
a b

Appearance of the building fragment at the time of simulation at the following moments from the commencement: a – 5 min.; b – 30 min.

Results of FDS simulation are used for numeric evaluation of the temperature values within the fire chamber, inside and nearby the surface of the construction of the façade heat insulation and their comparison with the data derived empirically (experimental results (a), FDS simulation results (b)



(a)



(b)

CONCLUSIONS

1. The numerical model was constructed in the CFD program Fire Dynamics Simulator (FDS) with analogous geometry and instrumentation. The general features of the fire test were well reproduced in the numerical model however temperatures close to the fire source could not be properly accounted for in the model. Simulation results derived allowed reproduction in due manner real conditions of testing, and when comparing experimental data and numeric calculations satisfactory results were obtained.

2. It was determined as result of computer simulation that maximum heat output of fire is reached at approximately 1,200 s (20 minutes) point of time and it is equal to 4600 kW. Local temperature values corresponding to maximum heat output reach 660 °C to 960 °C. Average temperature value within the burning area (fire chamber) at 20th minute equals to 760 °C to 780 °C.

3. The most critical zone on the facade is located above the fire room and is directly impacted by external flame outgoing from the fire compartment. General temperature values within the fire chamber derived experimentally and numerically were different by 12 % to 16 %, value of the temperature in the window opening was underestimated by 16 % to 24 %, and temperature nearby the surface of the heat insulating and finishing system within the model was both overestimated by 22 % (T16 and T20) and underestimated by 18 % (T17, T21 and T19). Temperature values inside the façade heat insulating system did not exceed experimental data and deviation of average temperature values was equal to 16 %.